LMOA

Locomotive Maintenance Officers Association

Proceedings of the 65th Annual Meeting

September 22 - 23, 2003

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2002 LMOA MVP RECIPIENTS

The executive board of LMOA wishes to congratulate the following individuals who were selected as the Most Valuable People of their respective committees in 2002.

Name	Company	Committee
Ron Begier	Portec Rail Products Inc.	Shop Equipment & Processes
Tim Black	Union Pacific R R	New Technologies
Leonard Buczkowske	Florida East Cost Rwy.	Shop Equipment & Processes
Dave Elvin	Ondeo-Nalco	Fuel, Lubricants and Environmental
Jim Fronckoski	CSX Transportation	Diesel Material Control
Leighton Haley, Jr.	Norfolk Southern Corp.	Fuel, Lubricants and Environmental
Jack Kuhns	JMA Railway Supply Co.	Diesel Mechanical Maintenance
Craig Prudian	GM-Electric Motive Divison	New Technologies
Les White	EMD-Canada	Diesel Electrical Maintenance

This honor is bestowed on an annual basis to those individuals who perform meritorious service and make significant contributions to their respective technical committees.

LMOA EXECUTIVE COMMITTEE

THE LMOA EXECUTIVE COMMITTEE
WOULD LIKE TO EXPRESS THEIR
SINCERE APPRECIATION TO
MR. JOHN WALSH
AND THE ENTIRE STAFF OF
THE CANADIAN PACIFIC RAILWAY
IN CALGARY, ALBERTA CANADA
FOR HOSTING THE
6TH ANNUAL LMOA JOINT TECHNICAL
COMMITTEE MEETING
ON
MAY 5 AND 6, 2003.

PAST PRESIDENTS

1939 & 1949 -	F. B. DOWNEY (Deceased) Shop Supt., C & O Ry.
1941 -	J. C. MILLER (Deceased), MM, N.Y.C. & St. L.R.R.
1942-1946, Inc. -	J. E. GOODWINN (Deceased) Exec. Vice President, C. & N.W. Ry.
1947 -	S. O. RENTSCHILLER (Deceased) Chief Mechanical Officer, Bessemer and Lake Erie R.R.
1948 -	C. D. ALLEN (Deceased) Asst. C.M.O. - Locomotive, C. & O. Ry. & B. & O. R.R.
1949 -	J. W. HAWTHORNE (Deceased) Asst. Vice-Pres.- Equipment, Seaboard Coast Line R.R.
1950 -	G. E. BENNET (Deceased) Vice-Pres.-Gen. Purchasing Agent, C. & E. I. Ry.
1951 -	P. H. VERD (Deceased) Vice-Pres.-Personnel, E. J. & E. Ry.
1952 -	H. H. MAGILL (Deceased) Master Mechanic, C. & N. W. Ry.
1953 -	S. M. HOUSTON (Deceased) Gen. Supt. Mech. Dept. Southern Pacific Co.
1954 & 1955 -	F. D. SINEATH, Retired Chief of Motive Power, Seaboard Coast Line R.R.
1956 -	T. T. BLICKLE (Deceased) General Manager - Mechanical, A .T. & S. F. Ry.
1957 -	J. T. DAILEY (Deceased) Asst. to Pres.-Mech., Alton & Southern R.R.
1958 -	F. E. MOLLOR (Deceased) Supt. Motive Power, Southern Pacific Co.
1958 -	F. R. Denny (Deceased) Mechanical Supt., New Orleans Union Passenger Terminal
1959 -	E. V. MYERS (Deceased) Supt. Mechanical Dept., St. Louis-Southwestern Ry.
1960 -	W. E. LEHR (Deceased) Chief Mechanical Officer, Pennsylvania R.R.
1961 -	O. L. HOPE, (Deceased) Asst. Chief Mechanical Officer, Missouri Pacific R.R.,
1962 -	R. E. HARRISON (Deceased) Manager-Maintenance Planning & Control, Southern Pacific Co.
1963 -	C. A. LOVE, Retired Chief Mechancial Officer, Louisville & Nashville R.R.
1964 -	H. N. CHASTAIN, (Deceased) Gen. Manager-Mechanical, A. T. & S. F. Ry.
1965-	J. J. EKIN, JR. (Deceased) Supt. Marine & Pier Maintenance, B. & O. R.R.
1966 -	F. A. UPTON II (Deceased) Asst. Vice-President-Mechanical, C. M. St. P. & P. R.R.
1967 -	G. M. BEISCHER, Retired Chief Mechancial Officer, National Railroad Passenger Corp. Washington, D.C. 20024
1968 -	G. F. BACHMAN, (Deceased) Chief Mechanical Officer, Elgin Joilet & Eastern Ry.
1968 -	T. W. BELLHOUSE (Deceased) Supt. Mechanical Dept., S. P. Co., - St. L. S.W. Ry.
1970 -	G. R. WEAVER (Deceased) Director Equipment Engineering, Penn Central Co.,
1971 -	G. W. NEIMEYER (Deceased) Mechanical Superintendent, Texas & Pacific Railway
1972 -	K. Y. PRUCHNICKI (Deceased) General Supervisor Locomotive Maintenance, Southern Pacific Transportation Company
1973 -	W. F. DADD, (Deceased) Chief Mechanical Officer, Chessie System
1974 -	C. P. STENDAHL, Retired General manager M.P.-Electrical, Burlington Northern Railroad, 1052 W. California Ave., St. Paul, MN 55117
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1976 -	J. D. SCHROEDER, Retired Assistant C.M.O.-Locomotive Burlington Northern Railroad, 244 Carrie Drive, Grass Valley, CA 95942
1977 -	T. A. TENNYSON (Deceased) Asst. Manager Engineering-Technical, Southern Pacific Transportation Co.
1978 -	E. E. DENT, (Deceased) Superintendent Motive Power, Missouri Pacific Railroad,
1979 -	E. T. HARLEY, Retired Senior Vice President Equipment, Trailer Train Company, 289 Belmont Road, King of Prussia, PA 19406

1980 -	J. H. LONG, Retired Manager Locomotive Dept., Chessie System 5454 Cleander Drive, Cincinnati, OH 45238
1981 -	R. G. CLEVENGER, Retired General Electrical Foreman, Atichison, Topeka & Sante Fe Rwy.
1982 -	N.A. BUSKEY (Deceased) Asst. General Manager-Locomotive, Chessie System
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2001-	LOU CALA, Consultant, LJC Rail, Duncansville, PA 16635
2002-	BOB RUNYON, Engineering Consultant, Roanoke, VA 24019

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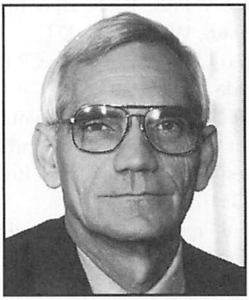

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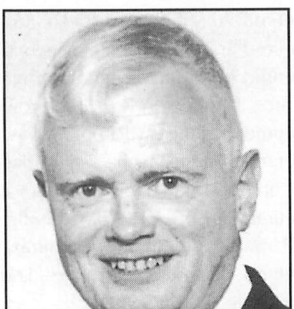

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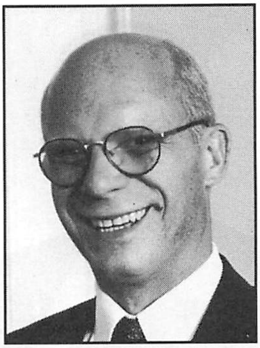

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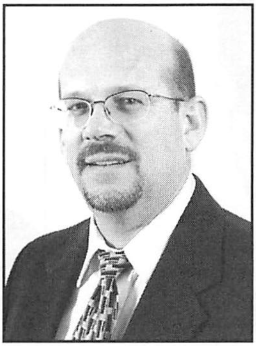

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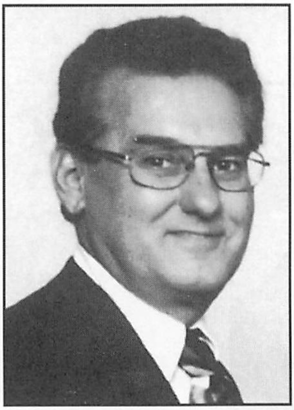

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Engineering & Quality
Union Pacific Railroad
Omaha, NE 68179

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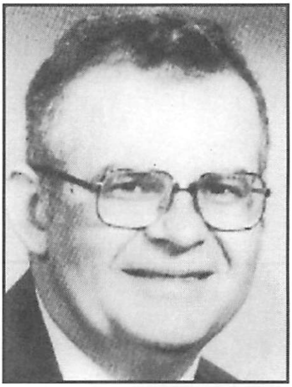
Bombardier Transit
Los Angeles, CA 90065



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Cleona, PA 17042

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Supt. - Locomotives
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Selkirk, NY 12158

MR. H.H. (MIKE) PENNELL
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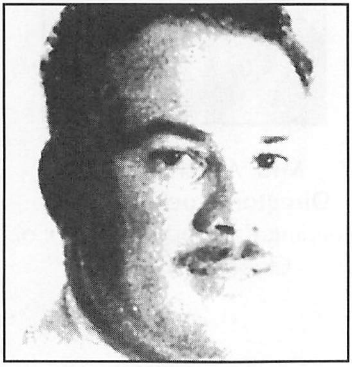
Keller, TX 76248

OUR PAST PRESIDENTS



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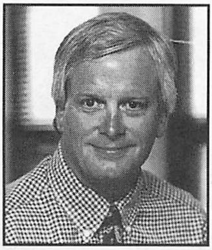
Amtrak
Hollywood, FL 33019

MR. DAVID M. WETMORE
General Supt. - Equipment
NJT Rail Opns
Kearny, NJ 07032

OUR REGIONAL EXECUTIVES



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BNSF Rwy
Topeka, KS 66616

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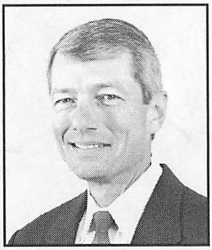
Beech Grove, IN 46107



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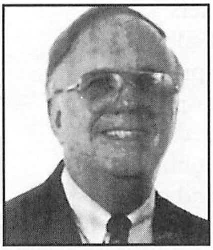
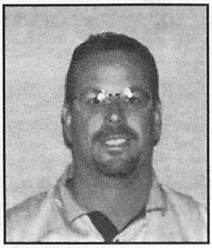
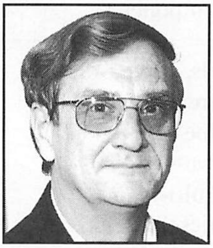
National Electric Carbon Products
Scottsdale, AZ 85255



JAY HOLLEY
Director Mechanical Operations
CSX Transportation
Jacksonville, FL 32254



MR. MIKE SCARINGE
Director Warranty Enforcement
Amtrak
Beech Grove, IN 46107



MR. LES WHITE
District Service Representative
ElectroMotive Division
Montreal, PQ
Canada H3B 2N2

Newly elected President Brian Hathaway (center) presents Past President's Pin to outgoing President Bob Runyon (right) as newly eleected 2nd Vice President Tad Volkmann looks on.

Newly elected 3rd Vice President Bruce Kehe (left) and newly appointed Regional Executive Bruce Butts (right) present an LMOA attache bag to Tim Black who was selected as the new Chairman of the New Technologies Committee.

Newly elected President Brian Hathaway (right) presents LMOA blazer to newly elected 3rd Vice President, Bruce Kehe. The ceremony was witnessed by newly elected 2nd Vice President, Tad Volkmann.

Outgoing President Bob Runyon (center) turns the gavel over to newly elected President Brian Hathaway as newly elected 2nd VP Tad Volkmann looks on.

General Executive Committee Members: (seated - left to right): Newly elected President Brian Hathaway; outgoing President Bob Runyon; and newly elected 1st VP Bill Lechner, Norfolk Southern.

(standing - left to right): Newly elected 3rd Vice President Bruce Kehe; EJ&E; Secretary-Treasurer Ron Pondel and newly elected 2nd VP Tad Volkmann, Union Pacific.

Acceptance Speech by President Brian Hathaway September 24, 2002

Good afternoon, ladies and gentlemen on this the 64th year of the LMOA. It is with pride that I follow such a long list of past presidents.

My background in the LMOA dates from 1986 when I was taking delivery of locomotives at National Railway Equipment, and working with Dick Donavan. He suggested that I join LMOA and be on the Electrical Committee. I arrived at my first committee meeting and looking around the table saw all the big boys (CN, CP, CSX, NS, UP, and yes Conrail); and they were talking about changing batteries in something called a black box, and microprocessors, and having central computers, and EPA cleaning and so on. Well, coming from a small railway I never had seen nor heard of these items and this was all new to me, and I'm thinking what in the world did he get me into.

We are still talking about the black box, microprocessors and EPA, but things have changed over the past 10-15 years. Science fiction has become reality: the introduction of AC locomotives, high-speed locomotives, and even magnetic levitation locomotives. Modern technology has played a big role in the railroad industry, whether applied on new locomotives or to our existing fleet.

Railroads have merged, and downsized; people have taken early retirement, packages, buyouts, etc. A large amount of experience has left, but new experience and ideas are waiting on the horizon. It still comes back to locomotive maintenance. Whether it is light repairs, heavy repairs, or a major overhaul, it is still a major part of the railroad organization, and it must be complete in all respects, without defect when called upon.

This is the purpose of the LMOA, with its six committees. Their function is 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, and to make constructive recommendations on locomotive maintenance procedures through the technical committee reports for the benefit of the railroad industry.

The LMOA has also conformed to changing times. We have revised the constitution and by-laws to adapt to the changing industry. In 1998, the LMOA adopted the best practice series to address the concerns of the shortlines and regionals as well as the Class 1's, and has been working well each year. In 1998 we were able to have all the committees together for the first time in many years; this practice still continues. The committees are setting aside time at each meeting just to talk to each road about what is being done at its railroad, not to copy from each other, but to better every road.

But over the years membership in the LMOA has decreased. In 1988 there were 369 railroad members with 298 associates, and in 2001 there were 235 railroad members with 165 associates. This is a decrease of 36% from the railroad membership and total membership decrease of 40%. We need to enhance the membership.

We call upon each mechanical department head to examine its participation of membership on the association or committees and take advantage of this excellent opportunity to pass along situations or problems for the committees to study and investigate and report on solutions.

The executive board will get together and discuss how to make this organization grow, what we need to change, how can we reach people, and when we do it, is it the right response they are looking for. One main objective is to get ideas from the membership.

I would like to thank all of the committee members, and officers for their support, my friends, colleagues, definitely, Ron Pondel, my two sons and especially my wife, Sheri. Without all of this I could not have reached this achievement.

Thank you for all your support for the Locomotive Maintenance Officers Association, for this year and all the years past and future.

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT AND PROCESSES

MONDAY, SEPTEMBER 22,2003
2:30 P.M.

Chairman
BILL PETERMAN
President
Peterman Railway Technologies, Inc.
Baie D'Urfe, Quebec

Vice Chairman
JOHN MORGANO
Mechanical Superintendent
CN/IC RR/NFDL
North Fond du Lac, WI

COMMITTEE MEMBERS

C. Aday	Facilities & Fleet Maint Mgr	Metrolink-SCRRA	Los Angeles, CA
K. Albrecht	General Mech. Supt.	Montana Rail Link	Livingston, MT
K. Batley	Rail Products Manager	L&S Electric Inc.	Appleton, WI
R. Begier	Consultant	Portec Rail Products Inc.	Broomfield, CO
R. Collen	Product Manager	The Macton Corp	Oxford, CT
C. Fette	President	TESCO	Erie, PA
G. Lapinas	Mgr-Process Engineering	Canadian Pacific Rwy	Calgary, Alberta
R. Mckim		Amtrak	Beech Grove, IN
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D. Tetley	RR Acct. Manager	Snap-On-Tools Corp.	Omaha, NE

THE LMOA SHOP EQUIPMENT AND PROCESSES COMMITTEE

WISHES TO EXPRESS THEIR SINCERE APPRECIATION TO THE FOLLOWING COMPANIES FOR HOSTING COMMITTEE MEETINGS IN 2002 / 2003:

Long Island Railroad and
New York City Transit Authority
November 2002

METROLINK / SCRRA
Los Angeles, CA
February 2003

I. LOCOMOTIVE SHOP SUPPORT SYSTEMS & EQUIPMENT

Prepared by: Charles Aday,
Facilities and Fleet Maint. Manager
Southern California
Regional Rail Authority

Availability of the locomotive fleet is paramount to the success of freight and commuter railroads. Locomotive failures on a freight railroad can result in large revenue losses and traffic congestion that can take from hours to days to recover from. In many metropolitan areas freight railroads share trackage with commuter railroads. Locomotive failures by either property can impact movement of precious time-sensitive cargo and disrupt the lives of hundreds of daily commuters traveling to and from major employment centers.

Being regulated by the Federal Railroad Administration (FRA) and other State and Federal regulatory agencies exposes railroads to severe financial liability for failure to meet regulatory requirements. Railroads invest millions of dollars to provide facilities where locomotive maintenance can be performed in a safe and efficient manner, allowing the equipment to achieve a high level of service quality and reliability while keeping the cost of performing this maintenance at an acceptable level.

Just as the proper maintenance of the locomotive fleet is important to the fleet's service life and the success of the railroad, the proper maintenance of the locomotive facility and its associated support systems and equipment is of equal consequence. Without proper preventive and predictive maintenance practices the service facility performance will deteriorate and result in undesired service equipment downtime and/or catastrophic failure.

Not all railroads have the opportunity to invest capital in new service facilities for maintaining their fleet of locomotives. Many existing service facilities undergo continuous structural and equipment upgrades in an effort to achieve many of the efficiencies that a new facility would provide.

With this said, what does a modern locomotive service facility look like and what support systems and equipment are required to deliver the desired level of service, thus ensuring the reliability required of a railroads' locomotive fleet? When should support systems or support equipment be replaced or refurbished? What criteria should be used to decide whether refurbishment is appropriate or replacement is required?

Locomotive service facility

A locomotive service facility, whether belonging to a freight or commuter railroad, will have most of the same support systems in place. Necessary support systems are:

- Building shell
- Lighting
- Compressed air
- Elevated work platforms
- Fire suppression & alarm
- Rolling doors

- Steam (colder climates)
- Wayside power
- Lube oil dispensing & extraction
- Fuel storage & dispensing
- Heating & ventilation
- Air quality monitoring
- Lifting systems
- Sand delivery
- Communication & information technology
- Material storage
- Sanitary disposal
- Industrial waste disposal & sewer
- Health & welfare areas
- Locomotive washing

Along with these support systems a well-equipped locomotive shop would have the following support equipment:

- Under floor wheel truing machine
- Drop table
- Transfer table
- Split rail
- Fork lift
- Filter crusher
- Parts cleaner
- Welder
- Grinder
- Band saw
- Steam cleaner
- Wick tank
- Hydraulic wrenches
- Portable hydraulic jacks
- Chop Saw
- Battery water dispenser
- Refrigerant recovery device
- Specialized jigs & tooling used to aid in removing locomotive components.

Expected service life

Both support systems and support equipment can be categorized into expected life categories:

Category 1
1 year to 5 years service life

Category 2
5 year to 10 years service life

Category 3
10 year to 20 years service life

Category 4
20 years plus service life.

Support systems expected service life

Table 1 assigns each support system to an expected service life. Please notice that the majority of support systems fall into the 10 to 20-year category. It may seem that 10 to 20 years is a broad category to place these systems into. These types of support systems are the major infrastructure of a facility. With proper routine preventive and predictive maintenance these systems will last a full 20 years or more. With proper routine preventive and predictive maintenance the decision to rebuild or replace these systems at the 20-year mark is easily made. Without preventive and predictive maintenance these systems will start failing in the first 5 years of operation.

The first 5 years of a facilities operation are the most important in determining the expected service life of support systems. Planning for the maintenance of these systems should start at their installation during the construction of the facility. The management team responsible for the design and construction of the facility should ensure that the construction contract document has provisions for the proper transfer of warranties of support systems and proper commissioning of these systems involving the end users of the facility. This should include the transfer of documentation of recommended maintenance practices and properly identified spare parts. Warranty periods of longer than the standard one-year warranty typically offered by the construction industry should be negotiated during the construction contract bidding process.

It is imperative that the department responsible for facilities maintenance is properly staffed with technicians that are trained in maintenance of these support systems. If proper maintenance is not performed in the first years of the facility operation, warranty claims may be challenged by the responsible installing contractor or system manufacturer.

There are many computer-based maintenance-tracking systems available today that aid in the planning and tracking of support systems and equipment maintenance. It is not in the scope of this paper to discuss these systems; however the reader is encouraged to become familiar with the programs that are available on today's market. This topic will be the subject of a future paper by the Shops Committee.

Support equipment expected service life

Table 2 assigns each category of support equipment to an expected service life. You'll notice that a large amount of support equipment falls into the 1 to 5 year category. Larger, heavier and more expensive equipment falls into the 10 to 20-year category. Equipment that is permanently installed with less wear parts fall into the 20-year plus category.

Support equipment placed in the 1 to 5 year category can have its expected service life extended by initially installing a higher quality of equipment that is designed to take rugged use. This type of support equipment tends to be undersized for the tasks it is expected to perform. Without proper supervision and training mechanics using this type of equipment tend to abuse it and disregard the daily cleaning and maintenance it requires.

Proper cleaning and lubrication of support equipment should be the responsibility of the mechanic who uses the equipment. There should be an open channel of communication between mechanics and facilities maintenance staff for reporting of unusual occurrences with equipment operation. Mechanics should be able to report unusual sounds equipment may make or signs of undesirable operation. A proper reporting procedure should be in place in order to capture these reports and track repairs.

Refurbish or replacement criteria

When does a support system or piece of support equipment require refurbishment or replacement? What information is needed in order to make the business decision to refurbish or to replace?

To make these decisions data needs to be gathered that is relevant to the way an organization conducts business and the basis on which it makes financial decisions. The most common areas that are relevant to this decision-making process are depreciation, interest (cost of money), operational costs and revenues. These are areas where factual data can be obtained in order to aid in the decision making process. There is one additional area that cannot be quantified and that is irreducible factors.

Depreciation is the cost of the support system or equipment, (asset) minus its salvage value, divided by its expected service life. The result of this equation is the cost of owning the asset over its expected service life.

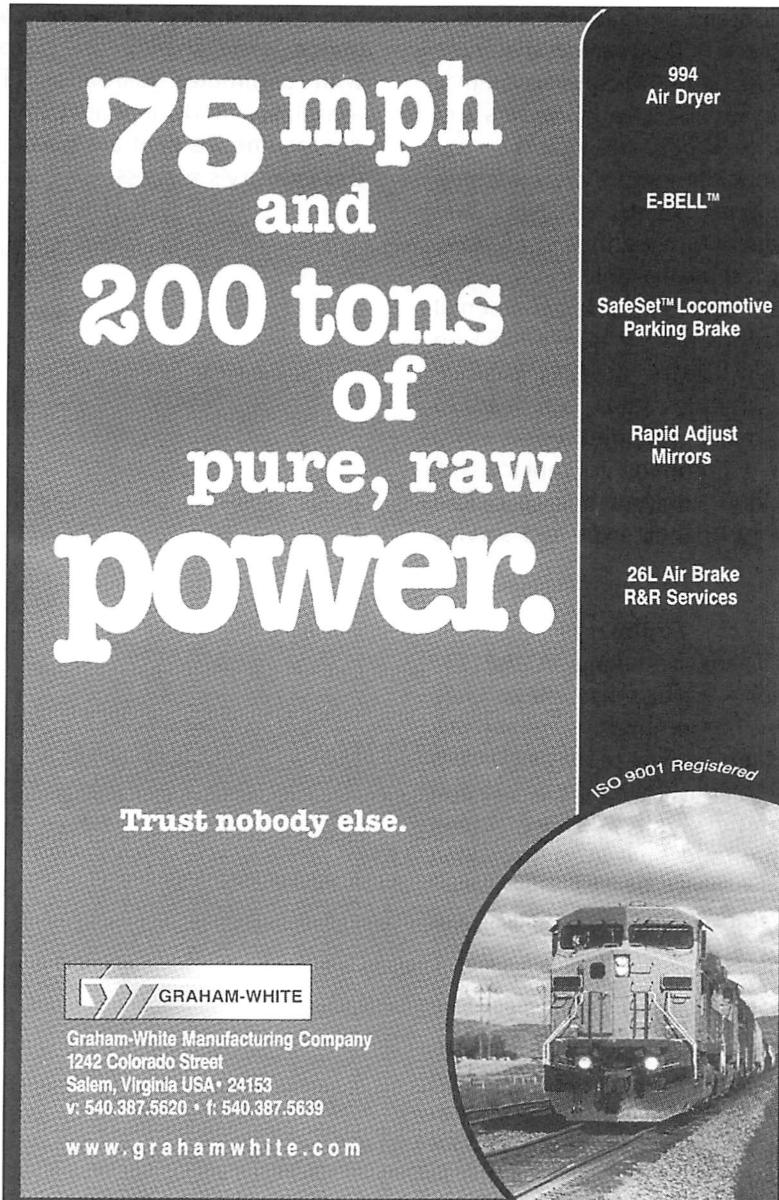
Interest is the cost of the money tied up in owning asset. If a company borrows money to purchase an asset then this is the cost of borrowing the money. This is sometimes referred to as the "out-of-pocket" cost of owning the equipment. If a company's capital is used to purchase the asset then this capital is no longer available for other investments, which could bring them a return. This is sometimes referred to as the "opportunity cost" of owning the asset.

Operating cost is the cost associated with the use of an asset. Typical operating costs are expenditures for labor, materials, supervision, maintenance and power. These costs are usually presented as annual costs. When estimating operating costs for future periods of time consideration should be given to likely increases in wages and increased maintenance costs as the asset ages.

Revenues are the return on investment a company receives for owning and operating the asset. In a locomotive maintenance facility revenue would depend on how the asset contributes indirectly to the success in performing the maintenance and repair of the locomotive fleet. Traditionally, support services such as maintenance activities are viewed as costs and they enhance revenues by being efficient. In a service facility this will probably be the hardest data to quantify.

To make the comparison between refurbishment and replacement the average annual cost of each of the old and new asset must be calculated. The cost of refurbishing the old asset must also be calculated along with its new expected service life in the comparison. This would be the cost of the old asset used to calculate its annual depreciation.

The average annual cost of the old and new asset is the sum of annual depreciation, annual interest expense, and annual operating costs less the revenue advantage.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When the total average annual cost of the old and the new asset has been calculated the business decision can be made to refurbish or replace. Other factors that must be weighed in the comparison that cannot be quantified in dollars and cents are irreducible factors.

Irreducible factors are operating efficiencies, safety, reliability and new technologies that in all likelihood will be available to the industry in a few years. Environmental regulations have a large impact on all industries in the 21st century. These requirements can lead to equipment obsolescence and force a company to replace systems and equipment long before the end of their expected service life.

Summary

Railroads operating in the 21st Century have many new challenges before them. Freight railroads are moving more cargo from coast to coast than ever before and commuter railroads are being planned and built in metropolitan areas in order to ease the impact that automobiles and trucks have on the environment and the population's quality of life.

Availability of the railroad's locomotive fleet is paramount to success. Millions of private sector and taxpayer dollars are being spent to build the infrastructure needed for freight and commuter railroads to operate. Maintenance of these assets is imperative in order to extend their expected service life. Due to the current economic environment, commuter railroads face challenging funding hurdles. Freight railroads struggle to maintain their market share of commerce while sharing the railroad with commuter railroads. The availability and dependability of the locomotive fleet are musts for this industry's success.

Table 1
Support Systems, Expected Service Life

	Category 1 1 Year - 5 Years	Category 2 5 Years - 10 Years	Category 3 10 Years - 20 Years	Category 4 20 Years Plus
Building Shell				X
High Bay Lighting			X	
Compressed Air			X	
Steam Generation			X	
Wayside Power			X	
Lube Oil Dispensing & Extraction			X	
Fuel Storage, Receiving & Dispensing			X	
Heating & Ventilation			X	
Air Quality Monitoring			X	
Lifting Systems (Jacks & Overhead Cranes)			X	
Elevated Work Platforms				X
Fire Suppression & Alarm			X	
Rolling Doors		X		
Sand Storage & Delivery			X	
Communication & IT		X		
Material Storage			X	
Sanitary Disposal				X
Industrial Waste disposal & Sewer				X
Portable Water System				X
Health & Welfare areas				X
Locomotive Washing				X

Table 2
Support Equipment Expected Service Life

	Category 1 1 Year - 5 Years	Category 2 5 Years - 10 Years	Category 3 10 Years - 20 Years	Category 4 20 Years Plus
Under Floor Wheel Truing Machine			X	
Drop Table				X
Transfer Table				X
Split Rail			X	
Fork Lifts			X	
Steam Clean	X			
Parts Washer	X			
Wick Tank	X			
Portable Hydraulic Wrenches		X		
Portable Hydraulic Jacks		X		
Filter Crusher		X		
• Welder	X			
• Grinder	X			
• Band Saw	X			
• Chop Saw	X			

II. HAND TOOLS - AN ERGONOMIC UPDATE

Prepared by: Don Tetley,
Railroad Acct. Manager
Snap-On-Tools Corporation

What is the definition of tool ergonomics? Simply stated, it is the study of the relationship between the attributes of the tool, the requirements of the task, and the physical and psychological capabilities of the technician. Ergonomic design focuses on understanding the problems of the tool user. Ergonomic design objectives include improvements in operating safety and comfort, the control of medical costs associated with tool use, and an increase in productivity. Tool users, academic authorities, and tool manufacturers are working together to increase the understanding of the relationship between the tool, the task, and the technician. The goal of any tool design is to lower the level of exertion required to perform the task. A tool design with ergonomic features allows the user to transfer strength more efficiently. Therefore, stress to the user can be reduced.

The following points regarding tool ergonomics should be clearly understood. There is no such thing as an "ergonomic tool" per se. The primary design criterion for tools is safety, the second is ergonomics. Ergonomic principles should guide the design, selection, and the use of the correct tool for the specific application. Every person is different. Each has a unique height, hand size, arm length, physical capabilities, and other attributes. A tool that works well for one person will not necessarily work well for another, even when they are performing the same task. The proper maintenance of any tool or item of equipment is essential in helping to prevent or reduce safety and ergonomic hazards. Tools should be inspected and maintained in accordance with the manufacturer's specifications. Any tool found to be defective must never be used.

Factors for injury risk resulting from tool use include, the continued repetition of components of the upper limb, wrist, and hand during the work cycle; the amount of force required for finger or grip pressure; concentrated contact stress on the palm; the posture or degree of joint deviation; continuously sustained posture or forces; exposure to vibration; and exposure to temperature extremes. Now, let us look at a few of the latest examples of hand and power tool designs that incorporate ergonomic features.

Hand tools

A number of hand tools now incorporate handles made of a soft, comfortable, rubber like material. Soft grip tool handles feature a triangular cross section that provides the optimum shape to match the typical human hand for ease of use. A contoured thumb stop provides the best position for the thumb to enable users to comfortably bear down on fasteners.

Elastomer handle material prevents slippage, allowing more torque to be transmitted to the fastener. The soft material is comfortable and warm to the touch. Examples of tools now using the soft grip handle include screwdrivers, ratcheting wrenches, files and saws.

Grip design may be changed to improve tool ergonomics. A pistol grip type screwdriver provides a comfortable hand/wrist position. It produces over twice the turning power of conventional screwdrivers, achieving higher torque with less effort.

Cushion grips provide similar ergonomic benefits. Cushion grips provide an even distribution of forces across the hand to reduce fatigue and pressure against the hand and fingers. The elastomer material is comfortable, and prevents slippage. Examples of tools using cushion grips are adjustable wrenches, pliers, cutters, hammers, tape measures, and torque wrenches. Figures 1, 2 and 3 show a unique new sledgehammer with an unbreakable handle. You've heard that term before, but this one really is. The spring steel inner handle is covered with a rubber material. This material is very durable, comfortable, and non-slip. This cover, along with the spring steel inner shaft, absorbs the hammering impact, transmitting very little shock or vibration to the mechanic. Directly under the hammer head, there is an added area of rubber padding. This padding further absorbs impact shock in case of a hammer mis-strike.

Pistol or "comfort" grips increase tool strength, accessibility, and comfort for pliers or other cutting tools requiring a squeezing force. The grips reduce operator fatigue and place the operator's hand in a more comfortable position. The "cradle" type grip prevents the tool from slipping out of the operators hand.

Power tools

Some of the greatest ergonomic improvements have taken place in the realm of power tools. New power tools weigh less and produce greater power. Less weight translates to less fatigue. More power equals less tool running time. New designs and manufacturing technologies, including motor balancing, emphasize vibration reduction and isolation. Specially designed gloves are available to further reduce the transmission of vibration to the hand and fingers. Human metric data is incorporated in power tool handle design to provide an optimum hand fit. Cushion handles are now the norm on impact tools. Composite, aluminum, and titanium materials are commonly used in the manufacture of impact wrenches. A 1/2" drive impact wrench now typically weighs less than four pounds, yet produces 600 ft-lbs of torque in forward and reverse. Replaceable cushion grips reduce the transmission of vibration to the operator and provide a comfortable, non-slip surface. A 3/4" drive impact wrench will typically weigh less than eight pounds;


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Cushion grips are now common on a variety of other power tools, including: die grinders, air ratchets, and air drills. Cushion grips reduce the transmission of vibration to the operator, and provide a comfortable, non-slip surface. Exhaust systems have been engineered for noise reduction. A few power tools feature a convertible muffler. Turning a valve in one-direction routes the exhaust through a muffler, considerably reducing exhaust noise, but proportionately reducing power. Turning the valve in the other direction provides a straight through exhaust. This setting allows the tool's full power potential to be realized. In many instances, the full power of the tool is not needed to remove or install fasteners. Air exhaust is now typically routed through the tool handle to cool the tool, reducing the amount of heat transmitted to the operator's hand.

Pneumatic tools must be maintained in accordance with manufacturer's specifications. Compressed air supplies should be moisture free. An automatic oiler should be installed in the air supply line, or a few drops of oil should be placed in the tool air inlet prior to use. A well maintained tool produces more power, reducing run time and the amount of vibration transmitted to the operator.

Pneumatic torque systems

More railroads are attempting to phase out older 3/4" and 1-in. drive pneumatic impact wrenches. They are typically heavy, vibration intensive, and have less power than new products. Heavier spline type drives are becoming obsolete, and many tool manufacturers are curtailing or discontinuing the production of spline drive sockets and accessories. One alternative to the removal of large fasteners, such as crab nuts, is the use of pneumatic torque systems. These systems offer several advantages. They use an air motor driven gear reducing system. This system does not produce any type of vibration or hammering. A system weighing only 21-lbs. produces a full 3,000 ft-lbs of torque. The tools' reaction arm absorbs all reactionary forces. No torque is transmitted back to the operator. Reaction arms are easily removable, and custom reaction arms may be constructed to meet any variety of specific applications. The tool tightens fasteners to their correct torque value simply by setting the air pressure to the corresponding torque value. The wrench will stall when the desired torque value has been obtained. Successful applications to date include General Electric power assembly hold down bolts and barring-over tools; EMD crab nuts; EMD fuel tank bolts; and traction motor support bearing cap bolts. Systems ranging from 350 to 4,500 ft-lbs are available. The only drawback to this type of tool is speed. The gear reducer turns at a very low RPM, making fastener removal a slow process. It might be advisable to use the torque system to initially break loose and apply the final torque to fasteners. A lighter, lower power 3/8" or 1/2" drive impact wrench may be used for final fastener removal or installation.

Hydraulic tools

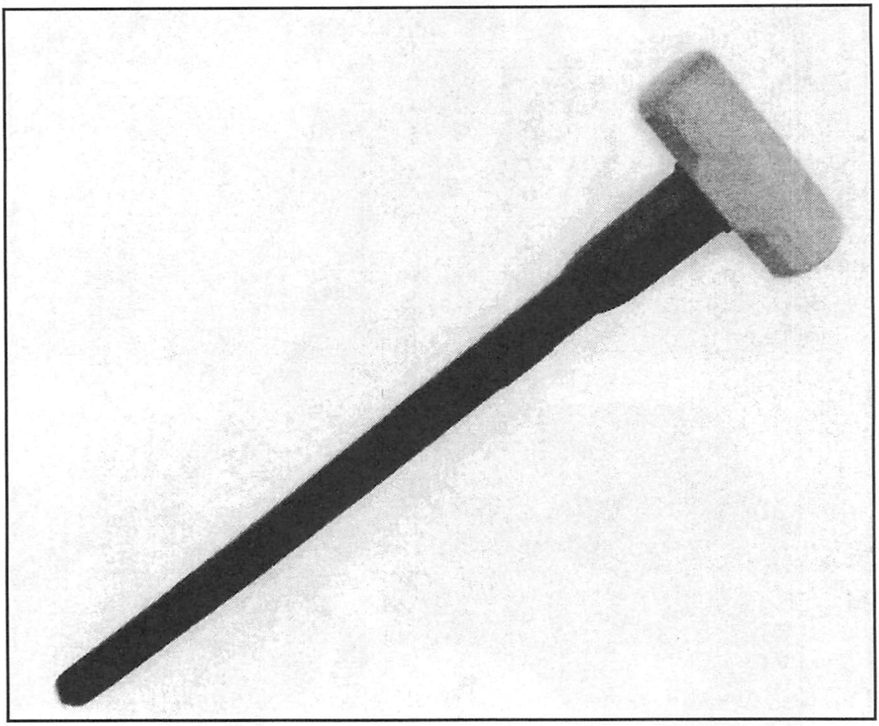
Hydraulic tools offer another alternative to heavy, high capacity impact wrenches. They are light weight, and do not produce any type of vibration or hammering that may be transmitted back to the operator. There are basically two types of hydraulic wrenches: a conventional type with a movable reaction arm, and a low profile type with removable cartridges. A hydraulic wrench weighing less than two pounds will produce up to 5,500 ft-lbs of torque. Proven applications using hydraulic wrenches include EMD water pump valves; and fuel tank drain bolts. This type pf wrench also has the disadvantage of running slower than conventional pneumatic tools.

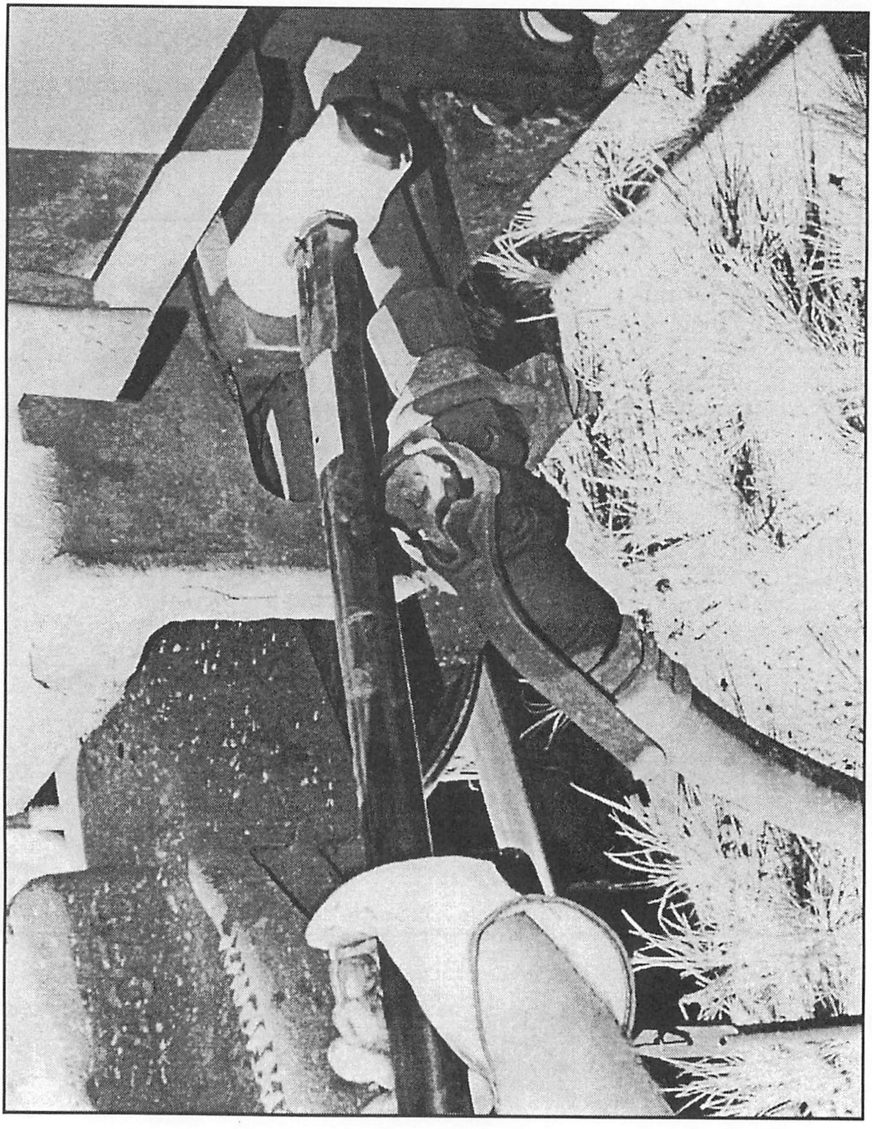
Specialty tools

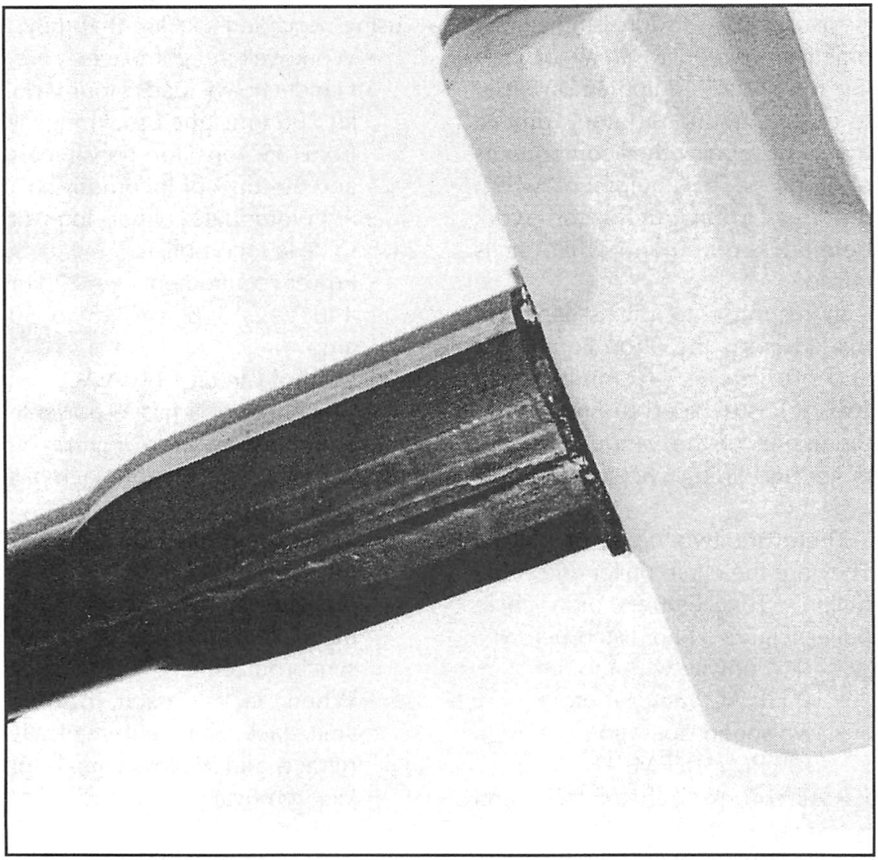
An effective way to improve ergonomics is through the design and manufacture of tools intended for specific maintenance applications. Specialty tools may improve ergonomics by reducing the amount of force required to perform a certain maintenance task or improving mechanical posture or joint deviation. Specialty tools also provide the added benefit of increasing productivity. Some examples of specialty tools include extendable length 1/2 and 3/4 in. breaker bars that requires less effort for fastener removal; a half-moon ratcheting wrench that provides easier access to engine components such as water pumps; a freight car door handle tool that protects the operator from handle spin. (the tool also provides extra leverage to turn the handle); an extended length wrench for injector pipe removal. (the extra length decreases the amount of operator exertion); a hydraulic handhold straightener that eliminates the effort normally required with manual straightening. Other specialty tools have been designed to accomplish various types of maintenance tasks, including air brake valve removal; vent cap removal; armature ring removal; and cotter pin removal.

Future design trends will continue to emphasize tool safety and ergonomics. Lighter weight components such as composites and titanium will be used in power tool construction with more frequency. These trends will continue to be driven by the industry's desire to provide a safer, more comfortable work environment for its employees.

A 1/2-in. drive impact wrench may be able to produce 800 to 1,000 ft-lbs of torque and still weigh less than 5 lbs. Three quarter inch drive impact wrenches may produce up to 2,000 ft-lbs of torque, and weigh less than 8 lbs. Technology and the railroad's unrelenting demand for improved safety and comfort will continue to drive the design and production of safer, better, easier to use tools.







III. LOCOMOTIVE LIFTING SYSTEMS

Prepared by: Ron Begier, Consultant
Portec Rail Products, Inc.

Introduction

The Federal Railroad Administration (FRA) has issued *Safety Advisory* 99-1, addressing safety practices related to lifting or jacking of railroad equipment in order to change traction motors, remove trucks or repair other components on a piece of equipment which requires individuals to work beneath equipment while it is raised.

In response to the issuance of this advisory, the Shop Equipment and Processes Committee of LMOA has decided to present this discussion of the various types of puller and lifting systems currently available.

There are two types of pullers. They are the chain puller and cable puller. The features of a chain puller (Figure 1) are listed below:

- 40-ft runway with rabbit
- 10 HP AC vector motor
- Two-speed operation-(30 FPM/10FPM)
- All sprocket, chain, cable and sheaves
- Floor plate over drive pit.

The typical installation of a cable puller is illustrated in Figure 2. The cable usually lies on the floor which creates a potential tripping hazard.

There are five types of lifting systems and equipment. They are listed below:

- Portable jacks
- Droptables
- In-floor jacks
- Overhead cranes
- Portable overhead beam and sling.

Portable jacks

The features and advantages of using portable jacks are that they:

- Work well in tight places
- Handle heavy loads - four jacks lift 200 tons (the usual range is from 35 tons for transit cars and 60 tons for locomotives)
- Accommodate either four or six axle locomotives
- Power requirements are 220 or 440 VAC, 3 phase, 40 to 50 amp
- Control Circuit - 110 VAC.

An example of a raised portable jack is illustrated in Figure 3. Additionally, the portable jack has many safety features:

- In the event of a power failure, the screws lock
- Jacks set at same height, automatically shut down when not synchronized
- When jacks reach bottom limit, jack plate automatically retracts and deploys wheels for jack removal.

Droptable

The second type of lifting system is the droptable (Figures 4, 5 and 6). Some of the specifications for a droptable are:

- Single axle hydraulic droptable -50 ton nominal capacity
- 10" bore cylinder capable of lifting 100 ton end of locomo-

tive 5″ above top of rail
- 78 inch wide table with ergonomically friendly work area.
- Push button controlled, two-speed, traction motor tilt positioning cylinder
- Push button controlled hydraulically operated table locking bars
- Programmable logic controller (PLC) incorporating all necessary machine controls and safety interlocks.

Some of the benefits of using a droptable from a safety and maintenance standpoint are:
- Simpler design - uses one hydraulic cylinder per service track to replace four mechanical screws and associated components
- Lower maintenance cost - fewer, more reliable parts require less maintenance and repair
- Quiet and smooth operation - operators enjoy a safer environment because of ease of communication
- Integrated hydraulic tilt cylinder - safer because it is integrated into the main hydraulic system eliminating secondary power supplies
- Hydraulically operated lock bars - easier than manual lock bars and with limit sensing switches are safer because movement of work table only occurs when desired.

In-floor jacking

The third type of lifting system is in the in-floor jacking system (Figures 7, 8 and 9). A manufacturer was approached by a major Class I railroad to develop an in-floor jacking system for locomotives. The concept called for stationary 11-in. jacks at front of pit with traversing 11-in. jacks at the rear to accommodate all locomotives. The jacks feature a revolving head piece to swivel under the jacking pads on the locomotive.

Overhead cranes

The fourth type of lifting equipment is the overhead crane (Figures 10 and 11). Overhead cranes are versatile but require a substantial investment to build a structure to house a 250-ton crane. The overhead crane is capable of lifting a 440,00 pound locomotive for truck removal. The versatility of a crane allows for the lifting of a heavy locomotive or smaller components such as an engine shroud.

Overhead beam and slings

The last type of lifting system to be covered is the overhead beam and slings (Figures 12, 13 and 14). This lift system features a four-point lift. The lifting units are box design with retractable wheel assemblies and are equipped with a three-stage telescopic double acting cylinder with safety holding valve. The power requirements are either 220/440 electric motor or gasoline engine.

This equipment can be used for double truck change-outs. It has a setup time of 2-1/2 hours. It can lift and swap trucks in 1-1/2 hours.

If an overhead crane is used instead of a forklift, the setup time is reduced to 45 minutes.

Acknowledgements

The author would like to acknowledge the cooperation, help and contributions received from friends, fellow committee members and associates from the AAR, Amtrak, Canadian National Railroad and Union Pacific Railroad. The author also thanks Portec Rail Products for allowing David Hartman and myself to prepare this paper.

Note: This paper was presented at the September 2002 Annual Technical Convention.

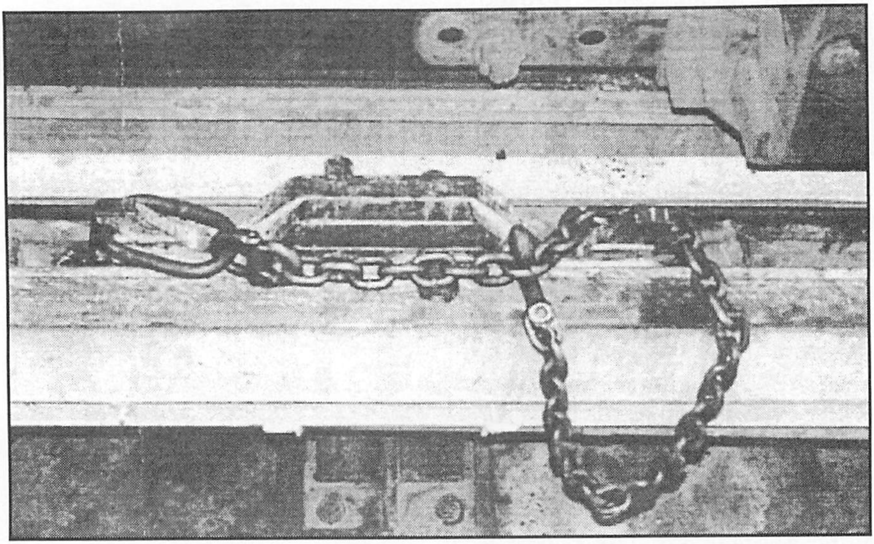


Figure 1 - Chain Puller

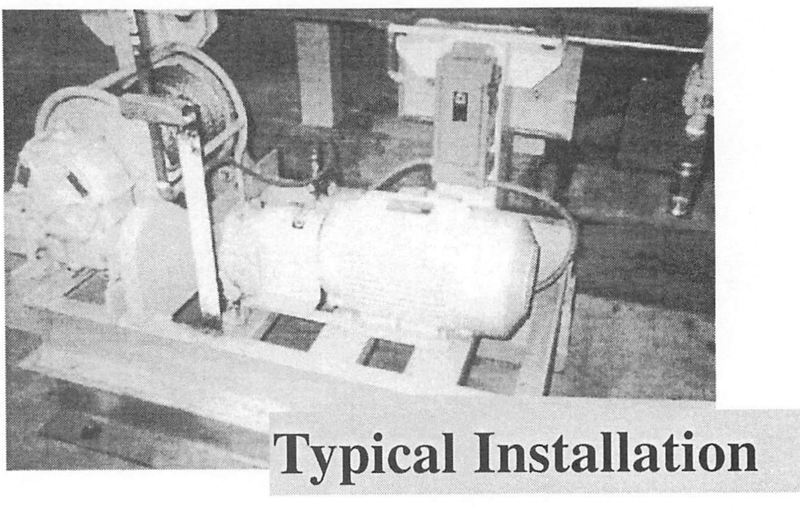
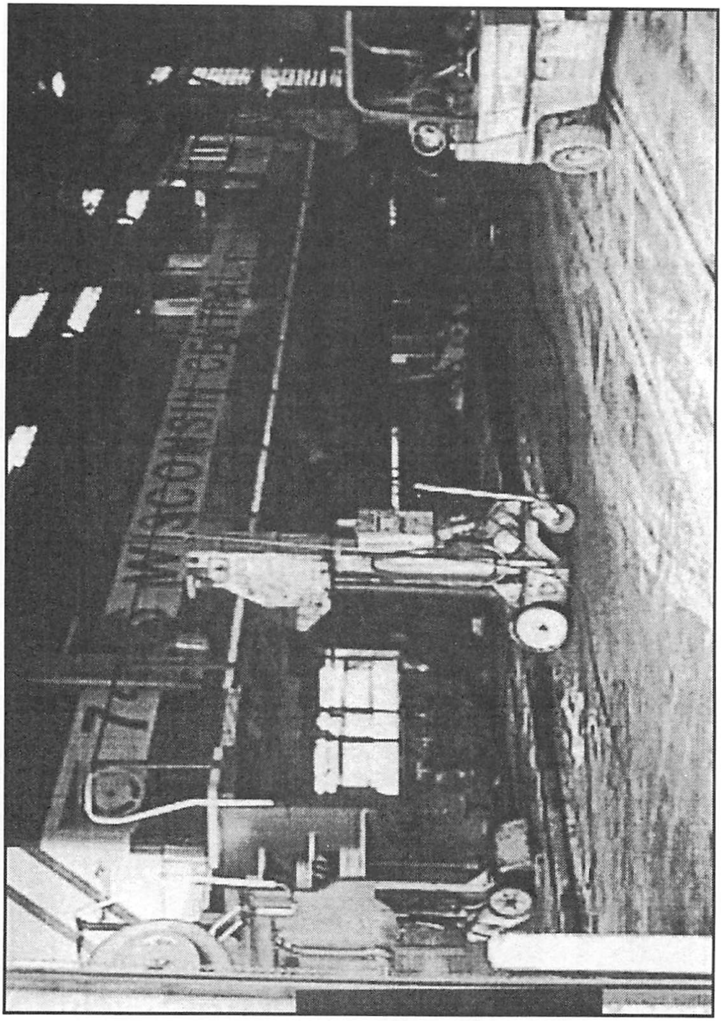


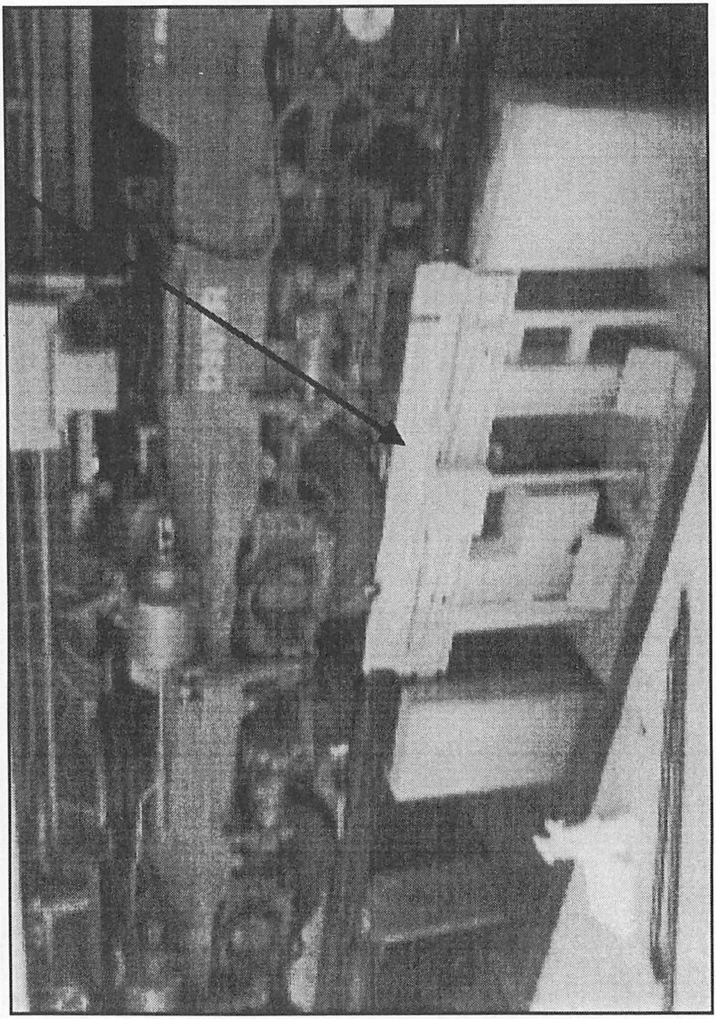
Figure 2 - Cable Puller

Figure 3



Raised Portable Jack

Figure 4



Drop Table

Figure 5

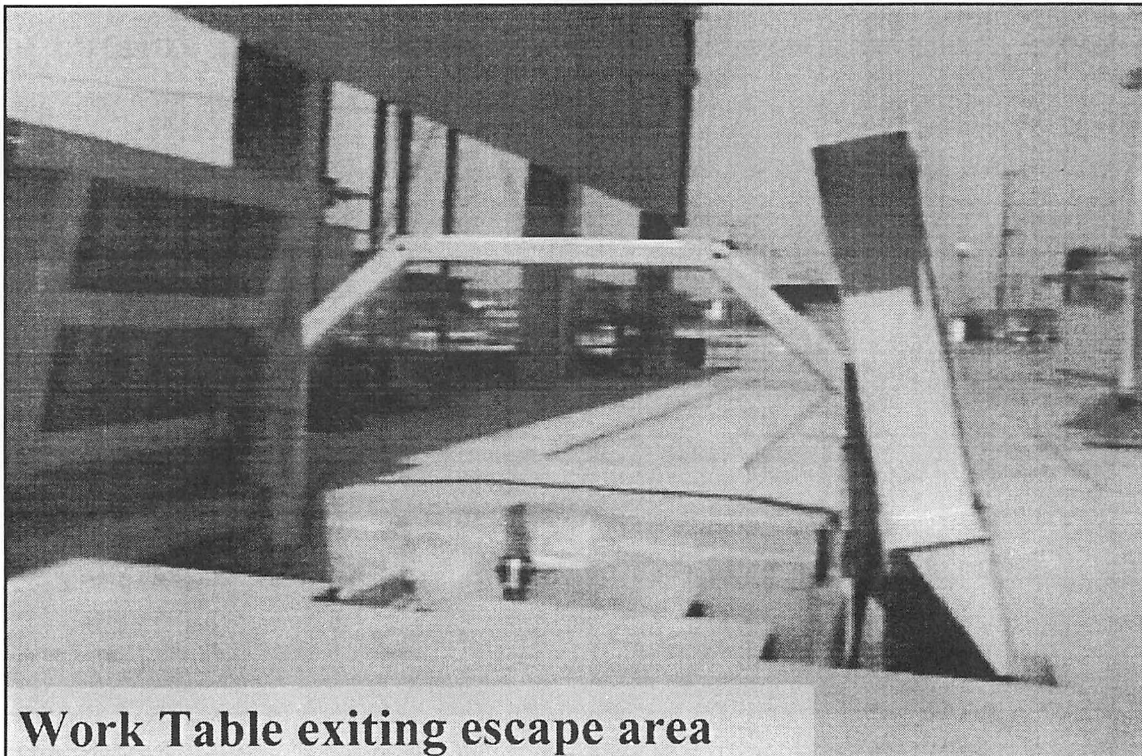

Work Table exiting escape area

Figure 6

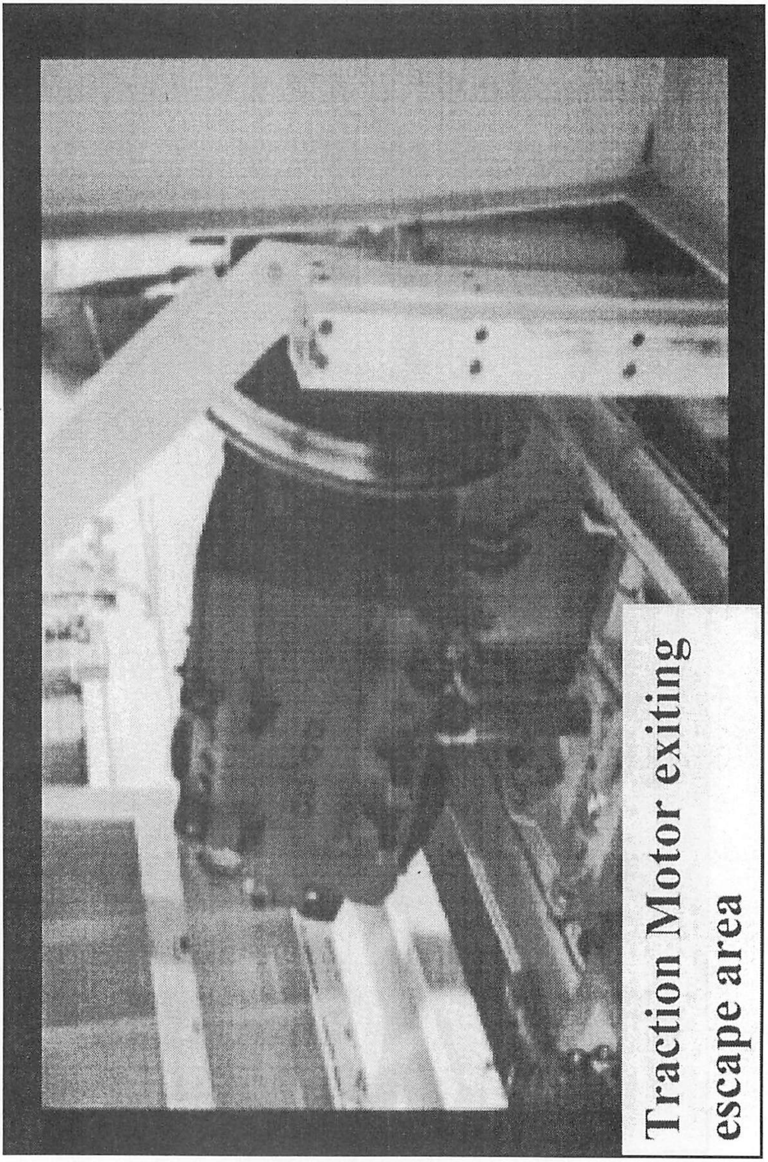
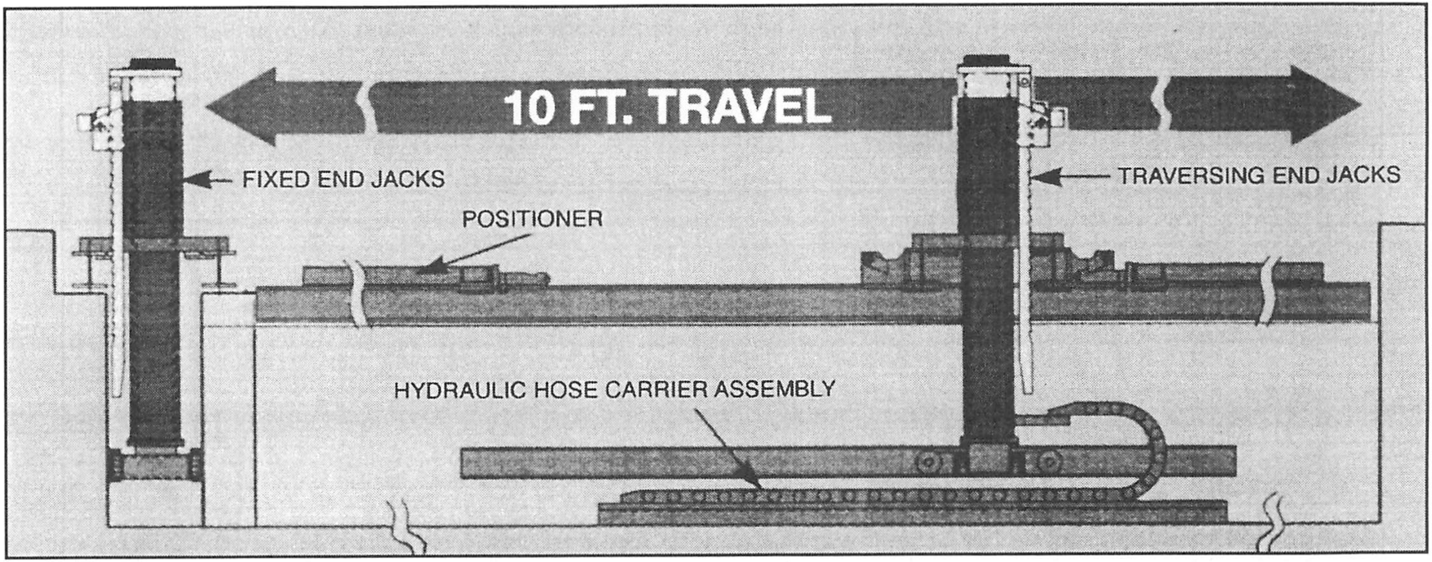
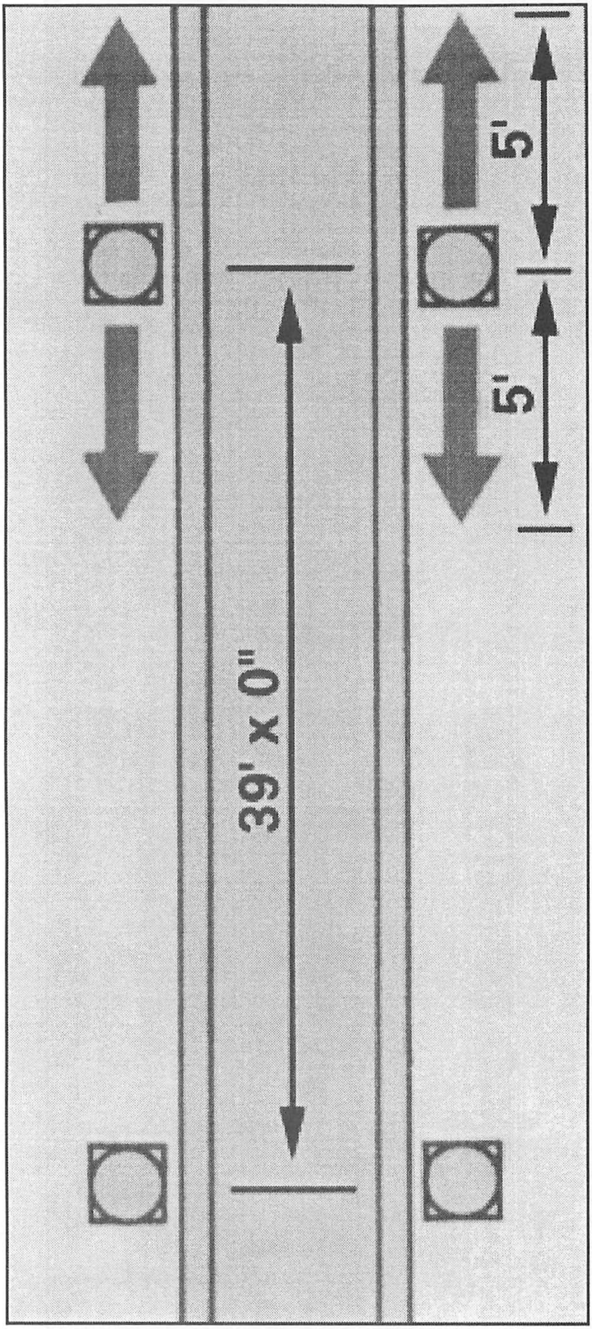


Figure 7



In-Floor Four Point System for Locomotives

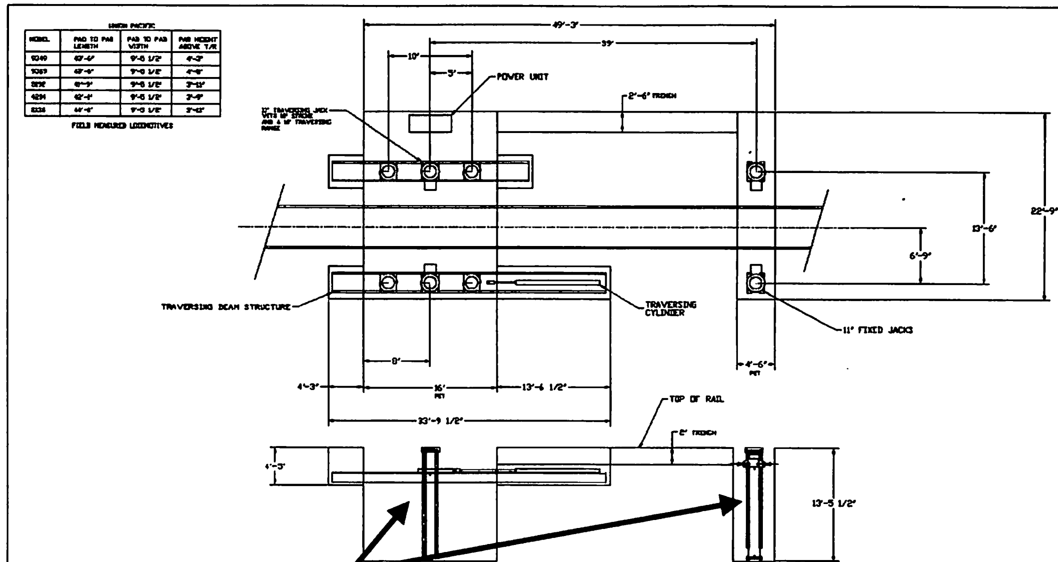
Figure 8



Four Point System for Locomotives

Figure 9

Four Point System for Locomotives



- **Front jacks fixed**
- **Rear jacks centered 39' from front jacks with allowable travel of 5 +/- feet, forward or backward**

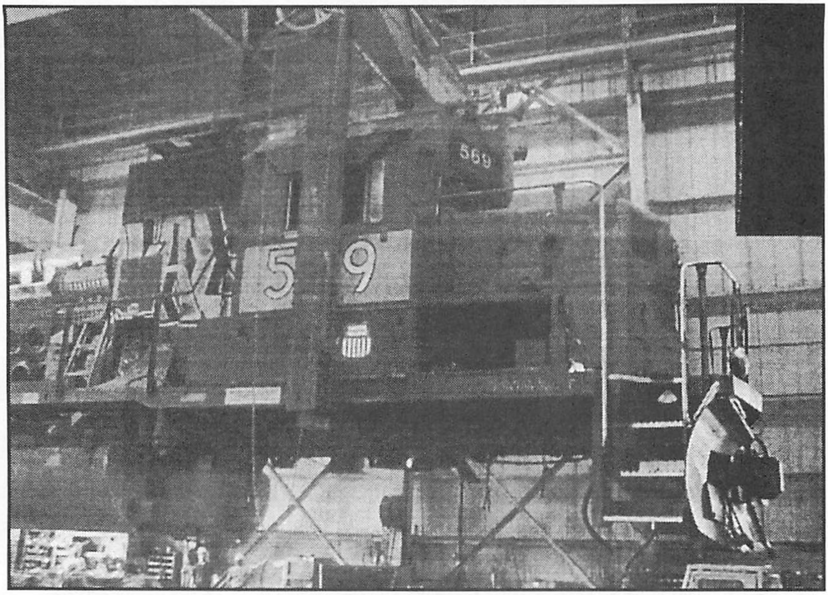


Figure 10
Overhead Crane

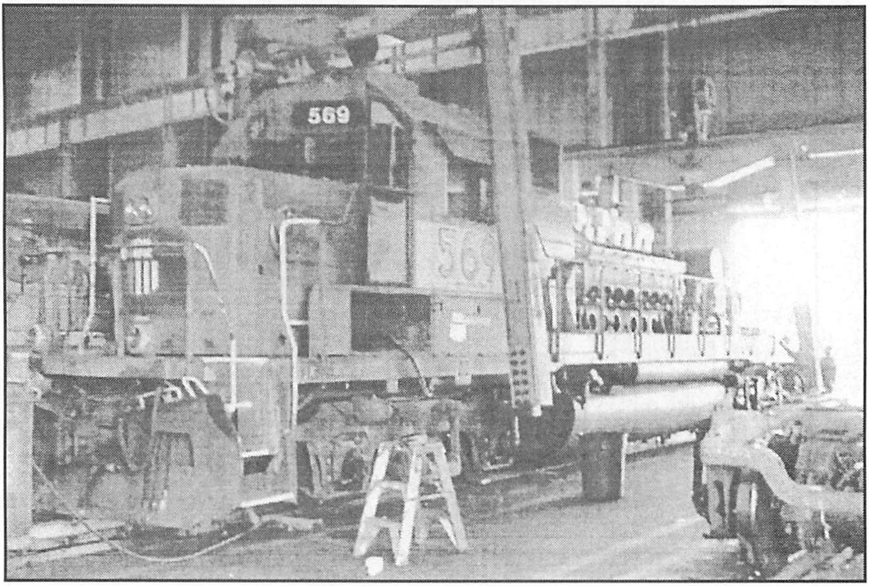
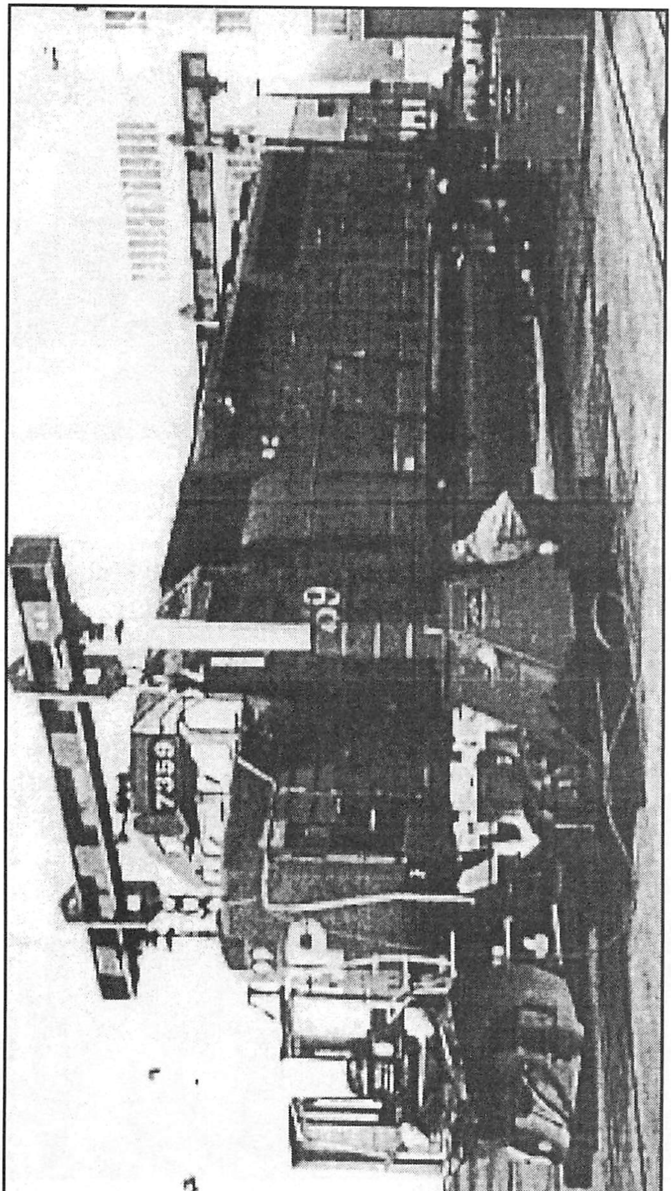


Figure 11
Overhead Crane

Figure 12



Overhead Beams and Slings

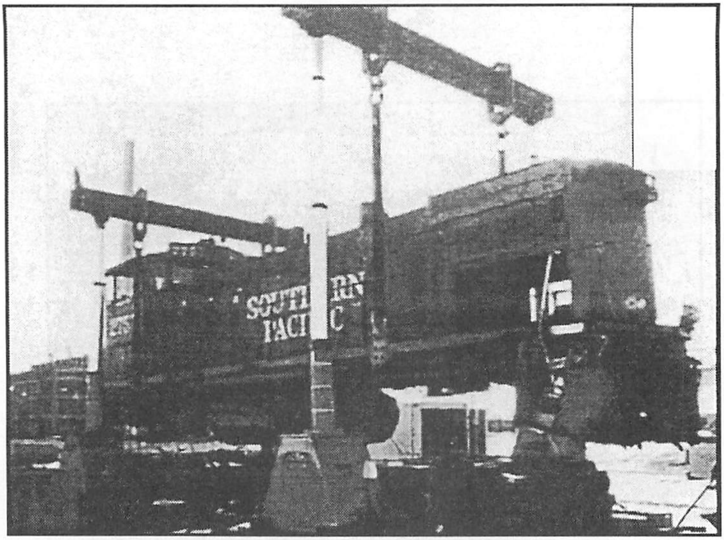


Figure 13
Lifting a switching engine for a double truck change-out

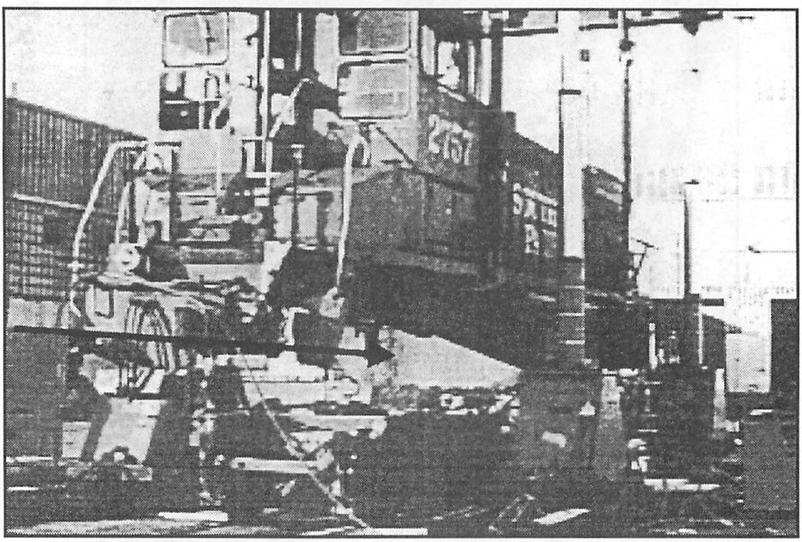


Figure 14
Observe clearance between the engine body and trucks

REPORT OF THE COMMITTEE ON FUEL, LUBRICANTS AND ENVIRONMENTAL

MONDAY, SEPTEMBER 22, 2003 3:45 P.M.

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PERSONAL HISTORY

Thomas Pyziak

Thomas J. Pyziak, Chairman of Fuel, Lubricants and Environmental Committee, was born in Chicago on August 10, 1954. Tom is a graduate of Gordon Technical High School in Chicago. He attended and graduated from St. Norbert in DePere, Wisconsin in 1976 with a Bachelor of Science degree.

Tom began his career as a lab technician with Motor Oils Refining Company in McCook, Illinois which is a re-refiner of petroleum lubricants. He learned all aspects of manufacturing from plant operation to quality control and research and development.

Tom transferred to marketing as a Technical Sales Representative and subsequently became an Industrial Sales Rep. He was given railroad/sales responsibility in 1984, handling product development, marketing/sales and oil waste removal sales. In 1989, this portion of the operation was sold to Breslube which two years later was acquired by Safety-Kleen Corp. Tom's current position is Senior Account Executive, handling all aspects of railroad engine oil development, sales/marketing with added technical responsibilities to the OEM's, GM, Ford and Chrysler.

Tom's hobbies include gardening, Chicago softball and auto racing. He is married. His wife's name is Katie and they reside in Palatine, Illinois.

I. LABORATORY RESULTS MAY PUT YOUR LOCOMOTIVE AT RISK

Prepared by Dennis W. McAndrew,
Fuel and Lubricants Specialist
General Electric Co.

Introduction

What is the purpose of having a used oil analysis program?

GE Transportation Systems (GETS) depends on the results of oil analysis to determine the condition of both diesel engines and engine oils used in locomotive applications. Quality oil analytical programs are critical to maintaining engine oil condition. Used oil analysis is predictive and preventive: by analyzing trends that indicate potential diesel engine failure, action can be taken which prevents the failure from occurring or reduces any potential damage. Improved diesel engine reliability and durability may be directly attributed to a quality used oil analysis program.

Quality in used oil analysis can be achieved by running several standard original equipment manufacturer (OEM) recommended tests. These tests comprise direct measurements of the physical and/or chemical properties of the oil, which, in turn, can affect performance of the diesel engine. For test selection, consideration was also given to analytical methods for which all-necessary laboratory equipment and procedures could be readily obtained by each railroad. Over the years, results from these recommended analytical tests were empirically correlated to engine conditions. From these correlation studies and additional laboratory tests, used engine oil condemning limits were established.

Each railroad typically conducts its own used oil analysis program. Today many railroads employ commercial laboratories to perform the engine oil analysis. Many of these laboratories are not familiar with OEM recommended analytical methods. Validity of the results from any contracted laboratory must be established by a correlation study comparing the laboratory's results with the results obtained by an OEM approved/recommended laboratory.

These concerns are magnified by the fact that several laboratories are using methods that differ from OEM recommendations. In some cases, engine oil condition is being evaluated based on these non-recommended methods without any connection to engine condition.

This correlation study was commissioned to evaluate the results of the recommended and non-recommended methods. Results of used oil analysis from several laboratories have been correlated to the results from the reference laboratory. The degree of correlation, or lack thereof, is an indicator of the validity or non-validity of the results reported by these laboratories.

Expectations of the laboratories

Used oil analysis programs should be able to identify a potential diesel engine problem. This identification makes it possible to bring the locomotive in for maintenance before a minor mechanical problem becomes severe or the oil is beyond its useful life and becomes corrosive to the engine. Trending the data and observing the upper and or lower condemning limits can help accomplish this goal. The oil analysis results should also be used to direct the required maintenance. For example, if the oil viscosity is too low, the mechanics should look for a fuel leak.

Methods

The main focus of this study was reproducibility of results between laboratories, although repeatability of results (within a laboratory) was also noted. Several oil specimens were split into two samples, one of which was sent to a railroad's laboratory and the other to the reference laboratory. The laboratories ran their standard tests on the used oil samples. All data was compiled into a spreadsheet for the correlation studies.

In order to facilitate an understanding of the correlation method and its implications, a brief description follows.

Typically a linear best curve fit was calculated for each data set. The mathematical equation describing that best fit approximation is $y=mx+b$. The slope (m) and intercept (b) are calculated during regression analysis, along with a value called goodness of fit (R^2). A perfect correlation occurs when $R^2 = 1$, slope = 1 and the intercept = 0. Figure 1 is an example of such a perfect fit. The $R^2 = 1$, slope = 1 and the intercept = 0. Figure 2 is an example of data with a bias, i.e., the best-fit line does not pass through zero, and Figure 3 is an example of a poor fit.

Test, test results, and correlations

The testing methods used included the recommended methods and the railroad's methods. Although wear metals were determined they are not included in this study. The tests were as follows:

- Viscosity
  - ASTM D445
  - Infrared spectrometer
- Insolubles
  - LMOA PI
  - Infrared spectrometer
  - Dielectric determination
- Base number
  - ASTM D4739
  - Infrared spectrometer (sulfate or carbonyl/ oxidation band)
- Oxidation
  - Infrared spectrometer (carbonyl band)
- Wear metals
  - Inductively coupled plasma
  - Ark spark

Tables 1 and 2 are the tabulation of the different analytical tests used and the correlations.

Discussion of results

The correlation results indicate two primary conclusions. First, many weak correlations were observed. These weak correlations indicate that the results reported by the railroad's laboratory differ from those reported by the reference laboratory. Second, a significant number of strong correlations were observed. These strong correlations indicate that the results reported by the railroad's laboratory are the same as those reported by the reference laboratory. In addition, strong correlations demonstrates that the recommended methods can have a high degree of reproducibility between laboratories.

The laboratories that used automatic viscometers correlated very well to the reference laboratory viscosity measurements. Figure 4 is an example of an excellent viscosity correlation with a $R^2 = 0.9942$, slope approximately 1, and intercept of 0.57. Figure 5 is an example of a weak viscosity correlation test with $R^2 = 0.3950$, slope = 0.8891, and intercept 1.085. In the data set for figure 5, the railroad's contracted laboratory uses an infrared spectrometer to calculate the oil's viscosity. The weak correlation suggests the method cannot be successfully used, or the laboratory needs to re-evaluate the internal calibration of its method.

Another strong correlation is illustrated in Figure 6. Figure 6 is a plot of the alkalinity of the oil (base number) determined by ASTM D4793 by both laboratories. Figure 7 is an example of two different analytical methods used to determine the base number. In this example the oil's base number was determined by ASTM D4739 (on the x axis) and by an infrared spectrometer (on the y axis). Note that the infrared spectrometer values were not converted by a transfer function to values that were scaled to titration method values. Therefore, with this data set the R^2 is acceptable, but further understanding of the slope and intercept is required before accepting the correlation. Figure 8 is the same data set, but with an exponential curve fit rather than a linear fit. This illustrates that sometimes an improved fit can be obtained with a non-linear fit, since all correlations are not necessarily linear.

Figure 9 illustrates an example of poor correlation. In this example, the railroad's laboratory used an infrared spectrometer and a transfer function to mathematically convert the infrared absorption units to values that should be equal to results from a titration (ASTM D4739). Note that the R^2 is 0.7057, the slope is 0.3979, and the intercept is 9.5022. The significance of this correlation is in the slope and intercept. Let us use the reference laboratory as a base line. A condemning base number of 3 measured by the reference laboratory would be reported as high as 10.696 by the railroad's laboratory. This artificially high base number value will not trigger a warning to bring the locomotive in for maintenance. The over reporting of the oil's alkalinity places the engine at risk for corrosive attack and the possibility of leading to a catastrophic engine failure. A perfect correlation regression line was added to Figure 9 to visually show the difference in the actual and expected curve fits.

Several correlation methods may be helpful in validating a laboratory's test results. One method is to have multiple laboratories analyze several oil specimens (the method used in this study). Another method is to use one laboratory as a reference and compare results from multiple laboratories to those obtained by the reference laboratory on the same several oil specimens. If nine out of ten laboratories have a strong correlation and one does not, the observer may conclude that the reference lab and the nine laboratories are correct and the one that did not correlate is having some difficulties.

A third method would be to evaluate test results from several test methods on an oil specimen and determine if as a data set the results make sense. For example, if there is a high insoluble there should be low base numbers and high viscosity. Unrealistic results, such as high insolubles and high base numbers, should trigger a retest of the oil specimens.

A fourth method to validate results is to look at the correlation between different methods. Figures 10, 11 and 12 are examples of such correlations. Figure 10 shows that as the oil oxidizes the viscosity increases as expected; these data are from the reference laboratory. It must be noted that overall there was not strong correlation in the oxidation railroad sets. Figure 11 shows that an increase in soluble content corresponds with increased number of days. Figure 11 illustrates data from 5 different locomotives. Figure 12 illustrates data from only one of those five units. Figure 11 and 12 show that the insoluble content increases with time at some expected rate. In other words there are expected trends between the insolubles and days. Those trends should be used to help in the validation of the results. Note that correlations of insolubles to days are typically better when plotting data from one locomotive. This is because when data from several units are plotted together the units have different utilization, oil consumption, oil additions, and other factors unique to a unit that tend to lower the R^2.

The last methods discussed is the understanding of the useful oil life and expected changes in oil chemistry, which should be fundamental to any laboratory manager and laboratory chemist or technician. There is a fixed weight percent of additives in the oil, which are consumed with the utilization of the locomotive. So if a unit is heavily used (high Megawatt-hour (MWh) value) the additives are consumed at a faster rate. This consumption of the additives follows a decay or depletion trend line that is directly related to utilization. If a laboratory is reporting only slight drops in the oil's alkalinity after 92 or 184 days with high utilization, a warning should be raised to re-run that specimen. If this slight drop is typical for many locomotives, then one must conclude that the laboratories' instruments, methods, or process need to be re-evaluated.

Figure 9 is an example of an instrument, methods, or process that does need to be re-evaluated. The data for Figure 9 were from laboratory 2. This information was given to that laboratory January of 2003. After 11 weeks of re-standardization and testing of their instrumentation a new round robin was conducted on 50 used oil specimens. Those improved results are reported as laboratory 3.

Conclusions

With the push to extend oil drains, missed drains, different analytical methods, the inconsistency indicated by this correlation study shows that it is clearly necessary to improve the engine oil testing process.

- Several laboratories were capable of running all or most of the tests.
- When recommended tests were run, results could be reproduced by some of the laboratories.
- Typically the railroad laboratories do not run all of the recommended tests due to sample volume and time constraints.
- Several laboratories' alternative methods correlated very well to the recommended methods.
- Some laboratories were not capable of running the recommended tests.
- Many railroads run or specify alternative tests with poor correlation to the recommended methods.
- Some railroad laboratories do not run any recommended tests except viscosity, and one runs an alternative method for viscosity.

Although there were some strong correlations there were too many poor results. The lack of consistent, well-correlated results may place the locomotive's engine at risk. Only one test method in the round robin was run on the oil specimens by all the laboratories, which showed reasonable correlation, indicating that most laboratories had no difficulties in running that test. That test, viscosity, was one of the most basic and fundamentally important methods.

This study clearly shows much work is required to improve the reliability and value of the results the used oil analysis programs generate.

Recommended action

It is this committee's position that the LMOA FL&E, railroad's laboratories, and other interested parties need to work together to develop repeatable and reproducible methods that correlate with conditions found in the engines.

The adoption of any new ASTM methods or methods unique to the the railroad industry must be correlated with the existing knowledge base developed from the existing test methods. Furthermore, consideration should be given to methods that are faster, less dependent on the skill of a chemist or technician, not affected by differences in additive or base stock differences (sources), test equipment readily available, and other factors. Only after a suitable alternative process has been proven can standardization start.

Acknowledgements:

The author wishes to thank General Electric Transportation Systems for permission to publish this work. I would like to also thank the LMOA's FL&E Committee for its review of this paper, and additional thanks to Mr. Gary Dudenhoefer for his assistance in editing the paper.

Table 1													
	Viscosity			LMOA PI			LMOA PI / Soot			Base Number			
Railroad	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept	Railroad
1	0.9942	0.9598	0.5767	-	-	-	0.3529	0.3867	1.7529	-	-	-	1
2	0.3950	0.8891	1.0851	-	-	-	0.7886	0.4936	0.8332	-	-	-	2
3	0.9798	0.9349	1.0497	0.8559	0.9022	0.4476	0.8777	0.9096	0.4052	0.9790	1.1553	-2.1998	3
4	0.9411	0.9972	0.0078	0.7334	0.3955	0.5225	-	-	-	0.9942	1.0340	-0.7922	4
5	0.9797	1.0014	0.0292	0.8131	1.1154	-0.1958	0.3317	2.9199	0.7846	0.9919	0.8817	1.2858	5
6	-	-	-	0.9950	0.8629	0.2744	-	-	-	-	-	-	6
7	-	-	-	0.6258	0.8761	0.2341	-	-	-	-	-	-	7
8	-	-	-	0.9115	1.0213	0.1870	-	-	-	-	-	-	8
9	-	-	-	0.8294	0.6848	1.5670	-	-	-	-	-	-	9
10	0.9912	0.9780	0.3282	0.6080	0.6058	0.8589				-	-	-	10
11	-	-	-	0.9828	1.0878	0.1140	0.9851	0.8094	1.3309	0.9245	1.3284	-1.5974	11
12	0.7905	0.8769	13.9910	0.8278	0.9555	-0.8223	0.8912	1.4497	-1.6407	0.9976	1.0413	-0.5780	12
13	0.9635	0.9927	0.3569	-	-	-	0.8134	3.3340	0.3880	0.8815	0.9419	-5.6290	13
14	0.9349	0.9783	0.3672	-	-	-	0.5509	10.0830	60.0570	-	-	-	14
				LMAO PI Alt Method			LMAO PI / An-Oil-Izer						
15	0.9341	0.8622	2.2773	0.4057	0.6245	1.7136	0.3721	6.2914	6.8140	-	-	-	15
16	0.4451	0.8510	2.4910	0.2281	0.4253	1.3733	0.2981	4.8125	10.3400	-	-	-	16
17	0.7972	0.9165	1.4278	-	-	-	-	-	-	-	-	-	17
18	0.8480	0.8186	3.0512	-	-	-	0.3847	5.7351	7.0850	-	-	-	18
19	0.8746	0.8627	2.1711	0.4418	0.8237	2.0538	0.3852	8.3261	3.0389	-	-	-	19
20	0.9763	1.0700	0.9604	-	-	-	0.3316	5.2711	9.6930	0.9396	0.8692	0.8734	20
Avg -->	0.8478	0.9228	2.0864	0.8183	0.8507	0.3187	0.6989	2.5482	7.9889	0.9615	1.0638	-1.5851	<-- Avg

Table 2													
	Base Number / Sulfate			Sulfate			Soot			Oxidation			
Railroad	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept	R^2	Slope	Intercept	Railroad
1	0.9295	0.6862	2.5961	0.8978	-12.7730	16.1330	0.8130	4.7512	0.4504	-	-	-	1
2	0.7057	0.3979	9.5002	0.6670	-7.7919	18.0530	0.8458	2.8218	0.4349	0.6384	25.9570	-2.4807	2
3	0.9782	1.1406	-2.0053	0.8484	-19.5660	20.3400	0.8575	7.3588	-0.8878	0.8818	30.7410	-2.6712	3
4	-	-	-	-	-	-	-	-	-	0.6110	1.0340	-0.7992	4
5	0.3766	-1.6193	35.8530	0.2184	33.8040	1.8480	0.4207	36.2280	-7.9445	0.5789	74.1090	-13.3760	5
6	-	-	-	-	-	-	-	-	-	-	-	-	6
7	-	-	-	-	-	-	-	-	-	-	-	-	7
8	-	-	-	-	-	-	-	-	-	-	-	-	8
9	-	-	-	-	-	-	-	-	-	-	-	-	9
10	-	-	-	-	-	-	0.4810	1.2624	2.6056	-	-	-	10
11	-	-	-	-	-	-	-	-	-	-	-	-	11
12	0.9920	0.8365	0.8791	0.9589	-13.4780	14.9510	0.9932	4.0557	-0.9536	0.9235	39.0090	-2.8325	12
13	0.9251	-3.5988	53.4110	-	-	-	-	-	-	0.7130	0.3472	0.8494	13
14	0.7230	-1.9142	47.3650	0.8514	36.6870	8.1076	0.9766	55.3670	-10.4220	0.4167	28.8890	8.2012	14
	BN vs. pH												
15	0.5305	0.2962	4.3395	-	-	-	-	-	-	-	-	-	15
16	0.5502	0.2929	4.5308	-	-	-	-	-	-	-	-	-	16
17	-	-	-	-	-	-	-	-	-	-	-	-	17
18	0.6193	0.1946	5.3992	-	-	-	-	-	-	-	-	-	18
19	0.5071	0.2996	4.1481	-	-	-	-	-	-	-	-	-	19
20	0.8542	-2.7450	42.9500	0.9038	59.7970	-15.6270	0.9817	59.2290	-6.1052	0.5513	42.3330	-0.8258	20
Avg -->	0.8043	-0.5816	21.0856	0.7403	2.8137	13.2388	0.7697	15.9778	-2.3881	0.6805	28.5837	-1.8727	<-- Avg

Figure 1

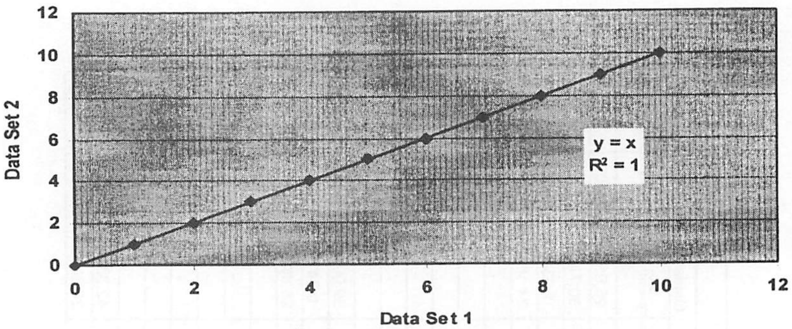


Figure 2

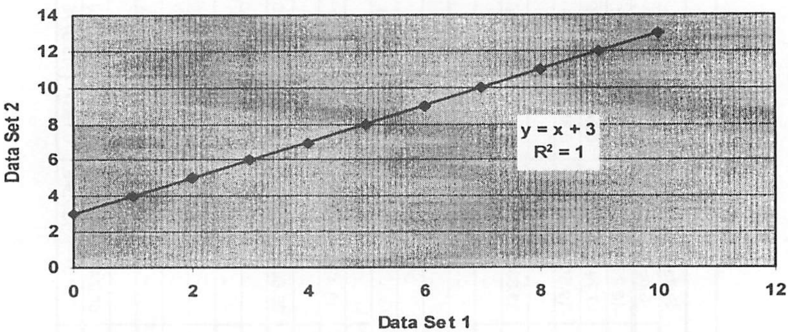


Figure 3

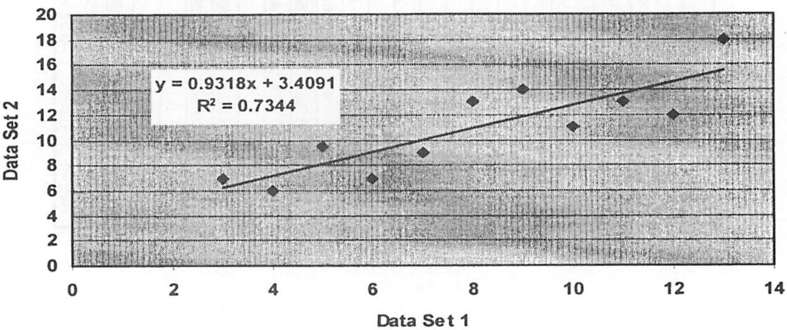


Figure 4
Viscosity

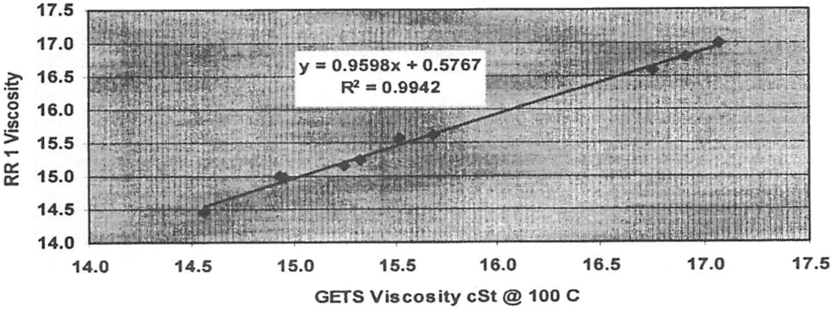


Figure 5
Viscosity

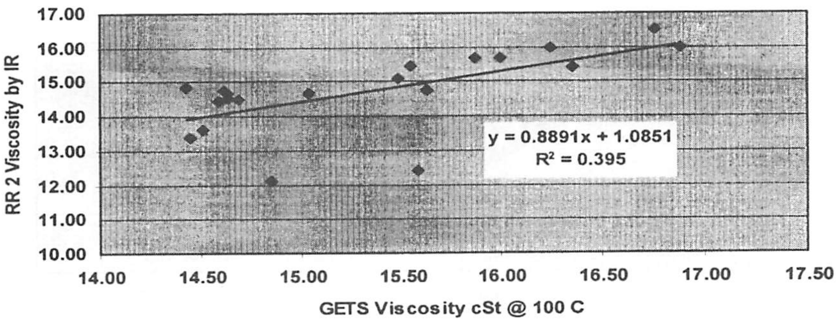


Figure 6
GE BN vs. RR 4 BN

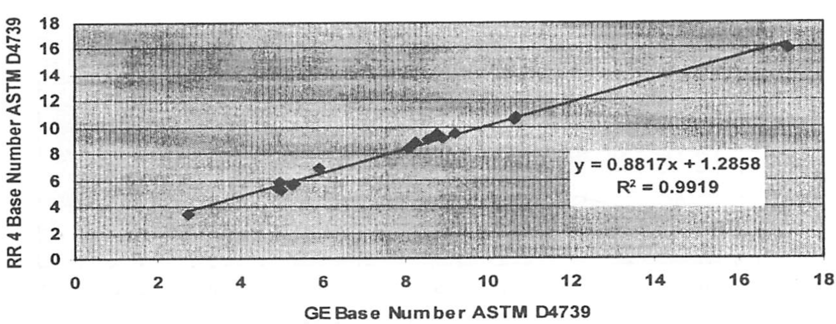


Figure 7
ASTM D4739 to Infrared Spectrometer

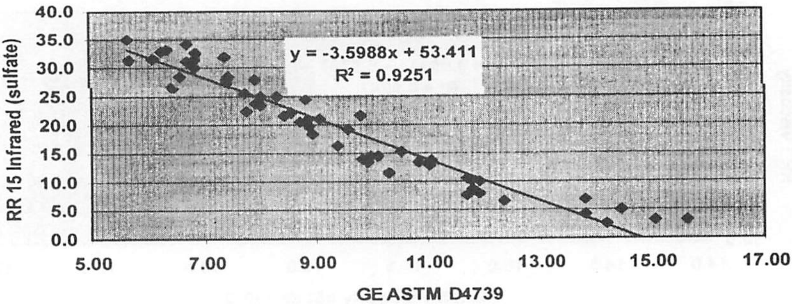


Figure 8
ASTM D4739 to Infrared Spectrometer

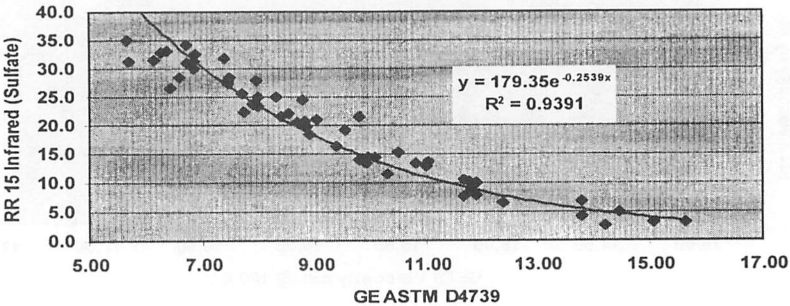


Figure 9
ASTM D4739 to Infrared Spectrometer

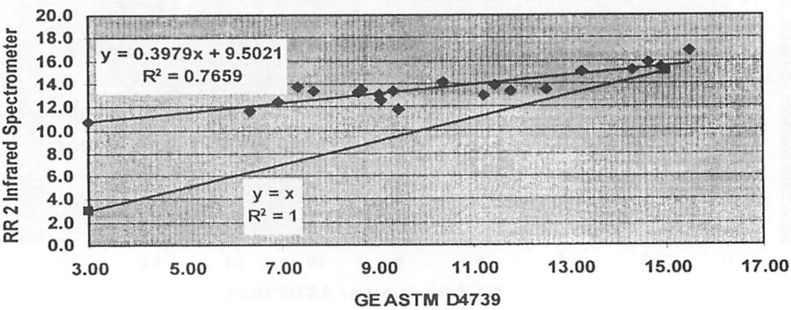


Figure 10
RR 13 Viscosity vs. Oxidation

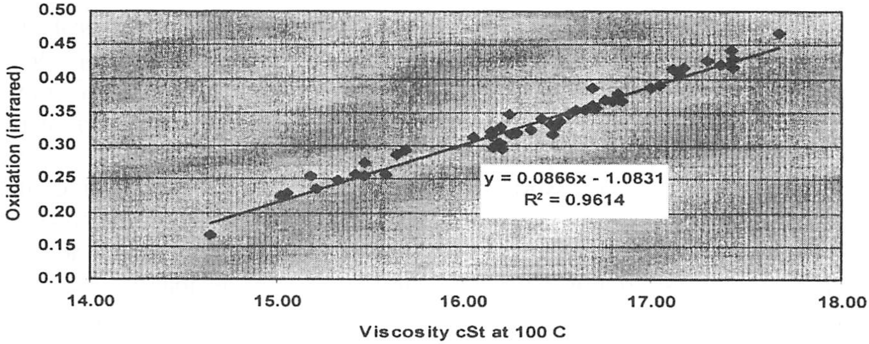


Figure 11
Days vs. Insolubles RR 15, 5 Units

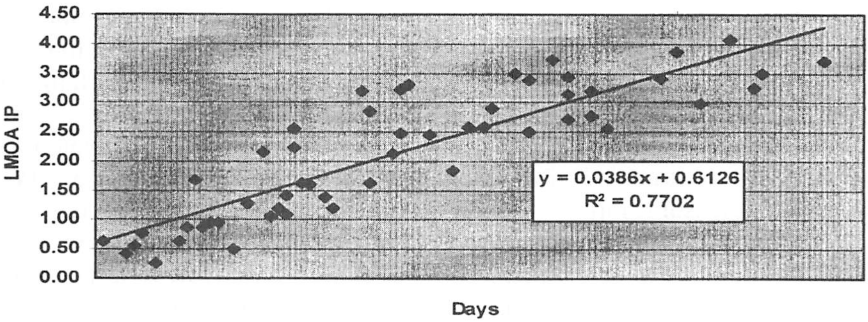
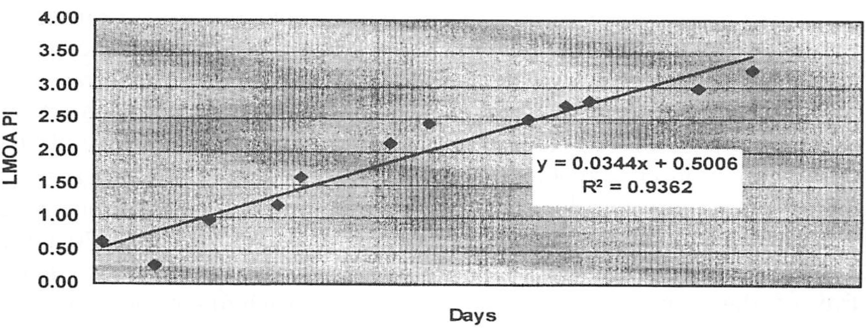


Figure 12
Days vs. LMOA PI 1 Unit



II. TOP OF RAIL FRICTION MODIFICATION STUDIES ON THE BNSF

Prepared by Glenn Bowen,
Director Laboratory Services
BNSF Railway

In the last few years a number of railroads have expressed an increased interest in an alternate form of locomotive borne rail lubrication: top of rail friction modification (TOR FM). A large part of this interest has come about because of derailment prevention. With the influx of intermodal articulated equipment over the last 15 years, many railroads have seen a big rise in the number of rail rollover derailments generated by excessive lateral forces with these cars.

Testing by individual railroads and by the AAR's Transportation Technology Center, Inc. (TTCI) has clearly demonstrated TOR friction modification substantially reduces lateral forces in curving, an advantage not normally seen with conventional flange lubrication. Further interest has come from testing at TTCI and other railroad test showing energy savings from TOR friction modification exceeding those from flange lubrication.

While a lot of railroads have shown interest in TOR FM, there has not been significant growth in the use of these systems for a variety of reasons. There is the substantial cost of the application equipment and friction modifier, the logistics of application (you apply the friction modifier only from the rear locomotive of the consist) and there is "hangover" from the bad experience railroads had with flange lubrication. This "hangover" is due to the high costs of maintenance, poor reliability and ease of defeating (engineers shutting the lubricator off) the spray flange lubrication systems. For all of these reasons the BNSF and many other railroads are wading into the TOR friction modification very slowly with a keen eye on the economics and equipment reliability.

In the summer of 2002 the BNSF conducted a series of "Coast Down" tests at Elmdale, Kansas aimed at better understanding the economics of the TOR friction modification. You will recall the testing at TTCI showed energy savings in a closed loop of near constant curvature in the range of 20-30%. With the railroad nearly 80-85% tangent (straight) track, we questioned how the savings seen at TTCI related to that in tangent track service. We thought a study of the energy savings on tangent track, what we refer to as a "Coast Down" test, would provide a better prediction of the real world savings.

Elmdale, Kansas was selected as the site of the testing because of the track characteristics of zero curvature, well maintained track and near constant grade over several miles.

A test consist was made up of one GE-9 locomotive, BNSF research and test car 83, 10 loaded gondolas and one GP-35 unit pointed the opposite direction for making reverse moves. Triplicate runs were made at 10, 30, 50 and 70 mph. Energy consumption was determined for each run by measuring the locomotive voltage and amperage over time and converting that value to kilowatt-hours. An instrumented coupler on Test Car 83 was used to determine the coupler force work done (ft-lbs) in pulling the train. That coupler measurement was used to check against the locomotive power measurements for consistency from run to run.

A wind sensor was mounted to the front of the locomotive and used to measure and correct for wind speed and direction. Winds over 5 mph can have significant influence in these tests and runs with higher wind speed were generally thrown out.

Lubrication measurements for coefficient of friction (COF) were made on the gage corner and top of rail with a hand tribometer at several locations along the test route before and after each run.

Over the test period of 4 weeks we evaluated:

- Baseline or dry conditions
- Spray flange lubrication with normal spray output (0.05 cc/ 300ft.)
- Spray lubrication with elevated output (0.10 cc/150ft.)
- Spray with elevated output and the nozzle redirected to the wheel tread
- TOR friction modification
- Stick lubrication.

Test results are summarized in the table below:

	Average % energy savings
Spray flange lubrication/ normal spray output	0
Spray flange lubrication/ elevated output	0
Spray flange lubrication/ elevated output/ nozzle redirected	10.46
TOR friction modification	6.65-12.64
Stick lubrication	0

The biggest surprise in the testing was the absence of energy savings seen with the spray flange lubrication. In similar tests in the early 1980's we had seen considerable savings with flange lubrication. Differences in those tests were the type of lubricant tested at that time (a heavy graphite solids lubricant in the 1980's versus a simple lithium based grease in this test) the output of the lubricators and the nozzle alignment.

The tribometer test results suggest the major difference in the spray lubrication tests conducted in the early 1980's and the 2002 tests was the nozzle alignment. Substantial energy savings were achieved with spray lubrication only when the nozzle was directed to the tread. The tribometer measurements show you have to get lubricant on the top of the rail and reduce that COF in order to achieve energy savings on tangent track. If the locomotive isn't hunting (where lubricant applied to the throat of the flange can be transferred to the rail) or if the lubricant does not migrate to the tread and on top of the rail, you will not get savings on tangent track.

I haven't mentioned one important reason for conducting the test in the manner that we did. Normally when you pull a train you have to overcome a number of different train resistances: grade resistance, acceleration resistance, curve resistance, rolling resistance and aerodynamic drag. You will recall our tests were conducted at constant speed with no curvature and no grade. Essentially we had no grade, acceleration or curve resistance, what we were measuring was pure rolling resistance and aerodynamic resistance. If you can calculate the affect that the TOR friction modification has on the rolling resistance and aerodynamic resistance, you can input that knowledge into any train performance calculator (a computer model) and simulate/predict the energy savings in any train on any route.

This was accomplished by converting the kilowatt-hour energy results from the TOR friction modification tests into foot-pounds and dividing that value by the length of the test zone to get the instantaneous train resistance in pounds. Dividing that value by the train tonnage puts the resistance in units of lbs./ton. These are the same units used in the Modified Davis equation, the most widely known and recognized formula for calculating the rolling resistance and aerodynamic resistance of a given train.

The Modified Davis equation comes in the form of "cV^2+a". The constant or "a" term is generally associated with rolling resistance. The "c" term is often called the aerodynamic resistance as it is driven primarily by the aerodynamic characteristics of the train. However, the "c" term does include other resistances (for example; truck hunting resistance) that vary with the square of the speed. What we did with the data from the dry and friction modified runs was plot the train resistance (lbs./ton) at each of the test speeds and do a least squares analysis applying an equation in the form of the Modified Davis equation. That analysis is represented in the graph depicted at the end of the paper. You can see we reduced the rolling resistance term by 12.90% and the acceleration resistance term by 0.71% with TOR FM. We are not really affecting the aerodynamics of the cars or locomotives through the use of TOR FM, we are apparently affecting other resistances that vary with the square of the speed, possibly truck hunting.

As I mentioned before, if you know how the rolling resistance and aerodynamic resistance terms have been affected by TOR FM, you can input that knowledge into any train performance calculator and simulate/predict the energy savings in any train on any route. You can also look at the potential energy savings globally across the railroad. From past computer simulation studies, we know that approximately 15% of our energy is consumed in overcoming rolling resistance with another 30% consumed in overcoming aerodynamic resistance. The results of the "Coast Down" tests suggest the TOR FM would reduce the rolling resistance by 12.90% x 15% or 1.94%. TOR FM would reduce the aerodynamic resistance term by 0.71% x 30% or 0.21%. You will remember we have not considered the savings that you can get from reduced curve resistance through the use of TOR FM. We've gotten estimates from the test personnel at TTCI that good curve lubrication can reduce the curve resistance by approximately 50%. We already have a pretty elaborate wayside lubrication program on the BNSF as well as stick lubricators on our locomotives, so we are figuring that we can only further reduce the energy used to overcome curve resistance by about 25% or .75% of our total consumption. Adding that to the 1.94% saved from reduced rolling resistance and the 0.21% saved from reduced aerodynamic resistance, we are looking at a potential total energy saving of 2.90% with TOR FM on the BNSF.

In 2002 the BNSF consumed about 1.7 billion gallons of diesel fuel operating trains. A saving of 2.90% through the use of TOR FM would save the BNSF 33.9 million gallons annually. There are other "soft" (harder to get a handle on) savings with TOR friction modification that should not be overlooked: increased tie and fastener life, reduced rail and wheel wear through lateral force reduction in curving, reduced wheel and rail wear through reduced hunting on tangent track and derailment reduction.

The BNSF is proceeding with studies to both confirm the energy savings estimated earlier and to test the reliability of the equipment. An outline of three different studies that are underway follows:

Reliability Studies:
- Transcon intermodal testing
- Purchased 4 TOR units
- Installed on GE-9 locomotives
- Reliability measured by:
  - Friction modifier consumption
  - On/off
  - Operational
  - Lateral force reduction

The first application was completed in BNSF 760 in March. The remaining 3 units were to be applied in May.

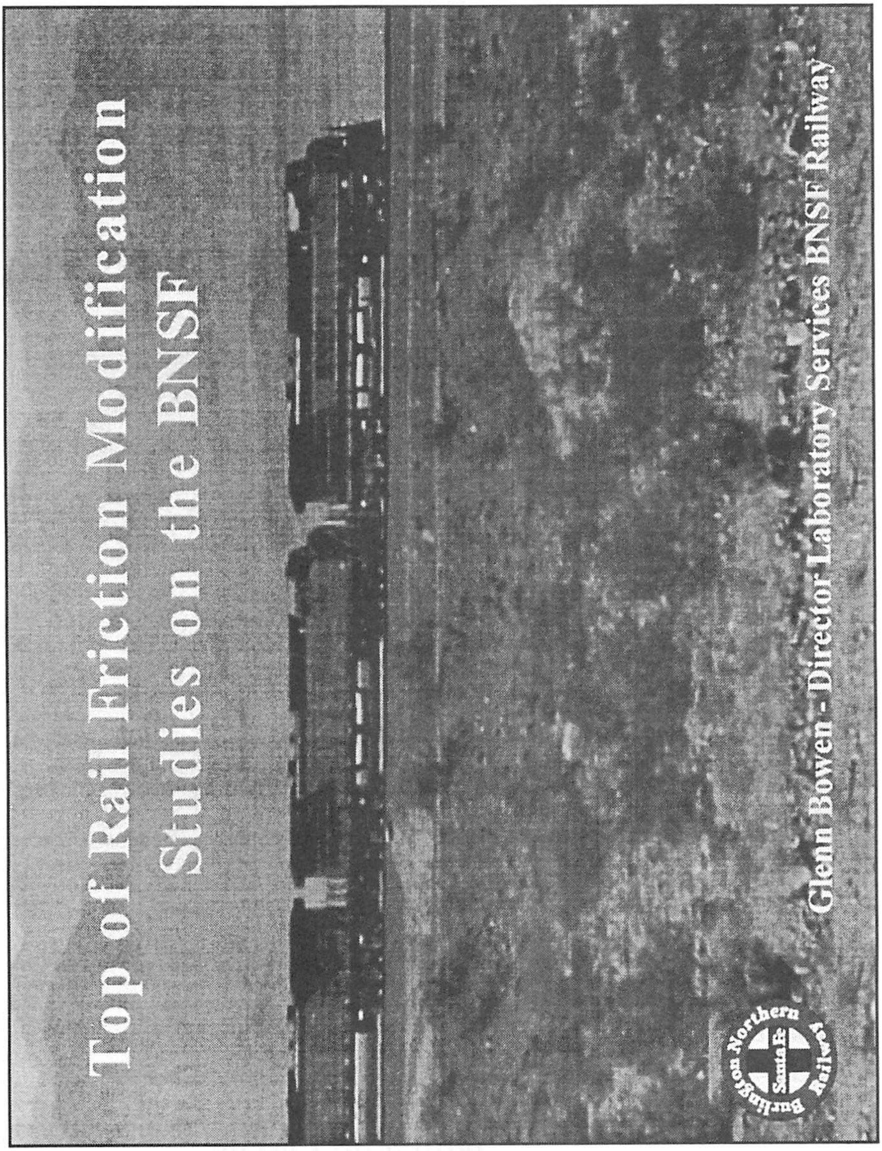
Fuel studies:
- Distributed Power Coal Train Tests
- Test Car 83 with remote fuel monitoring
- Minimum of 3 "Dry" and 3 "Friction Modified" Runs
- Test for:
  - Fuel savings
  - Adhesion problems
  - Lateral problems
- Tests to begin in late May

Converted Spray Flange Lube Systems
- BNSF has over 2500 locomotives equipped with spray flange lubricators.
- Evaluating if the systems can apply TOR friction modifier.
- Issues with FM suppliers being tied to equipment manufacturers.

To summarize, we have completed some "Coast Down" tests that we believe offer a more realistic view of the real world fuel savings to be achieved with TOR friction modification. We have the ability to predict the amount of savings in any given train on any territory. We are going to perform a field test to evaluate the validity of those predictions. We are pursuing a field test to evaluate equipment reliability. Lastly, we are testing the possibility of converting our existing flange lubrication systems to apply TOR friction modifiers. I hope to give the committee an update on the progress of these studies at the September meeting.

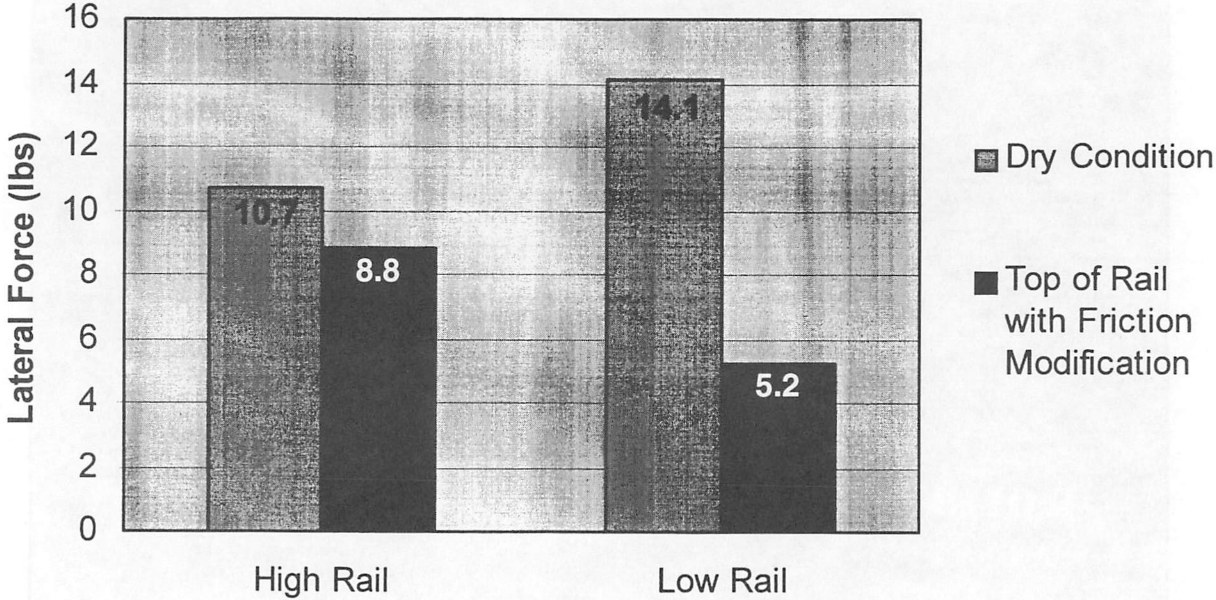
Acknowledgements

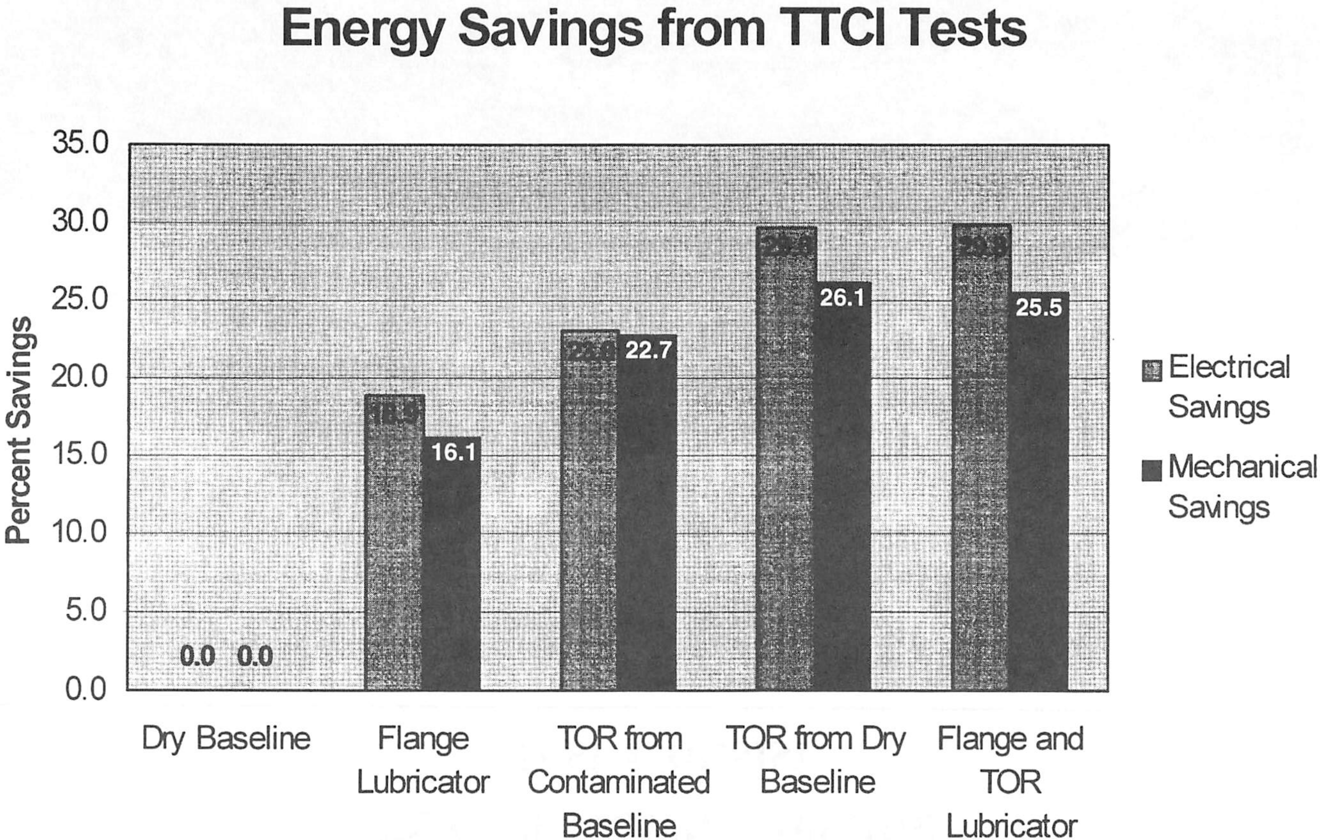
The author of this paper wishes to thank the Transportation Technology Center, Inc. for their permission to use data from energy consumption tests in developing this paper. Lastly, I'd like to thank the LMOA Fuel, Lubrication and Environmental Committee for their valuable review and input.


Top of Rail Friction Modification
Studies on the BNSF
Glenn Bowen - Director Laboratory Services BNSF Railway
Burlington Northern Santa Fe Railway

TOR Friction Modification Promises Lower Lateral Forces in Curving

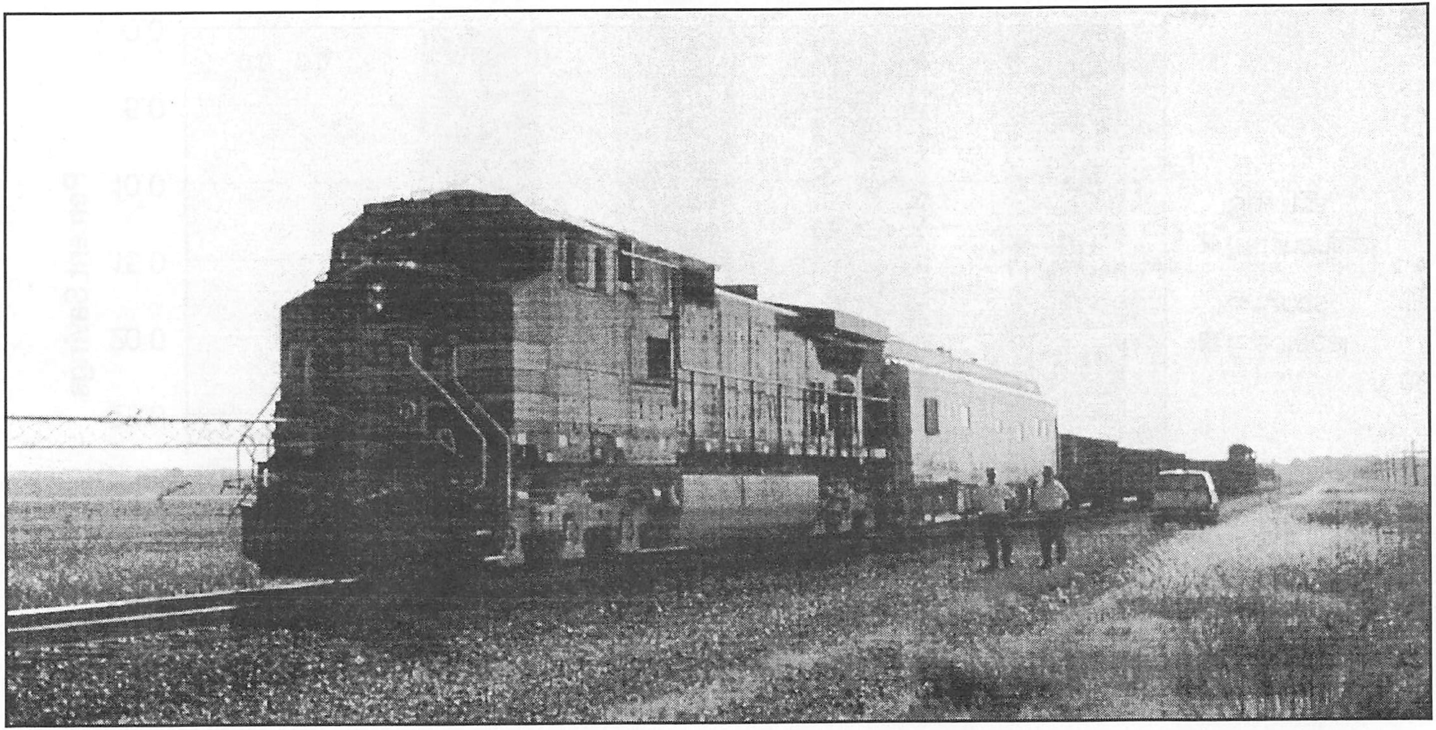
Siberia, CA - Lateral Force Data (Curve C678 MT1)

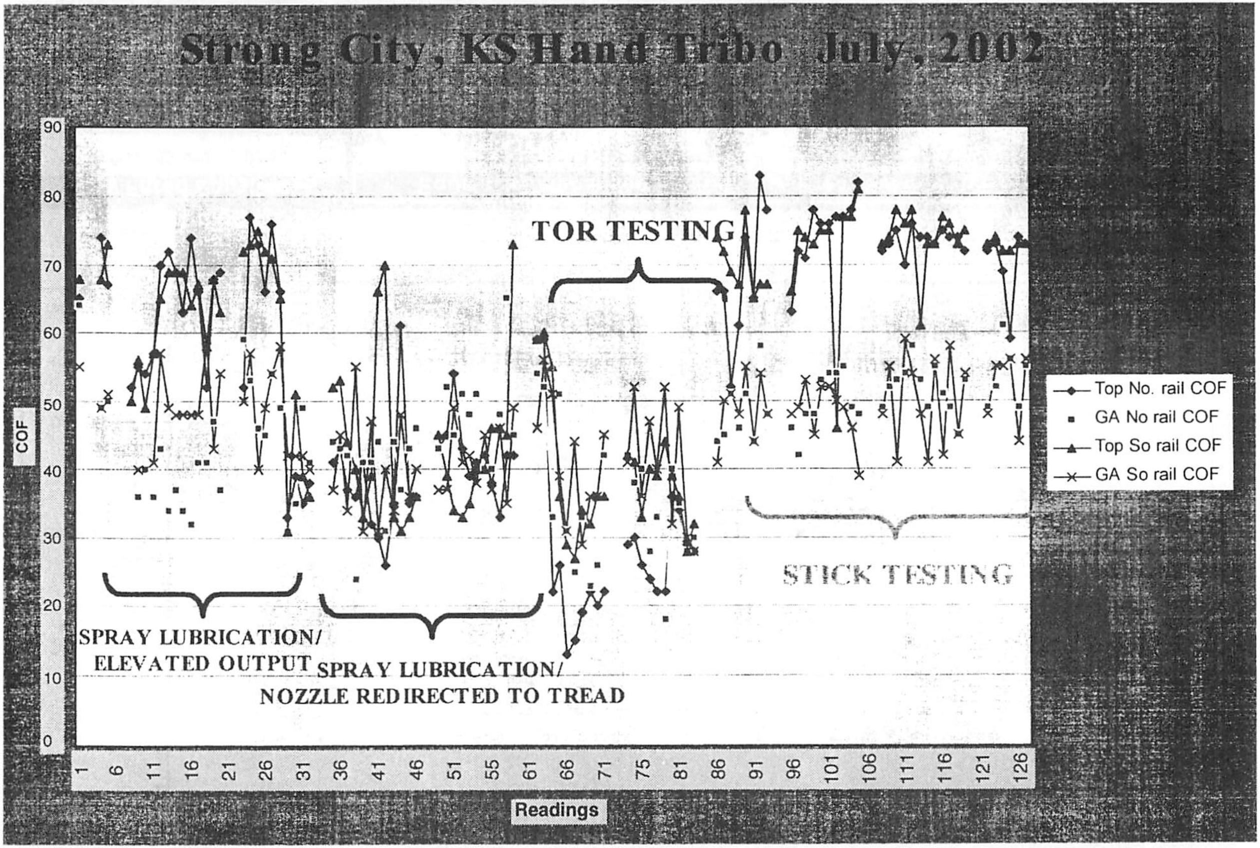




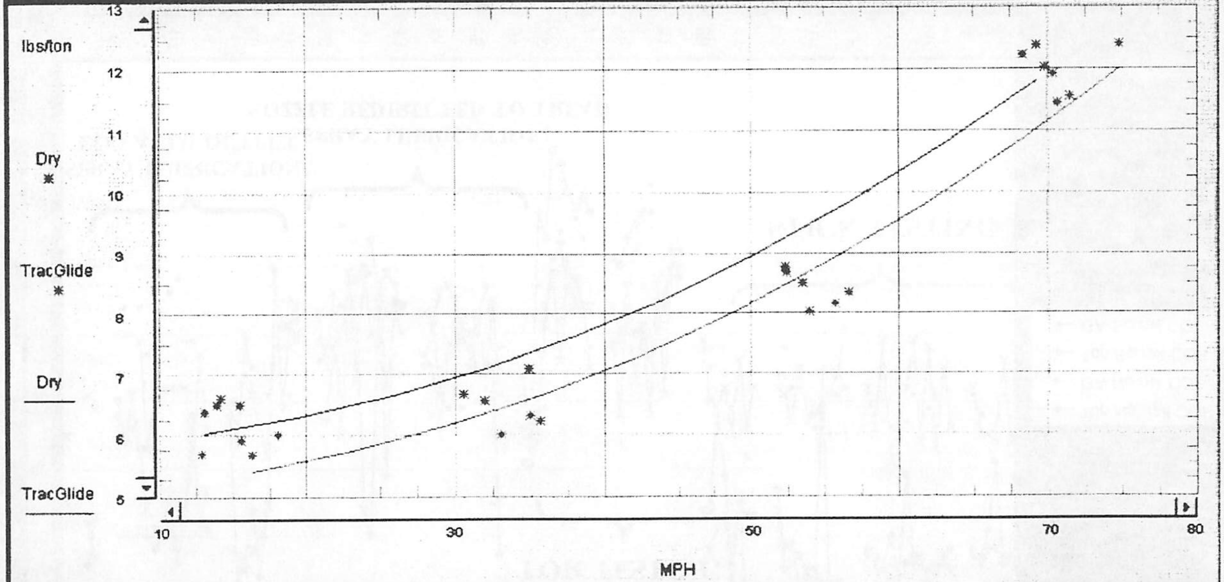
Energy Savings from TTCI Tests
Percent Savings
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
0.0
16.1
22.7
26.1
25.5
Electrical Savings
Mechanical Savings
Dry Baseline
Flange Lubricator
TOR from Contaminated Baseline
TOR from Dry Baseline
Flange and TOR Lubricator

"Coast Down" Testing
Test Consist




Strong City, KS Hand Tribo July, 2002
COF
90
80
70
60
50
40
30
20
10
0
Readings
1
6
11
16
21
26
31
36
41
46
51
55
61
66
71
75
81
86
91
96
101
106
111
116
121
126
TOR TESTING
STICK TESTING
SPRAY LUBRICATION/ ELEVATED OUTPUT
SPRAY LUBRICATION/ NOZZLE REDIRECTED TO TREAD
Top No. rail COF
GA No rail COF
Top So rail COF
GA So rail COF

Rolling Resistance vs Wind Relative Speed: Data From 0.5 Miles To 3.5 Miles



Dry Fitted Equation

0.001252 V^2 +5.823

TracGlide Fitted Equation

0.001243 V^2 +5.072

Equation Comparison

	Aero Term	Rolling Resist
Dry	0.001252	5.823
TracGlid	0.001243	5.072
% Diff	0.71	12.90

Predicted Energy

MPH	Dry	TracGl	% Diff
10	5.95	5.20	12.64
20	6.32	5.57	11.93
30	6.95	6.19	10.92
40	7.83	7.06	9.78
50	8.95	8.18	8.64
60	10.33	9.55	7.58
70	11.96	11.16	6.65

PrintScreen

Exit

REPORT OF THE COMMITTEE ON NEW TECHNOLOGIES

TUESDAY, SEPTEMBER 23, 2003
9:00 A.M.

Chairman
TIM BLACK
Manager-Locomotive Scheduling
Union Pacific RR
Omaha, NE

Vice Chairman
R. BRAD QUEEN
Mechanical Supervisor,
BNSF Railway
Topeka, KS

COMMITTEE MEMBERS

J. Christoff	Mgr-Transportation	Nat. Elect. Carbon Prod.	Cicero, NY
R. Dalton	Manager-Opns. & Maint.	Motive Power Inc	Conroe, TX
K. Gilbert	Director-Sales	GE Transportation Syst	Montreal, PQ
J. Pedulla	Technical Writer	Norfolk Southern Corp	Atlanta, GA
C. Prudian	Senior Syst. Engineer	Electro Motive Div.	LaGrange, IL

PERSONAL HISTORY

Tim Black
Manager Locomotive Scheduling
Union Pacific Railroad

Tim was born January 1953 in Manning, Iowa. Upon graduating from Woodbine High School in 1971, he attended Iowa Western Community College in Council Bluffs, Iowa. Tim has a degree in Industrial Electronics and is a 30 year employee of Union Pacific Railroad in Omaha, Nebraska.

His current position is Manager - Locomotive Scheduling in the the Network Operations group.

Tim has two daughters and two sons. Residing in Council Bluffs, Iowa he enjoys traveling, fishing and photography.

THE NEW TECHNOLOGIES COMMITTEE

WISHES TO EXPRESS THEIR
SINCERE APPRECIATION
TO
NATIONAL ELECTRIC
CARBON PRODUCTS

FOR HOSTING THEIR COMMITTEE
MEETINGS
IN GREENVILLE, SC
NOVEMBER 2002.

I. NEW MPXPRESS COMMUTER LOCOMOTIVE MODELS MP36PH-3S AND MP36PH-3C

Prepared by:
Rich Dalton, V.P.-O & M and
Rich Stegner, Motive Power, Inc.

Introduction

The new MPXpress locomotive design is driven by safety, improved efficiencies and customer specific requirements. For the past two years, Motive Power, Inc. (MPI) has been developing the MPXpress model MP36PH locomotive to respond to the opportunities presented by the procurement needs of passenger rail operators.

The technical requirements for new locomotive designs are now affected by new Federal and Industry regulatory standards. The major issues are:

49CFR 238 Passenger Equipment Safety Regulations

These new standards include requirements for crashworthiness, fire safety and hardware/software safety for digitally controlled equipment that are "safety critical" as interface with the braking systems.

Federal EPA Emissions Standards

The locomotive is equipped with a new 16-645F3B 16-cylinder, turbocharged, diesel engine. The engine is equipped with enhanced mechanical fuel injection and other emission reduction features to make the locomotive meet EPA Tier 1 requirements. The engine will deliver a nominal output rating of 3,600 horsepower. The engine speeds are controlled by the QES-3 microprocessor through a QEG-1000 rack actuator.

APTA Crashworthiness/ PRESS Safety Standards

The American Public Transportation Association (APTA) has been working with member transit agencies, user groups, equipment manufacturers and Federal regulatory agencies for many years to establish safety standards and recommended practices, specifically tailored to the passenger transit industry. APTA Passenger Rail Equipment Safety Standards (PRESS) and recommended practices use the Federal standards as the basic foundations for equipment specific enhancements for crashworthiness and other safety measures.

Locomotive Profile

Metra, Chicago's commuter rail system, provided significant input to the overall design and performance criteria for the MPXpress model MP36PH-3S (27 units presently being delivered in 2003 and 2004). The diesel electric locomotive model for Metra has the designation of MP36PH-3S is in keeping with the existing convention as follows:

- MP = Motive Power
- 36 = 3,600 horsepower for traction with no HEP load
- P = Passenger
- H = HEP equipped
- -3 = Microprocessor control system
- S = Static Inverter Head End Power (HEP).

The locomotive is a full-width carbody design with an aerodynamic nose compatible with Metra's new and existing commuter cars and existing locomotives. These locomotives will be capable of operating at speeds up to 100 mph, although, as built, they will be geared for operation at 88 mph.

The diesel engine is a 3,825 bhp model 16-645F3B that drives an MA15JBC/CA5A alternator at the back with the thick disc alternator coupling arrangement. The engine also powers a 625-kvA HA6 HEP alternator, shaft driven off the front crankshaft stub shaft, and a WLN air compressor close coupled to the opposite end of the HA6. The HEP alternator provides variable voltage, variable frequency, six-phase power to the static HEP inverter that, in turn, provides fixed 480-volt, three phase, 60-hertz power to the passenger coaches of the train. The output of the engine is closely monitored and controlled to support the auxiliary and HEP loads first, and what is left over will be available for traction. The locomotive produces approximately 3,533 traction horsepower when operating in its normal speed range while providing a minimum of 50 KW HEP power. With an estimated 2,850 thp with maximum HEP load of 500 KW, the locomotive has greater acceleration than existing Metra F40PHM-2 locomotives that produce an estimated 2,450 thp with 500 KW HEP.

The diesel electric locomotive model for the Joint Powers Board (JPB)/Caltrain (6 locomotives delivered in 2003) has the designation of MP36PH-3C is in keeping with the existing convention as follows:

- MP = Motive Power
- 36 = 3,600 horsepower for traction with no HEP load
- P = Passenger
- H = HEP equipped
- -3 = Microprocessor control system
- C = Caterpillar Diesel Head End Power (HEP).

The locomotive is a full-width carbody design with an aerodynamic nose compatible with Caltrain's new and existing commuter cars and existing locomotives. These locomotives will be capable of operating at speeds up to 100 mph, although, as built, they will be geared for operation to 82 mph.

The diesel engine is a 3,825 bhp model 16-645F3B that drives an AR10JBA/CA5 alternator at the back with the thick disc alternator coupling arrangement. The engine also powers a shaft driven WLN style air compressor. The separate diesel powered HEP alternator provides 600 KW fixed 480-volt, three phase, 60-hertz power to the train. The locomotive produces approximately 3,600 traction horsepower when operating in its normal speed range. With maximum HEP load of 600 kw being delivered by a separate power plant, the locomotive has greater acceleration than existing Caltrain F40PH locomotives.

Locomotive Specifications Summary

Locomotive Dimensions:

- Length over coupling pulling faces - 70 feet
- Height over cab and carbody - 15 feet 6 inches
- Width over cab handrails - 10 feet 7 1/2 inches
- Bolster centers - 43 feet 3 inches

Locomotive Weight:

- Weight on rails (loaded): 280,00 to 295,00 pounds (Depends on fuel configuration and Customer options).

Locomotive Performance Characteristics:

- Starting tractive effort - 85,000 foot-pounds
- Continuous tractive effort - 65,230 lbs @ 13 mph
- Maximum speed - Design speed up to 120 mph (typical gear ratio yields application speeds of 82 - 88 mph)
- Curve negotiation, single unit - 248 feet (23.1 degrees)
- Curve negotiation, w/85-foot car - 315 feet (18.2 degrees)

Locomotive Prime Mover Specifications:

- Prime mover - 16-645F3B, turbocharged
- Maximum engine speed - 954 rpm
- Idle speed - 270 rpm
- Low idle speed - 200 rpm
- Engine control system - Wabtec Q-tron QES-3
- EPA emission compliance - Tier 1

Other Major Equipment Specifications:

- New Main Generator (traction/companion alternators) - Baylor MA15JBC/CA5A
- Optional Traction Alternator - AR10JBA/CA5 (Remanufactured)
- Traction Motors - Motor Coils D87BTR, d.c. (Remanufactured D78 Motors are also available)
- Trucks - MPI 2237, outside swing hangar, wheelbase 9 feet-4 inches
- Optional Remanufactured "Blomberg" Style 9 feet - 0 inch wheelbase also available
- Wheel Diameter - 42 inches
- Braking System - Wabtec EPIC II blended air/dynamic; 26LUL+CS2 also available
- Fuel Capacity - Up to 2,500 gallons
- Lube Oil Capacity - 243 gallons
- Cooling System Capacity - 310 gallons
- Sand Capacity, Front/Rear - 14/20 cubic feet
- HEP - Prime mover driven, Baylor HA6 alternator, static inverter, 500kw
- Option up to 800 kw Diesel HEP available
- Auxiliary Generator - 18kw Super Aux by Dayton Phoenix

APTA PRESS (Passenger Rail Equipment Safety) Crashworthiness Standards

The American Public Transportation Association (APTA) has been working with member transit agencies, user groups, equipment manufacturers and U.S. federal regulatory agencies for many years to establish safety standards and recommended practices, specifically tailored to the passenger transit industry. APTA Passenger Rail Equipment Standards (PRESS) and recommended practices use the Federal standards as the basic foundations for equipment specific enhancements for crashworthiness and other safety measures.

Presently, the basic requirements of 49CFR 238 differentiate structural requirements with respect to track speed. Track speeds under 125 mph are designated Tier-1, while higher speeds are currently designated Tier-2. The structural requirements of 49CFR 238 Tier-1 are based on the fundamentals of the 800,000 lb. frame strength, 200,000 lb. anti-climber requirement, and 250,000 lb. truck-to-body attachment strength requirement, collision posts and the basic requirements of AAR S-580.

With the prospect of higher speeds, 49CFR 238 Tier-2 requirements incorporate new structural elements such as - high strength corner posts and higher strength underframes, as well as the potential for new techniques such as crash energy management (CEM).

APTA's approach is to enhance crashworthiness, using the basic requirements of 49CFR 238, while enhancing structural performance. The criteria that the MPXpress (model MP36PH) incorporate are APTA SS-C&S-0034. A summary of the requirements is as follows: (Figure 2 and 3)

- 800,000 lb. end strength of the main frame (under frame)
- Collision posts - 2 ea. @ 500,00 lbs. at the deck, 200,000 lbs. at 30" above the deck and 60,000 lbs. at the top of the structural member
- Corner posts - 2 ea. @ 300,00 lbs. at the deck, 100,000 lbs. at 18" above the deck and 45,000 lbs. anywhere along the length of the structural member
- Rollover - support the area of the locomotive above the cab from crushing the structure
- 200,000 lb. anti-climber
- 250,000 lb. truck-to-carbody attachment
- Attachment of major equipment - 8g longitudinal, 4g lateral and 4g vertical
- Side loads for operator's cab and side sill of the main underframe

Motive Power performed extensive finite element analysis (FEA) for the main structure and confirmed the analysis with a series of full-scale stress tests with strain-gage data acquisition. The full-scale strain gage stress tests were conducted at Motive Power's Boise, Idaho plant in June 2002. For the 800,000 lb. test of the underframe, a full-scale rig of hydraulic rams that apply the axial load through the draft gear pockets was applied. The collision posts and corner posts were also tested, consistent with APTA guidelines. Also, a full-scale test rig was prepared for a full-scale mock-up of the rollover structure. This test was conducted at Motive Power in January 2002.

Aerodynamic Cab

The nose and cab roof are streamlined composite caps over a steel primary structure. The locomotive cab design incorporated an aerodynamic cab/nose to present a new sleek, modern look to the public and at the same time provides a modern, comfortable environment for the crew. The cab is also well insulated for temperature and noise control confirmed by test. The engineer's position and helper's station feature ergonomically designed consoles. An extensive cross-functional team of railroad operating personnel, customer's representatives and maintenance personnel reviewed the MPXpress operator's cab. As described earlier, the cab is fully compliant with APTA crash-worthiness requirements. The primary structure of the cab is manufactured with a steel primary structure including corner posts and rollover members. Two steel collision posts with interconnecting steel plates are provided in the short nose to meet the CFR Part 238 crash worthiness requirements. The sidewalls and cab doors are steel. A steel support structure is used for the front windshield area. The front windshield is made up of four independent sections of flat glass; each glass section will be held with rubber in an aluminum frame that attaches to the support structure. All aspects of the cab have been reviewed for compliance with 49CFR 238.103 fire/smoke safety. The cab is fully insulated and is provided with an integrated heating, ventilation and air conditioning system for climate control and crew comfort.

Carbody design

Long Hood - The long hood structure features many design improvements for ease of assembly, in-service performance and long-term maintenance. The long hood side panels are constructed of lightweight composites that are corrosion free, reduce weight and reduce noise and vibration. The long hood is equipped with internal drains and seals for eliminating the intrusion of rainwater. The head end power compartment is also separately sealed and ventilated. All fans and blowers are mounted to the overhead structures with recessed substructures and mounting panels for ease of removal for maintenance, while establishing a low profile for vertical clearance.

Carbody Air Filtration System - Primary (carbody) spin-type inertial filters provide air to a clean air compartment toward the front of the unit for the engine filters, generator blower, and traction motor blower. Toward the rear of the unit, two inertial filter and blower assemblies provide filtered air to the HEP compartment. The forward HEP inertial filter provides cooling air to the HA6 alternator; this air is expelled outside the compartment through the underframe. The rearward HEP filter provides cooling air to the static inverter and the HEP compartment. Each of the three inertial filters has a motor-driven blower to expel dirty air out the roof of the locomotive.

Engine Cooling System- The locomotive radiators are arranged in two banks. Each bank contains three double-length, 6-row and three double-length, 3-row mechanically bonded cores. For each segment, the 6-row and 3-row cores are mechanically connected to form a single core for handling and installation purposes. Separate radiator headers are provided for the 6-row and 3-row radiators. The 6-row core is used for the jacket water circuit, and the 3-row cores is used for the aftercooler circuit. Airflow across the radiators is provided by three 48-inch, 9-blade Q-Fans. The QES-3 control system controls water temperature by opening radiator shutters and cycling on the cooling fans. The cooling fan on-off sequence is automatically changed to equalize the operation of the fans: 1-2-3, 2-3-1, 3-1-2.

Dynamic Brake Hatch - The locomotive is equipped with increased capacity dynamic braking, compared to normal four-axle units, by having six grids equivalent to 0.86-ohms each and two 18-horsepower fans. The dynamic brake grid arrangement is similar to a six-axle locomotive; however, the grid connection scheme will provide two distinct advantages. The locomotive is not equipped with manual dynamic braking; therefore, the grids are used only for blended braking and self-load test. In normal blended braking, the grids are arranged in two series-parallel circuits with three grids per circuit for a 50% increase in resistance per circuit to provide additional braking effort at high speeds. A DC1 contactor is included in the grid hatch to short out two grids (one per circuit) at approximately 38 mph on decreasing speed to improve low-speed braking. The increased capacity dynamic braking, in conjunction with air blending, improves the deceleration rate while relying more on the dynamic braking and requiring less air braking. A LTT2 coil-operated transfer switch is located in the grid hatch and cabled in the grid circuit so that in self-load test the grid hatch is arranged with three parallel circuits of two grids each to allow continuous self-load test capability without the traditional "rated load" feature. Dynamic brake ground relay and grid blower motor failure protection is provided. The microprocessor control system will nullify blended braking below 4 mph.

When the locomotive is set up for self load test, QES will pick up the LTT2 transfer switch in the grid hatch, which will reconnect the grids from two parallel circuits of three grids in series to three parallel circuits of two grids in series. Once LTT2 is picked up, then LTT1 will be picked up to connect the grid circuits to the main alternator. In this configuration, the equivalent resistance of the grid hatch is 0.57 ohms with the capability of handling up to 4,880 horsepower. Therefore, the self-load test feature will permit continuous full horsepower load testing without a "rated load" feature.

Head End Power (Static Inverter) & Diesel Power Plant

The locomotive is equipped with a 500KW static head end power (HEP) inverter system driven by the prime mover to provide a full 500kw output at Notch 3. An HA6 625 KVA, six-phase, variable voltage, variable frequency alternator that is driven off the engine's crankshaft front stub shaft, generates HEP power. The HA6 alternator is sized large enough to be able to generate its full output down to half engine speed of 475 rpm. Below 475 rpm, the output will be limited to the maximum design current at 475 rpm. The six-phase output of the HA6 is normally 0.65 volts/rpm phase to phase (120-deg separation) and is fed directly into the static HEP inverter. The input is applied to a six-phase rectifier / regulator assembly feeding a capacitor bank. Voltage on the primary DC bus will range from a maximum of 837 DC at full rpm and no load to a minimum of approximately 170 VDC at 200 rpm and maximum load.

The SCR rectifier normally operates fully phased with the bus voltage controlled by the field regulator. For transient conditions, the SCRs are phased back as necessary to limit the maximum primary DC bus voltage. The DC bus feeds into the boost converter, which regulates the inverter DC bus between 725 VDC and 850 VDC. The boost converter will shut down when the primary DC bus voltage exceeds 725 VDC to maximum efficiency. The boost converter ratio is 1:2 at full power and 1:4 at half power, and furnishes full power over the range of 475-954 with 50% overload available for 10 seconds. Overload is based on input current to the boost converter resulting in a maximum power output of 300% at full rpm. Minimum operating input voltage for the boost converter is 100 volts DC. The field regulator is an IGBT based DC-DC converter fed from the primary DC bus that regulates the HA6 field current to control the six-phase output per the HEP load schedule. The inverter section converts the boosted DC bus to 480 volt, 3-phase, 60 hertz sinusoidal power utilizing a conventional six IGBT bridge and space vector switching patterns to minimize device and filter losses.

The DC bus "feed forward" compensation is implemented to minimize the output total harmonic distortion (THD) to no more than 5% and improve regulation to 2%. Maximum output current will be 300% of rating for 10 seconds depending on boost converter input voltage and load power factor. During overload conditions the inverter will supply up to 300% output current as long as there is sufficient voltage on the inverter DC bus to maintain the output voltage. Sufficient inverter DC bus voltage will be available as long as the real power required by the load does not exceed the boost converter capabilities. The voltage on the primary DC bus limits the converter power output, which is a function of alternator rpm. At full rpm, full primary DC bus voltage is available, and the boost converter delivers a maximum of 300% of rated power for 10 seconds. At 475 rpm, the primary DC bus voltage is 50% of maximum limiting the boost converter output to 150% of rating.

Separate Diesel Power Plant HEP

The separate diesel head end power plant (HEP) delivers up to 800KW with no parasitic load on the traction engine. The HEP is a skid mounted diesel engine coupled to an alternator that generates 480 VAC, 400 - 600 KW, 3-phase power, with control cabinets for switchgear and controls. The head end power diesel engine-generator is independent of prime mover power, so that:

1. Traction power is not used for head end power.
2. Head end power is not utilized by the traction power system, except for layover protection.
3. The existing engine-generator sets are removable, as a single unit, through a roof hatch.
4. A system of quick disconnect-type connections is applied to cooling, exhaust, and electrical systems to allow ready removal of the roof hatch.

The head end power (HEP) is generated by a new model 3412 Caterpillar head end power engine / generator package capable of 600 KW output on a nominal basis, consistent with EPA certification, with a load power factor of 0.8. The HEP system is capable of operating under full load, consistent with EPA certification, in ambient conditions from - 40 deg. F up to +110 deg. F.

Truck Design

The MPXpress model MP36PH locomotive is fitted with two new MPI model 2237 (new Atchison Castings/MPI design) two-axle, outside spring hangers, bolster trucks having a wheel base of 9′-4″. The trucks are designed with reinforced pedestals to support half the weight of a 300,000-pound locomotive, and the 4″ longer wheelbase for improved ride quality and improved maintenance access. The trucks are equipped with coil spring primary suspension and low-profile elliptical secondary suspension; vertical, lateral, and yaw dampers are provided. Axles are per AAR Specification M-101; grade F, splined at the gear end only. Wheels are AAR E42″, class BR wrought steel with 1:20 contour, profile 1B, and witness groove. Also, 40″ wheels are available per customer preference. Gear ratio is consistent with customer specifications for maximum speed. Journal bearings are Class GG with HDL seals and plugged access hole for wheel truing. Single shoe brake rigging with 16″ composition shoes is provided with pin-type stack adjusters. Optional 9′-0″ wheel base remanufactured "Blomberg" style trucks are also available.

Four D87BTR traction motors power the locomotive; remanufactured D78 motors are available as an option. The motors are axle hung utilizing a U-Tube roller bearing support system. The motors are oriented in the traditional four-axle locomotive configuration with the motors in each truck facing opposite directions. The gear ratio is 66:20 permitting operation to 88 mph. The traction motors are connected in parallel during power operation utilizing four power contactors, P1-P4. A four-module motorized RV reverser controls the direction of locomotive movement. The locomotive is set up to operate with one traction motor cut out from the QES screen. When a motor is cut out, the other three motors will continue to operate in full parallel with power and current limits imposed to stay within the main alternator and traction motor ratings. A four-module motorized MB transfer switch controls transfer into and out of blended braking. In blended braking, the motors will be paired 1&3 and 2&4 in series-parallel with the two circuits feeding the two dynamic brake grids circuits. Blended braking will be nullified at speeds below 4 mph and during motor cut out operation. The following traction motor ratings are applicable to this locomotive:

Time	Amps
Continuous	1200
60-minutes	1225
30-minutes	1250
15-minutes	1315
5-minutes	1500

Vehicle Dynamics & Ride Quality Tests

MPI engaged the Transportation Test Center, Inc. (TTCI) at Pueblo, Colorado to perform vehicle dynamics analysis of the MPXpress locomotive using NuCars computer analysis software. All results were found to be satisfactory within the guidelines of Chapter 11 ride quality criteria. After the analysis was completed, Motive Power delivered the first completed locomotive to the test center at Pueblo, Colorado in November 2002 for full-scale vehicle dynamics track tests. While at TTCI, tests were completed over the instrumented track at the test center. In addition to the instrumented track, sensors were also mounted on the locomotive carbody and trucks. Instrumented wheel sets were not within the scope of the test program. All tests revealed satisfactory results, consistent with Chapter 11 ride quality criteria.

Control System

The MPXpress locomotive is equipped with a Q-Tron QES-3 microprocessor control system. The QES-3 has the primary responsibility for complete locomotive control including:

- Engine speed control
- Main alternator excitation and load control
- Blended braking control
- Engine cooling fan and water temperature control
- Engine systems performance monitoring and protection
- Power & blended brake setup plus TM cut out
- Ground relay reset and lockout
- Traction motor anti-plugging software.

Wheel Slip/Slide Control - Traction motor speed probes are used as the primary wheel slip/slide detection devices. The QES microprocessor has both differential and rate of change levels to control wheel slip/slide as well as allowed wheel creep. A backup system utilizing traction motor volts and amps is available to continue the locomotive in service in the event of the loss of a speed signal.

Blended Braking - To increase the capacity of the dynamic braking to enhance blended brake operation, the dynamic brake hatch has six 0.86 ohm grids arranged in two circuits of three grids in series. This grid arrangement has the advantage of increasing high-speed braking down to about 38 mph; however, below 38 mph, it has the disadvantage of less braking than a four-grid arrangement. Therefore, a DC1 contactor is included in the circuit to short out two grids as the locomotive slows down through 38 mph. In effect, the locomotive has two dynamic braking curves it can operate on. The grid resistance identifies these curves. The higher speed curve is 1.29 ohm; while the lower speed curve is 0.86 ohms.

To provide the best selection of blended braking, the QES microprocessor control system applies the following logic to select the curve to follow: If the locomotive speed is above 50 mph when the blended braking call signal is received, QES will set up the unit to operate on the 1.29 ohm curve; as the speed slows down, QES will pick up the DC1 contactor at 38 mph to shift the unit to the 0.86 ohm curve down to 4 mph. If the locomotive speed is at or below 50 mph when the blended braking call signal is received, QES will set up the unit to operate on the 0.86 ohm curve down to 4 mph.

During normal operation, the friction braking system is designated the primary brake, and the dynamic braking system is designated as the secondary brake. These two systems operating together make up the blended brake system. Blended brake operation is initiated by movement of the automatic brake lever, provided the throttle is in "Idle" and the unit is moving at least 5 mph, and a nominal 10-psi of brake cylinder pressure is applied. This 10-psi pressure is retained until brakes are released. This approach keeps the wheel treads clean and prevents snow or ice build-up on brake shoes in inclement weather. For service brake applications, blended brake operates in "dynamic priority". The blending system retains the 10-psi pressure at a minimum and determines what additional friction braking is necessary over the available dynamic braking to achieve the requested total braking force. During emergency braking, blended brake operates in "friction priority", and the dynamic braking will supplement friction braking with a fixed 250 amps of TM field current.

In normal operation, blended braking will be cut out as the unit slows down to 4 mph for a station stop. The MB will transfer the traction motor circuit back into the power mode so the unit will be ready to accelerate the train as soon as the station stop in complete. With this logic, it is not possible to enter blended or dynamic braking at zero speed. QES incorporates a maintenance screen setup to permit overriding the zero speed feature, permitting dynamic and blended braking operation to be qualified.

Self-Load Test - When the locomotive is set up for self-load test, QES will pick up the LTT2 transfer switch in the grid hatch, reconnecting the grids from two parallel circuits of three grids in series to three parallel circuits of two grids in series. Once LTT2 is picked up, LTT1 then picks up, connecting the grid circuits to the main alternator. In this configuration, the equivalent resistance of the grid hatch is 0.57 ohms with the capability of handling up to 4,880 horsepower. The self-load test feature permits continuous full horsepower load testing without a "rated load" feature.

Engine Design

The locomotive is equipped with a new 16-645F3B 16-cylinder, turbocharged, diesel engine. The engine is equipped with enhanced mechanical fuel injection and other emission reduction features to make the locomotive meet EPA Tier 1 requirements. The engine has a nominal output rating of 3,600 horsepower with no HEP load. The engine is fitted with spin-on turbocharger and fuel filters; the secondary engine filters, lube oil, fuel primary and electrical cabinet filters will be paper. The new, steel fabricated, engine block has been designed with strength upgrades that allow for reduced stresses. Optional remanufactured 645F engine blocks are also available.

The engine speeds are controlled by the QES-3 microprocessor through a QEG-1000 rack actuator. The basic speed schedule is as follows with a +/- 4 rpm tolerance for each notch:

Notch	RPM
8	954
7	865
6	830
5	675
4	570
3	510
2	355
1	270
I	270
LI	200

The QES-3 control system also provides engine purge (anti-hydraulic lock), start motor overload protection, and emergency fuel shutdown. Other conditions that will shut down the prime mover include engine overspeed, crankcase overpressure, low oil pressure, hot oil, low coolant flow, and air compressor low oil pressure as follows:

Overspeed: 1075 +/- 10 rpm

COP: 0.8" - 1.8" water

LOP: Linear from 6-10 psi @ low idle with 50 second delay to 26-30 psi @ notch 8 with less than 4.2 second delay; 4.2 second delay to be in effect above Notch 2.

Hot Oil: 255 F into engine

CLOPS: 6 psi

Emissions & Fuel Consumption/ Conservation

The MPXpress locomotive models MP36PH-3S and MP36PH-3C are certified compliant with the latest EPA criteria for Tier-1 engine emissions. MPI has made a significant investment to install a federally certified emissions test facility at the Boise, Idaho plant. This emissions test facility is one of four in the U.S., set up for locomotive tests. All of the emissions tests and fuel consumption optimization have been conducted with this equipment. During the manufacturing process for the Metra MP36PH-3S locomotives and the Caltrain MP36PH-3C locomotives, 100% of the locomotives are proof-tested prior to delivery for base-line emissions certification, consistent with the Tier-1 standards.

Revenue Service

Motive Power delivered the first locomotive to Metra in February 2002. It was successfully tested for final acceptance in a record 1-day trial, owing to all of the extensive testing described in this paper. Revenue service commenced soon after orientation training. To date nine of eleven locomotives delivered to Metra have received final acceptance. Improvements to the various control systems continue on Metra. Motive Power has also delivered the first locomotive for the Caltrain order. Acceptance tests are underway and conditional acceptance on three locomotives has been completed. Caltrain inaugurated express service with the new locomotives in second quarter 2003.

The MPXpress locomotive satisfies a niche in a commuter rail locomotive market for a safe, technologically advanced locomotive built to customer specifications. The MPI design team was able to incorporate new regulatory issues relative to safety, product enhancements to promote efficiency and customer specific requirements into the MPXpress locomotive and deliver them to the end user within two years. As safety and productivity become even more important to all railroad operations the drive to produce a better locomotive can be modeled from the MPXpress experience.

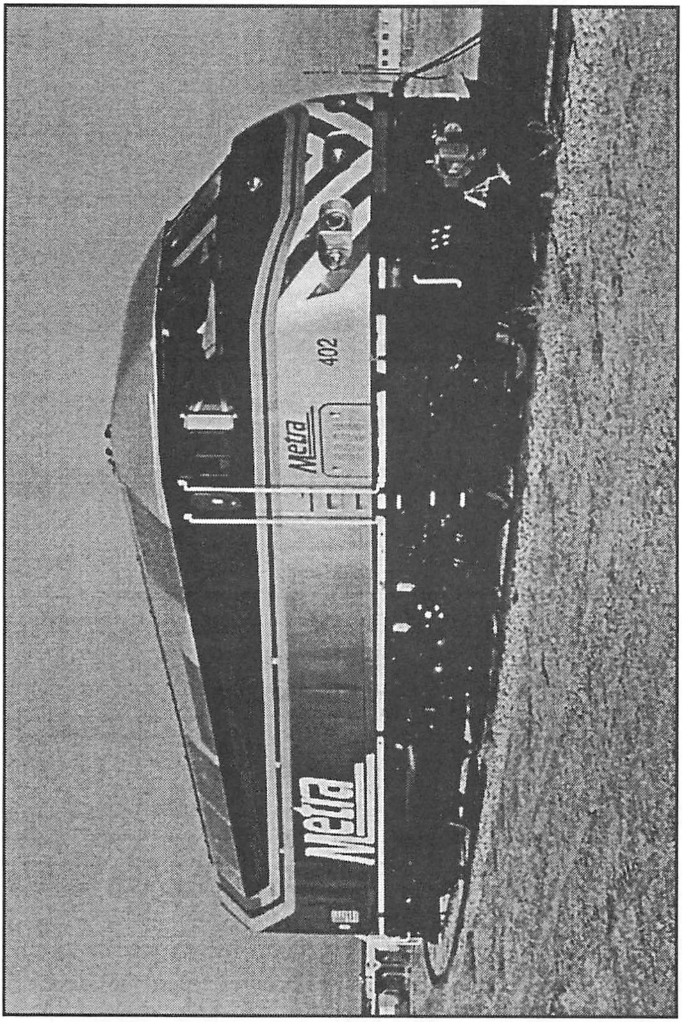


Figure 1

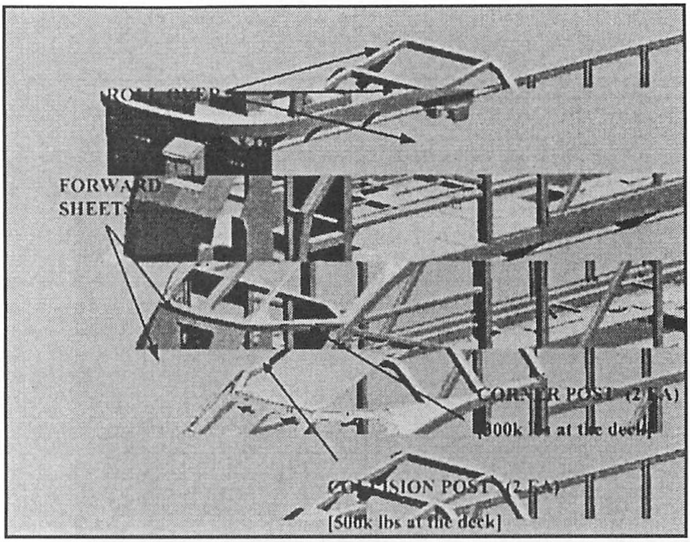


Figure 2

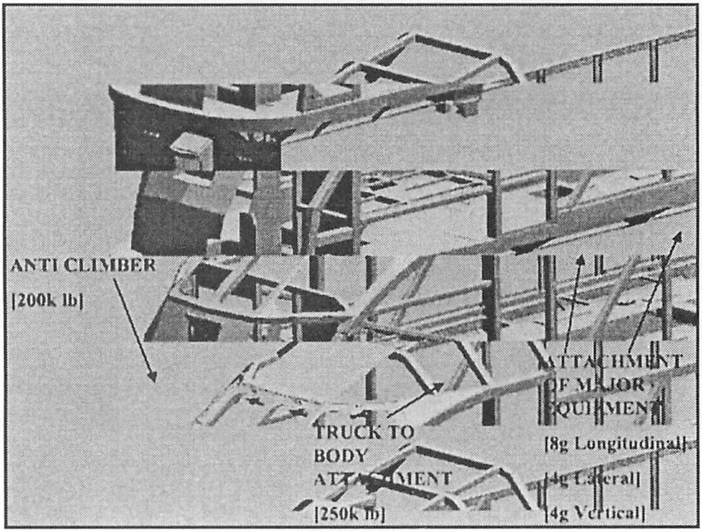


Figure 3

II. THE GREEN GOAT HYBRID LOCOMOTIVE

Prepared by:
R. Bradley Queen,
Mechanical Supervisor
Burlington Northern Santa Fe

What is a Green Goat?

In railroad terminology, the word goat is slang for a locomotive called a switch engine or yard switcher. The word "green" is a universal color usually associated with the earth and its environment. Green is also associated with better economics (saving money). So... What is a Green Goat? It is a hybrid yard switcher utilizing the same basic concept as the gas-electric hybrid automobiles now entering the consumer market. A hybrid vehicle is one constructed using electric motors for traction, powered by large batteries (Figure 1). A small generator propelled by a combustion engine using fossil fuels charges these batteries. The Green Goat was designed by Railpower Technologies Corp. and constructed on the premises of Norfolk Southern Railway.

Fuel consumption, emissions, and noise

Most conventional yard switch engines are 30-50 years old. They use diesel engines producing 1500-2000 hp that rarely operate at maximum output. Because they are confined to yard service with short distances of travel, switch engines make frequent starts and stops and spend a very high percentage of time in idle, wasting fuel and contributing to increased emissions. The fuel consumption comparison (Figure 2) chart uses a March 24, 2003 diesel fuel price of .93 cents per gallon. The Green Goat produces up to 2000 horsepower and consumes approximately 130 gallons of diesel fuel at $121 per day. An SW 1500 switch engine produces 1500 horsepower, consuming approximately 200 gallons of diesel fuel at $186 per day. The Green Goat's fuel consumption is 35% less than the SW 1500 switch engine. Compared to 300 gallons of fuel at $279 per day for a 2000 horsepower GP 38-2 locomotive in yard service, the Green Goat consumes 57% less diesel fuel, saving $158 per day. A small fleet of 150 GP 38-2 locomotives, replaced with Green Goats, would reduce fuel costs by $23,700 per day or $8,650,000 per year.

The Green Goat's hybrid power design reduces fuel consumption and key pollutants without a loss in the locomotive's performance. Along with the need to drastically reduce fuel consumption, pollution is another problem railroads face especially, with aging switching fleets. Even existing diesel-electric locomotives equipped with auto engine start stop systems still spend many hours idling. In addition, during normal daily operations, a switch engine would use notch-8 engine speed for only 1% of the day.

When comparing conventional yard switchers to the newer locomotive's electronic fuel injection controlled engines with considerably improved emissions, conventional yard switcher engines are considered the biggest polluters in rail yards. By using the hybrid power design and eliminating engine idle time with an auto start stop system, the Green Goat achieves a 90% emission reduction of nitrogen oxides (NOx) and carbon monoxide (CO), with a (19.5 grams/hp hour to 4.5 grams/hp hour) 77% reduction of Particulate Matter (PM) compared to typical 2000 horsepower locomotives.

With the introduction of this power design using a small highly efficient commercial diesel engine, the Green Goat becomes a quiet and almost vibration free switcher with more noise made from the release of air brakes than pulling a string of cars. This better suits operating in urban areas with the Green Goat's considerably lower noise levels.

The new power plant system

The Green Goat uses over 50,000 pounds of batteries (Figure 3). The batteries provide 95% of the horsepower. In order to produce the required horsepower, 320 two-volt absorbent glass mat (AGM) valve regulated lead acid battery cells are used. Being valve regulated, a better control of hydrogen gas release is allowed when the batteries expand in different temperatures. AGM batteries are constructed to be sealed, leak proof, and vibration resistant. They use a fiber floss glass mat with wicking characteristics tightly sandwiched between the lead plates which allows them to be constantly saturated in electrolyte. This allows for a faster reaction between the acid and plate material. These cells are divided into 40 steel racks containing 8 cells each of 16 volts per rack. Combined they make a total of 640 volts and have a total capacity of 1200 amp hours. In practical terms you would not need this much horsepower in notch 1. Voltage on groups of the battery cells are monitored by the onboard computer system for instant notification of a poor cell condition. If a battery cell did fail, it could be manually bypassed in the field until a scheduled repair could be made. Up to 10% (32) of the battery cells could be bypassed at one time. 92 day scheduled maintenance of AGM batteries would only consist of cleaning the battery cell rack and an inspection of the battery terminals for corrosion. Since the AGM batteries are sealed (maintenance free) electrolyte is not checked. The target for battery recycling is recommended after ten years of service. Lead acid batteries are far more advanced in the recycling markets and manufacturing processes than other battery designs to date. This makes the lead acid batteries the least expensive and most practical choice when purchasing new, reconditioning, or recycling. The Green Goat's batteries receive a constant trickle charge from a small generator driven by a small diesel engine. The batteries are kept to a partial state of 80% charge which increases when the battery's efficiency and extends their life.

The batteries produce 95% of the hp at full load. The other 5% comes from a 130 hp commercial diesel engine that drives a 90KW generator supplying the locomotive with traction horsepower or (trickle) charging the batteries (Figure 4). The engine operates at a set constant speed that is tuned for maximum performance and efficiency. With standard diesel fuel used, the Green Goat has the flexibility to utilize standard fueling points on existing railroad fueling infrastructures. The Green Goat's auto start stop system automatically shuts down the diesel engine when the locomotive is not operating at a constant load, the batteries are fully charged, and other specific required operating conditions are met, reducing further fuel consumption and emissions. A 100 hp diesel powered micro turbine prototype could be used in place of the commercial diesel engine. The advantages for using this type of an engine are cleaner emissions and lower maintenance. The disadvantages are that micro turbine engine costs considerably more and it is not as fuel-efficient. The Green Goat will produce a top speed of 40 mph and can operate in multiple with any locomotive that is MU able.

The Green Goat utilizes a rotary screw type air compressor (Figure 5) driven by a 30 hp a/c motor. The air compressor's a/c motor is powered from the locomotive batteries through an inverter. With the a/c motor rotating at 1725 rpm and through a step up gear box, it drives the compressor approximately 7000 rpm to maintain a 96 cfm (cubic feet/minute) at 140 psi. Depending on the required service needs, a larger a/c motor and power inverter could be used to increase the air compressor's capacity.

The Green Kid locomotive

The new Green Kid is a smaller hybrid locomotive that doesn't have a manned cab. Designed to operate only by remote control, the Green Kid is ideal for a less demanding duty cycle where a power rating of up to 1000 hp is sufficient. In comparison, the Green Goat is designed for full yard service or on a branch line under certain conditions for hauling 10-20 cars a distance of 10-20 miles with a power rating of up to 2000 horsepower.

Construction

In constructing the Green Goat, the frame of an EMD GP-9 locomotive was used. The large 16-cyl. diesel engine and main generator were removed. A smaller diesel engine and 50,000 pounds of batteries take up the space of the old engine (Figure 6). To ensure the wheels will still grip the rails, concrete ballast is also added for the remainder of removed equipment weight for a total of 130 tons. The Green Goat uses the same conventional 2200 gal. fuel tank, existing traction motors and the Electro-Motive switchgear. All components including the control stand, trucks, wiring, 26L brake system, traction motors and switchgear are remanufactured to the same specifications as a new locomotive. Some of the features added to the construction are: automatic traction motor isolation capability when a ground is detected, allowing one motor to be cut out at a time; automatic energy management by an onboard computer, system, plus individual wheel slip control, and new power electronics were also developed. The Green Goat is capable of producing the following: 120 or 480 vac and 24, 74 or 600 vdc @ 22kw auxiliary power for adding cab air conditioning or extra cab heating. Upgrades in the cab include: Installation of framed windows for easy change out with heated glass used to improve visibility while operating in cold weather. Anti-climbers for head on collision protection can be installed and an internal cab roll cage for roll over protection is built in since the long hood was cut down. The hybrid's modified hood offers operators an expanded view from the cab. With the hood cut down, the Green Goat looks like a yard slug with a cab (Figure 7).

Field testing and current cost

Operational field-testing has been conducted by the Union Pacific railroad at its Roseville, California yard. These tests covered hot weather conditions. Tests were then conducted in cold weather extremes at UP's Chicago yard. There are issues that need to be addressed prior to replacement. The Green Goat needs to be consistent in all operational phases of performance, as required for a standard yard locomotive. It has to have the ability to operate continuously three shifts per day, seven days a week. It must also maintain the traction effort needed to switch loaded cars continuously.

For a completely reconditioned GP-9 locomotive converted to the Green Goat Hybrid system, the cost would be approximately $600,000. Currently there are no leasing or contracted maintenance packages available. Another option railroads have is to overhaul their aging yard locomotives. They can replace their existing old power plants with the new hybrid system. Remote operating locomotive control (RCL) equipment could be applied or replaced if the locomotive is already equipped. The costs for this conversion would depend on the extent of the overhaul performed. Without modifying the cab or long hood and only overhauling the power plant the overhaul would cost less. In 2000, overhauling a GP 38-2 locomotive back to its original specifications cost approximately $283,417,000. This approach has less economical impact than typical Tier "0" upgrades.

The Green Goat locomotive is economically and environmentally friendly, and available in two models.

Figure 1

The Green Goat - Hybrid Locomotive

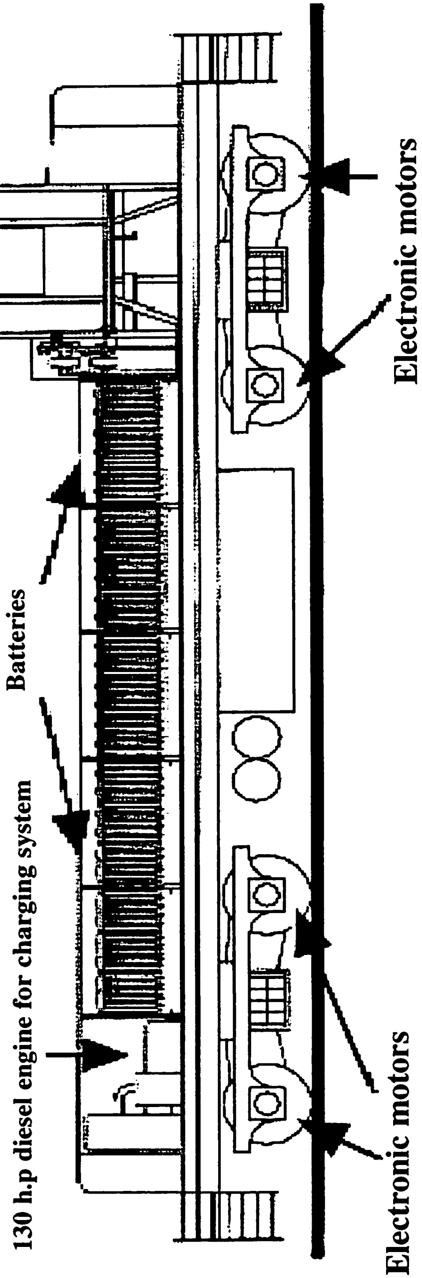


Figure 2

GREEN GOAT FUEL USSAGE COMPARISON CHART	MARCH 24, 2003

	HORSE POWER	DAILY CONSUMPTION	0.93 PER GALLONS	% OF SAVINGS
GREEN GOAT	2000	130 Gal.	$121.00	
SW 1500	1500	200 Gal.	$186.00	
GREEN GOAT		70 Gal. less	$65.00	35%
GP 38-2	2000	300 Gal.	$279.00	
GREEN GOAT		170 Gal. Less	$158.00	57%

Figure 3

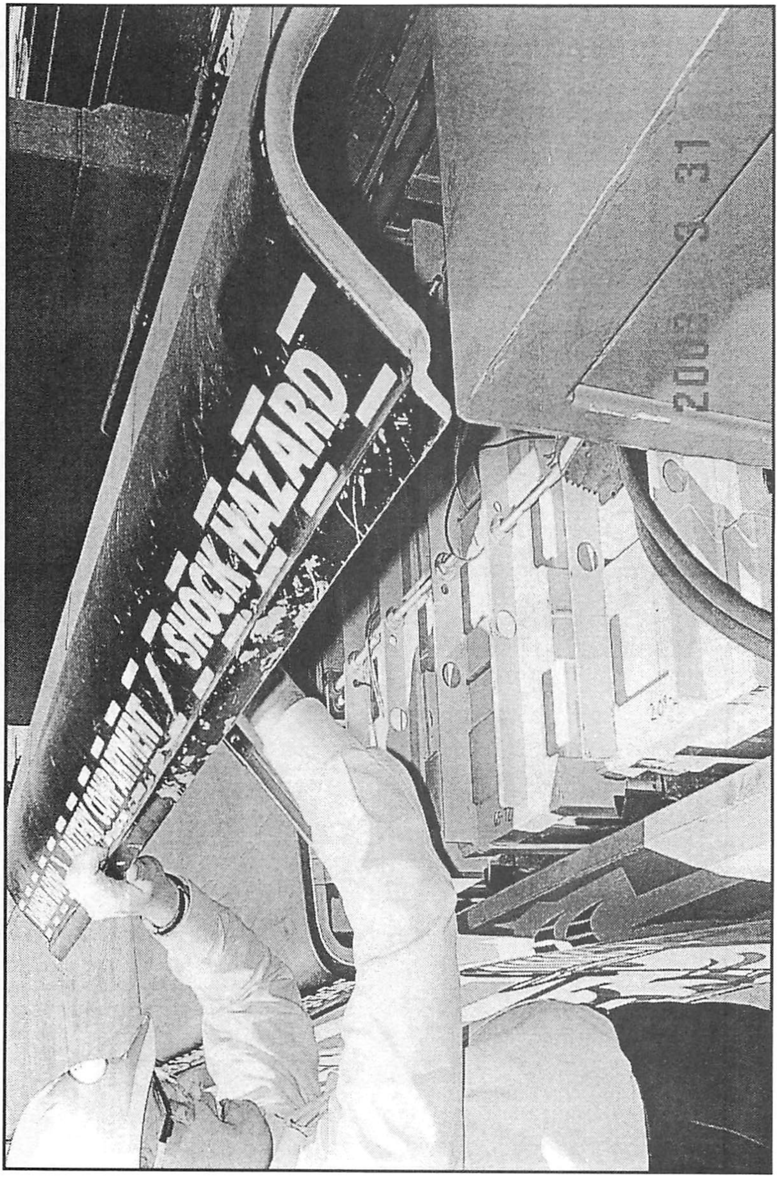
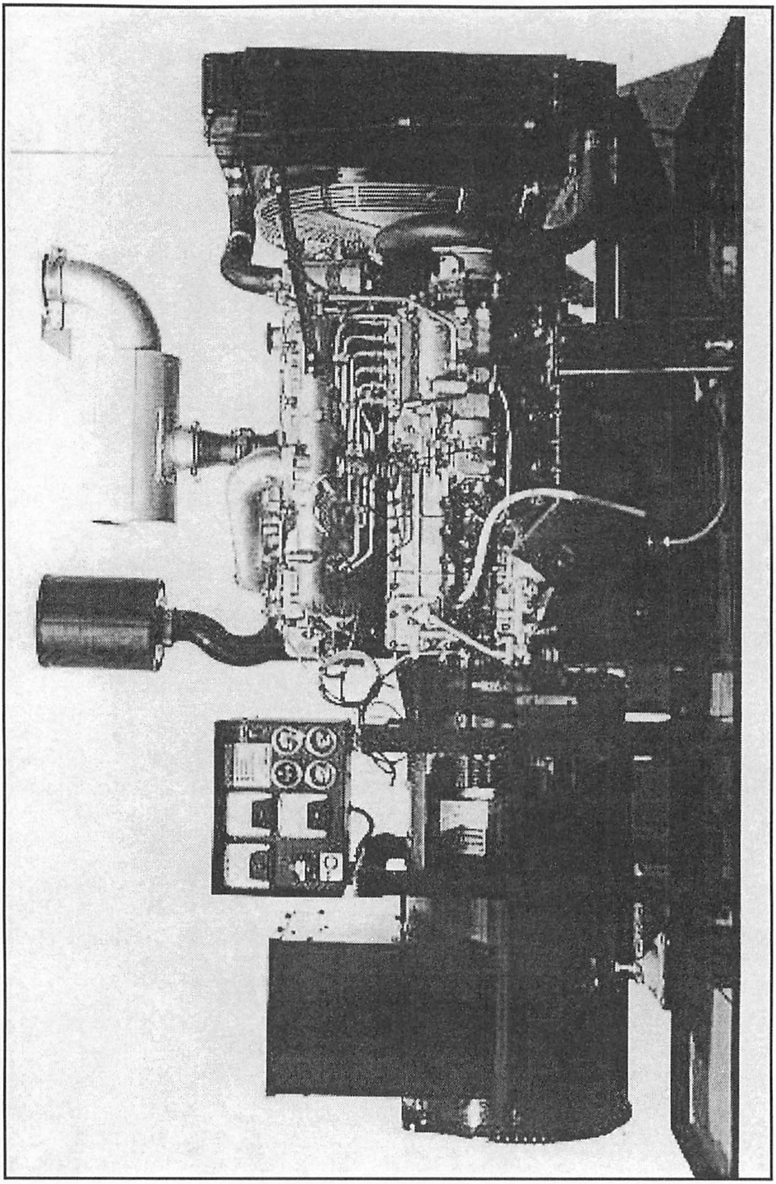


Figure 4



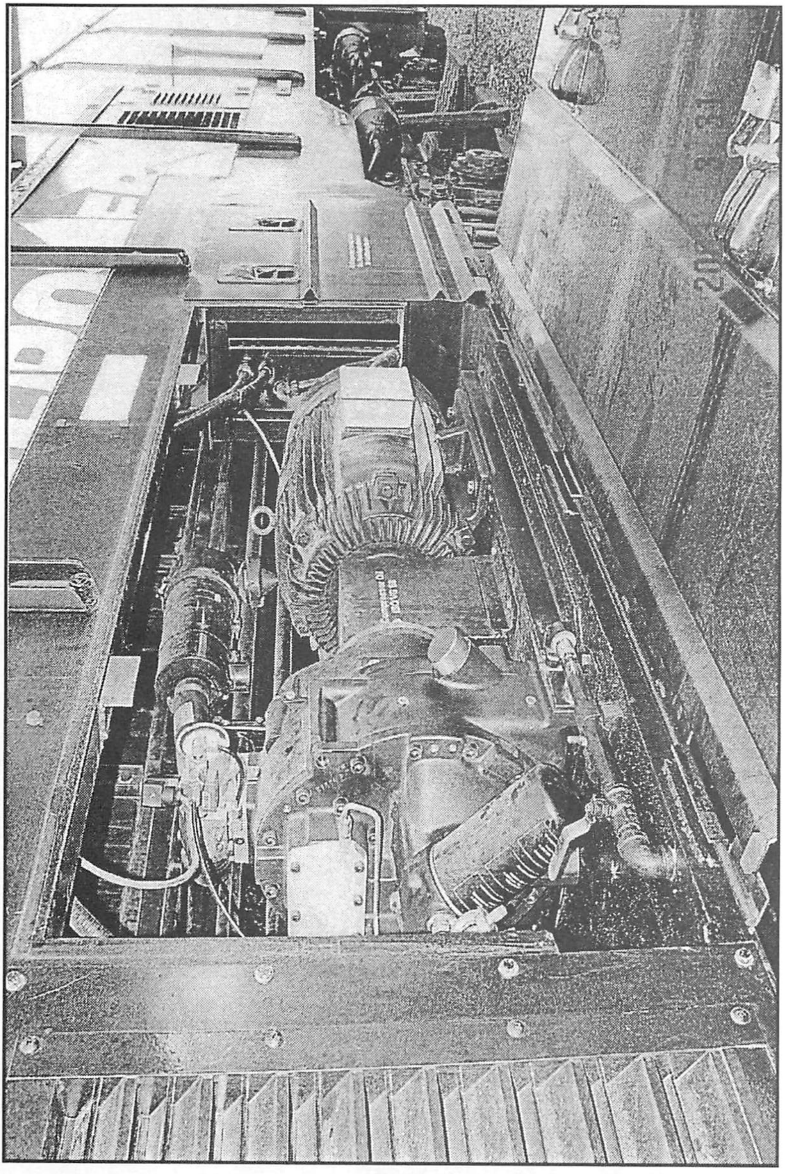


Figure 5

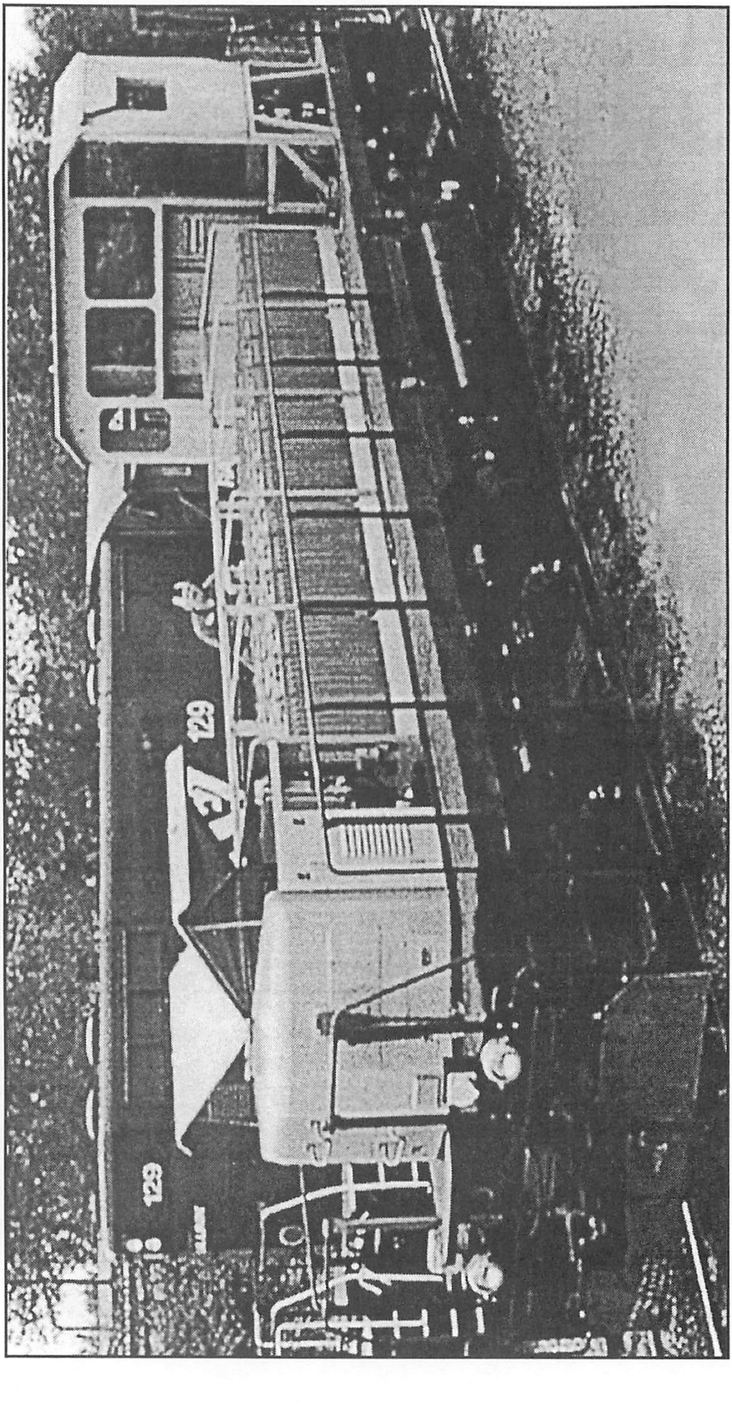
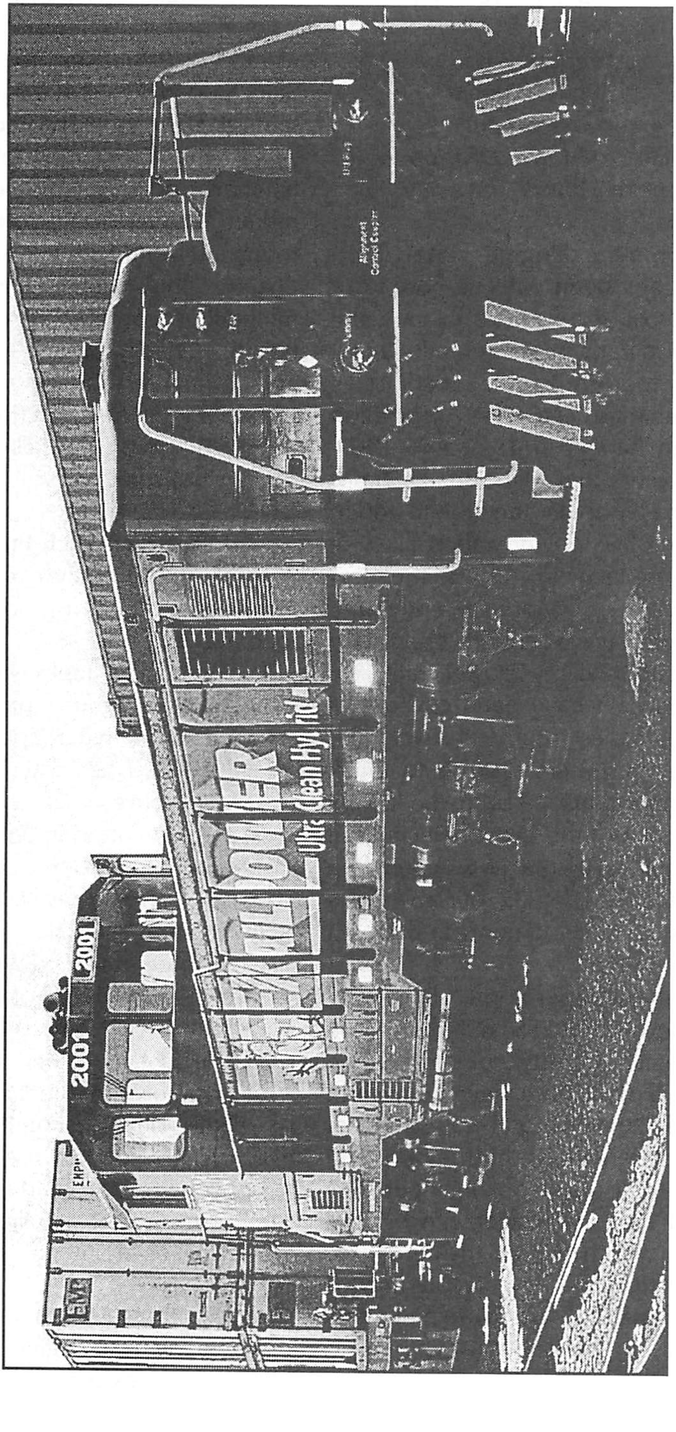


Figure 6

Figure 7



III. OBSERVATION ON AUTO ENGINE START/STOP

Prepared by:
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Senior Systems Engineer
Electro-Motive Division
General Motors Corporation

Automatic Engine Start/Stop (AESS) has been with us now for a number of years. In its infancy, the idea, and early implementations of it were reported to the Locomotive Maintenance Officers Association through papers in 1992 and 1993. In the years that followed, AESS has become a popular function to add to older motive power and is likewise commonplace in orders for new locomotives. More recently, the concept has expanded to include forms of auxiliary power units, or APUs, which have been covered as recently as last year, with two more papers presented. I wish to thank those members of both the Diesel Electrical and the Diesel Mechanical Committees of the LMOA for their diligence in keeping our members abreast of developments in this area over the years.

What this paper is intending to do, is review the AESS systems in use today, take the pulse of some of the railroads who have been using it in its various forms, and note some of their experiences, both good and bad. As a result of this input, it is hoped that the reader can be presented with a picture of the degree to which, this new technology is confirming early promises and meeting present expectations.

AESS – What It Is

Let's begin with a bit of background. What is Auto Engine Start/Stop or AESS? It is simply a system, applied to a locomotive, that acts to shut the prime mover down, whenever possible, to save fuel and reduce exhaust emissions. AESS then automatically restarts the engine, only when necessary, to maintain locomotive and/or train health. Critical locomotive systems and parameters are monitored by the AESS system for actions consistent with a particular railroad's shutdown/restart practices.

AESS – Why Such Interest?

There are currently two main factors driving the push for AESS in locomotives:

1. Potential for fuel savings - as an example, the Union Pacific estimates that it spends up to $300,000 per day, just to idle locomotives. If a significant amount of idle time can be eliminated, then a significant saving would result.
2. Emission reduction - presently, railroads are faced with the task of making much of their older power EPA Tier 0 compliant. The EPA has seen fit to look favorably on the potential for emission reduction through use of AESS - to the point of allowing Tier 0 certifications for some engine families that use AESS as an integral feature.

As well, there are other factors that play into the mix. Engine health benefits are expected as well;

measurable maintenance dollars can be saved as a result of not having to keep the engines idling unloaded for long periods of time.

Another environmental benefit is reduced noise pollution - implementation of AESS across a fleet of yard locomotives will make for a quieter workplace and immediate neighborhood.

History of AESS

As best as we can determine, AESS originally appeared in a form originally developed by Harmon in 1982, when the potential. for significant fuel savings was identified. Trials of a system, utilizing discrete components, were performed that same year on the Quebec North Shore & Labrador (QNS&L). The QNS&L referred to its system as "Arret Depart Automatique" (ADA). In the years since, other manufacturers have developed AESS as a part of an upgrade control system for early generation diesel-electric locomotives. Later, stand-alone systems were developed as well. Many of these early systems are still operating in locomotives throughout North America, with reported success.

Technical Standards of AESS

Parameters that act to allow shutdown and cause a restart have been thoughtfully and carefully developed and are generally agreed upon for operation in North America. The AAR has compiled a Standard, S-5502, entitled "Automatic Engine Start/Stop System", that deals specifically with:

1. Prime Mover shutdown conditions,
2. Engine restart conditions, and
3. Required safety markings.

Copies of this Standard can be obtained directly through the AAR, or online at their website at www.aar.org.

Review of the documentation reveals that the operation of AESS is relatively straightforward. Even so, there are a few conditions that may surprise the uninitiated. These apparent anomalies resolve themselves when one considers the importance of safety in AESS operations. Some of these unique features include:

1. Locomotive motion restarts engine - whenever a locomotive prime mover is shut down under the control of AESS, locomotive movement immediately initiates the engine restart sequence.
2. If AESS didn't shut the loco down, it will not start it up - this feature serves to make the restart sequence algorithm more easily understandable to personnel assigned to operate or maintain the locomotive.
3. AESS cannot shut down an "active" DP unit - a unit operating mid-train in distributed power mode that has been designated as the receiver of communication from the lead locomotive will not undergo AESS shutdown, in order to keep the unit "live" for maximum reliability of information flow. Other

locomotives that are MUed to this locomotive will continue to operate under normal AESS limits and parameters.

What's out there?

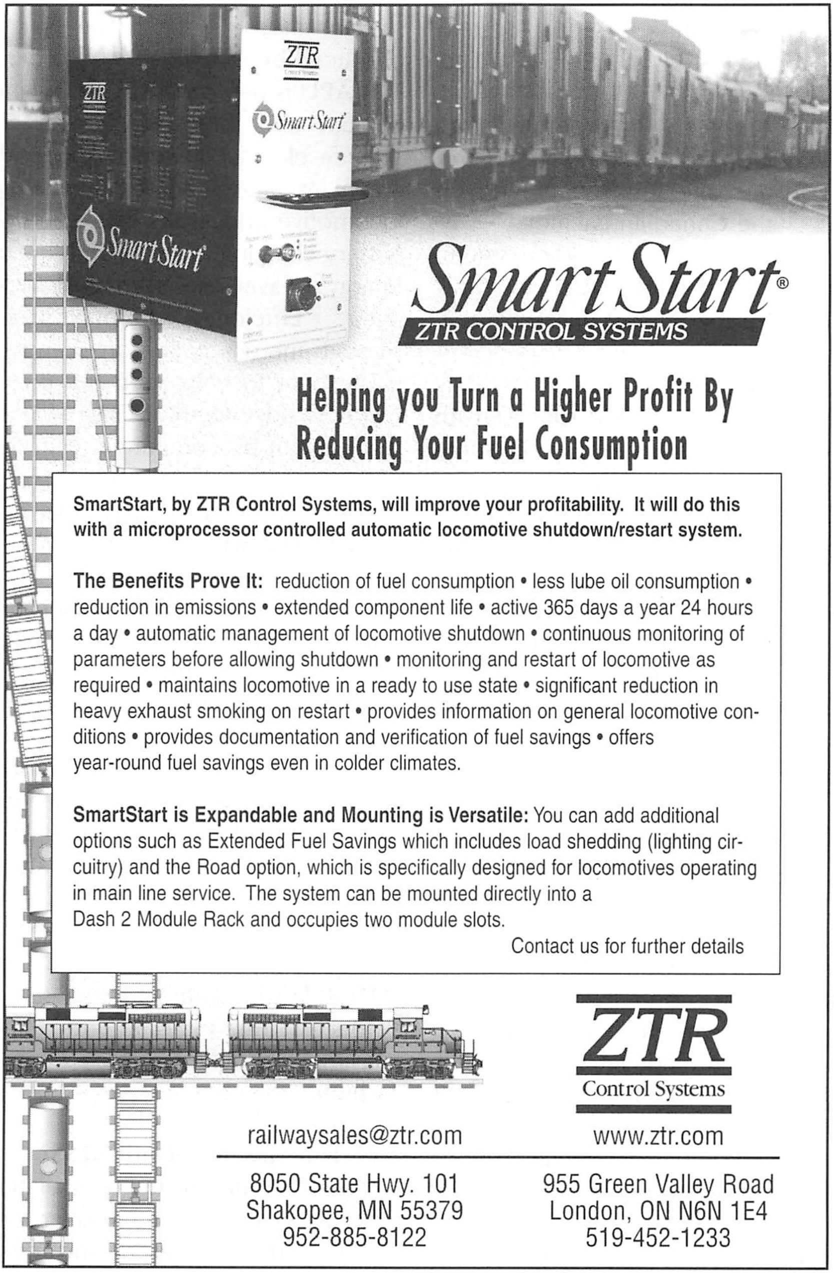
A given locomotive may have one of a number of different "flavors" of an auto engine start/stop system. Types of applications include:

1. OEM applications - available from both GE and EMD,
2. Stand - alone aftermarket systems that are designed for flexible retrofit,
3. AESS directly integrated into an aftermarket locomotive control computer system,
4. AESS combined with an APU for increased flexibility.

Some of the noteworthy points of the more popular AESS systems are provided below, for comparison and familiarization purposes:

1. GE OEM system
   - AESS is fully integrated into the locomotive control system,
   - AESS is enabled/disabled through an ASDS switch, installed in the cab,
   - All man-machine feedback is handled through either the DID or IFD panel, depending on locomotive options,
   - An Auto Stop override switch is provided for crew use - this is primarily intended to allow a lead unit in a consist to remain active, in order to maintain crew comfort features like air conditioning and other amenities.
2. EMD OEM system
   - Like the GE system, AESS is fully integrated into the locomotive control system,
   - The system defaults to AESS always "active"; no dedicated disable function is provided,
   - The man-machine interface consists of a three-light panel mounted in the cab for quick status display and either an EM2000 or FIRE screen for text messages, depending on locomotive configuration,
   - Remote communication to AESS is available when the EMD "intellitrain" option is installed in the locomotive.
3. ZTR "Smart Start"
   - The ZTR system is designed for retrofit flexibility, as many system elements are discrete; able to be mounted as best required for a particular application,
   - The system is compatible with:
     - older power, with the control system in a dedicated enclosure for mounting in any of a number of locations, or
     - Dash 2 type control, where the control computer is applied to a Dash 2-style plug-in module,
   - Simple controls are provided, for installation on the cab rear panel.
4. Q-Tron

   The Q-Tron AESS system is available in one of two configurations:
   - A stand-alone system, which


ZTR
SmartStart
SmartStart®
ZTR CONTROL SYSTEMS
Helping you Turn a Higher Profit By Reducing Your Fuel Consumption
SmartStart, by ZTR Control Systems, will improve your profitability. It will do this with a microprocessor controlled automatic locomotive shutdown/restart system.
The Benefits Prove It: reduction of fuel consumption • less lube oil consumption • reduction in emissions • extended component life • active 365 days a year 24 hours a day • automatic management of locomotive shutdown • continuous monitoring of parameters before allowing shutdown • monitoring and restart of locomotive as required • maintains locomotive in a ready to use state • significant reduction in heavy exhaust smoking on restart • provides information on general locomotive conditions • provides documentation and verification of fuel savings • offers year-round fuel savings even in colder climates.
SmartStart is Expandable and Mounting is Versatile: You can add additional options such as Extended Fuel Savings which includes load shedding (lighting circuitry) and the Road option, which is specifically designed for locomotives operating in main line service. The system can be mounted directly into a Dash 2 Module Rack and occupies two module slots.
Contact us for further details
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Control Systems
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www.ztr.com
8050 State Hwy. 101
Shakopee, MN 55379
952-885-8122
955 Green Valley Road
London, ON N6N 1E4
519-452-1233

provides AESS control, compatible with an existing locomotive control system (as tested on the Florida East Coast),

- A system incorporated into an overall locomotive control package (as is operating on the Canadian Pacific).

5. A new GE aftermarket system, with detailed information not available as of the time of this writing.

Many railroads that tried early AESS systems reported success with the devices, as installed. But some properties, particularly those in northern climates, experienced a level of frustration, as the prime movers would spend very little time shut down, due to the need to run the engine to keep it warm in cold weather. Something else was needed, if the promise of big fuel savings was to be realized. As a result, a new idea was born:

The APU

The APU (Auxiliary Power Unit) is an engine-driven portable power unit that can be installed in a locomotive to provide heat energy to keep prime mover fluids warm during shutdown, while also supplying electricity for critical systems, such as battery charging. The system acts much like an onboard version of a layover system, so popular in commuter locomotives. The commuter properties find layover useful because locomotives often spend many hours not being used (nighttime operation is rare), but must be ready-to-go, to support rush hour traffic demands.

There are two popular APU systems in use today. The first is produced by ECOTRANS (Figure 1). This APU is designed to heat engine coolant and lube oil, as well as provide electric power to keep cab amenities active, while maintaining locomotive critical systems, such as battery charging. A total of 40kw of energy is available from this package. Efficiency is maximized through the use of the drive engine waste heat to help keep the prime mover fluids warm. This APU is designed to be compatible with the Q-Tron AESS arrangement outlined above. Maximum fuel savings can be achieved when the two systems are tied together.

Another type of APU in use on a number of properties, is a somewhat smaller package, known as a DDHS, or diesel-driven heating system, manufactured by Kim Hotstart (Figure 2). This system is very compact, and is primarily focused on engine heating only, with only a small amount of electric power available for battery charging, and maybe a cab strip heater at most. This system is designed to be compatible with the ZTR AESS arrangement (marketed as "Hotstart SmartStart"), and offers maximum benefit when used in this fashion.

Is it easy to retrofit AESS?

When contemplating installation of an AESS system, one must consider the effort required and costs involved. Certainly the OEM installations are relatively transparent to the shop maintenance force, but retrofit of AESS requires some fixed commitment. Equipment-wise, a typical stand-alone Q-Tron or ZTR system for a Dash 2 locomotive would involve the addition of the following:

1. A main control processor,
2. the man-machine interface, which includes control switches, status indicators and a horn to warn of impending main engine startup or shutdown,
3. a layshaft assist device, for proper fueling during the cranking cycle, and
4. feedback sensors for the engine and attendant systems.

Estimated costs of a typical installation in a GP38 type locomotive would be expected to be somewhere between $7500 and $8000 in direct material. Manpower for application of one of these basic AESS systems should be in the neighborhood of 40 to 50 man-hours.

One of the other factors that must be considered is the effect on locomotive configuration records. For each series of locomotives, mounting and wiring details are likely to be unique, and will require a disciplined approach to maintaining detailed equipment and wiring information, to facilitate later troubleshooting efforts.

Who's using AESS?

AESS is being actively applied and utilized by all the major railroads and many smaller operations as well. Certainly, the locomotives that are the best candidates for this technology are ones that operate with the lightest duty cycles, yard switchers being a good example. As well, locomotives in warmer climates also have an opportunity to reap larger savings than those more north. Following, is an inventory of some of the more aggressive programs to apply AESS in North America:

1. BNSF
   - GE OEM systems applied to the Dash 9 fleet
     - 1250 locomotives
   - ZTR system applied to about 50 low HP units
2. Canadian Pacific
   - GE system on entire AC fleet
     - 280 locomotives total
   - EMD system being tested
   - ZTR system on 300 locomotives
   - Q-Tron system on 200 units
   - APU-two systems being evaluated
3. CSX
   - 785 locomotives equipped in early 2003
   - 600 more to be outfitted by year's end
   - Mostly EMD Dash 2s, SD50s, SD60s
     - Q-Tron system
     - AESS supplemented with APU
4. Norfolk Southern
   - OEM systems
     - 10 GE Dash 9s
     - 33 EMD SD70MACs
   - ZTR system
     - 100 GP38-2 locomotives, many of these inherited from Conrail

5. Union Pacific
   - GE system applied to 109 C44ACs
   - EMD system applied to 236 SD70s
   - ZTR SmartStart on 450 locomotives
     - Low horsepower units targeted
6. Alaska Railroad
   - EMD OEM system on SD70MACs
   - ZTR system on MP15s
   - Kim DDHS on test in GP38
   - ECTOTRANS APU on six GP40-2s
     - will likely apply more in near future

How's AESS performing? The expectations:

The earliest predictions for the benefits to be gained by using AESS were quite promising. In mild climates, using light duty-cycle equipment, it was estimated that up to 70-75% of idle time could be eliminated, on a locomotive that spends 65% of its life idling.

When creating a "business case" to justify application of AESS to locomotives in a fleet, a minimum threshold for fuel savings on most roads was as little as $20/day/unit, or generally sufficient to provide a 1-year payback, although some were happy with a 2-year recovery time.

Relative to pollution reduction, hopes were that application of AESS to some models of locomotives would obviate the need to apply other equipment in order to meet the emission limits of the EPA Tier 0 mandate for those locomotives.

Other benefits, such as reduction in wayside noise and reduced wear and tear were considered as mainly intangible benefits and rarely, if ever, quantitatively figured into a business case analysis.

How's AESS performing? The reality:

While the predictions for 70-75% idle time reduction are generally not achieved, an elimination of comfortably 1/2 of idle time of medium duty-cycle locomotives is common, and more for yard goats that have the lightest reported duty-cycles. Based on this reality, the 1-year payback time originally envisioned is readily achievable.

Fuel savings are routinely reported at 20 gallons or more per day, somewhat less for the most northern climates, more for areas that are among the warmest.

An excellent example of the maximum potential of AESS is demonstrated on the Canadian Pacific Railroad. Locomotives equipped with the ZTR AESS at their Coquitlam yards near Vancouver have been monitored for more than 4 years. Total fuel savings for this 39-unit fleet over an average of 4.2 years exceeds $3M Canadian (Figure 3).

In a case where we would expect minimum benefit from AESS, we look at new mainline locomotives operating in the winter months. The chart in Figure 4 shows the savings for the newest locomotives operating on the Union Pacific Railroad, with maximum utilization.

With EMD AESS, after 5 winter months, total fuel savings for 32 unit SD70M fleet exceeded $44,000 US.

Figure 4 shows clearly that, even when conditions allow for little benefit, substantial fuel savings can be realized.

Recommendations

The following recommendations are compiled from interviews with personnel involved with AESS systems on various railroads. Many of the comments gathered were voiced by multiple sources, with some of the more helpful views catalogued below:

1. Integral - Kevin Lopresti of the Canadian Pacific Railroad stresses the importance of having the AESS system integral to the control system whenever possible. In this way the potential for interface contentions between AESS and the rest of the locomotive is minimized, allowing seamless operation of the system.

2. Diligence - Curt Meyers of the BNSF, among others, is a big proponent of diligence in AESS applications. This translates to having a system that is always "active", unable to be easily overridden. It has been noted by some that whenever the system can be cut out, it likely will be, either by maintenance or operating personnel, unfamiliar with the workings of the system. A story from the Union Pacific relates that two similar switchers, in the same service, were outfitted with AESS. The only difference was that one had a control enabling it to be cut out, and the other did not. After a period of time, a check of fuel savings was conducted and the one equipped with a cut out switch had logged a 250-gallon saving, while the one without a cut out showed a saving of nearly 10,000 gallons!

3. Friendly Neighbor - In conversations with Josh Coran of the Alaska Railroad, he relates their experience with the public, in areas along the railroad right-of-way. In Alaska, both the noise and perceived pollution environment are important to the well being of the residents of the state. When the public is unhappy, many headaches inevitably result throughout the railroad hierarchy. As a result, Josh exhorts everyone to not underestimate the value of good public relations, through demonstrating sensitivity to the environment.

4. Columbus Ohio - Don Graab of the Norfolk Southern talks of his experience with us of AESS and APU enhancement. In order to determine whether it makes sense to use an APU in conjunction with AESS, he draws an imaginary line through Columbus, OH and Indianapolis, IN. Locomotives assigned to regions north of the line generally benefit most from AESS and APU together, while units south of that line do well with AESS alone.

5. Focus on Crew - Kar Gazarov of CSX is a proponent of APU use, in order to reduce the demand on the prime mover for all purposes practical. For instance, by powering the air conditioning system from the

APU, the operating crew are not compelled to keep the main engine operating to maintain a comfortable cab environment when stopped on a siding. In general it is thought that power coming from the APU is always more efficient than that from the prime mover, and that crews are well served to get all their needs met even when the main engine is in a dormant state.

6. **Beware the Spitters** - Kent Denkers from the Union Pacific tells of the time, early on, when locomotives equipped with AESS had undergone frequent restarts, after only short shutdown periods. It turned out that the air dryers that were on the locomotives were siphoning much of the compressed air supply off, causing the locomotives to restart due to low air pressure. He cautions that whenever there are subsystems that use the air supply, spitters being a prime example, that they be turned off whenever possible, during periods when the locomotive engine is shut down.

Conclusion

AESS is proving itself to be technology that works. Railroads that have implemented AESS are showing results in fuel and maintenance dollars saved. As well, there is a real environmental benefit that accrues, due to the reduction of pollutants that the EPA has deemed harmful to the ecology. And, as suppliers further optimize these systems, promise of profit to them from this new revenue stream will likely stimulate ongoing creativity in this arena.

These benefits are real, but they do not come without some cost. Many railroads report that there are some downsides to adding AESS functionality to their motive power. Older locomotives that were originally designed for someone to actually go back into the engine compartment to start the engine, are now getting less frequent visual inspections, which now reduces the potential of catching some failure modes earlier on. As well, frequent starts and stops tend to add new measures of stress to the engine and starting system. For instance, while an engine is shut down, lubricating oil, normally in abundance in galleries and critical wear areas, is reduced to a minimum of film thickness upon restart. Also, when considering older EMD locomotives, the added strain on the starting system serves to reduce the life of starting motors and ring gears.

The onward march of technology is offering us many opportunities. The railroad industry is, likewise demonstrating the need for advanced systems to help it transport its cargo (freight or passenger) more swiftly, safely and cost effectively. The introduction of AESS to reduce operating and maintenance costs is just one of many new technologies that are helping railroads compete successfully in the transportation industry. With the positive feedback gathered to date, the industry seems well served to pin high hopes on this product advancement. As operators get more familiar using the AESS platform, even more savings will result from increased "active time" of the system. And as familiarity grows, innovative new ideas to best focus AESS for specific needs are sure to emerge. Based on data collected to date, we can say that the best is yet to come!

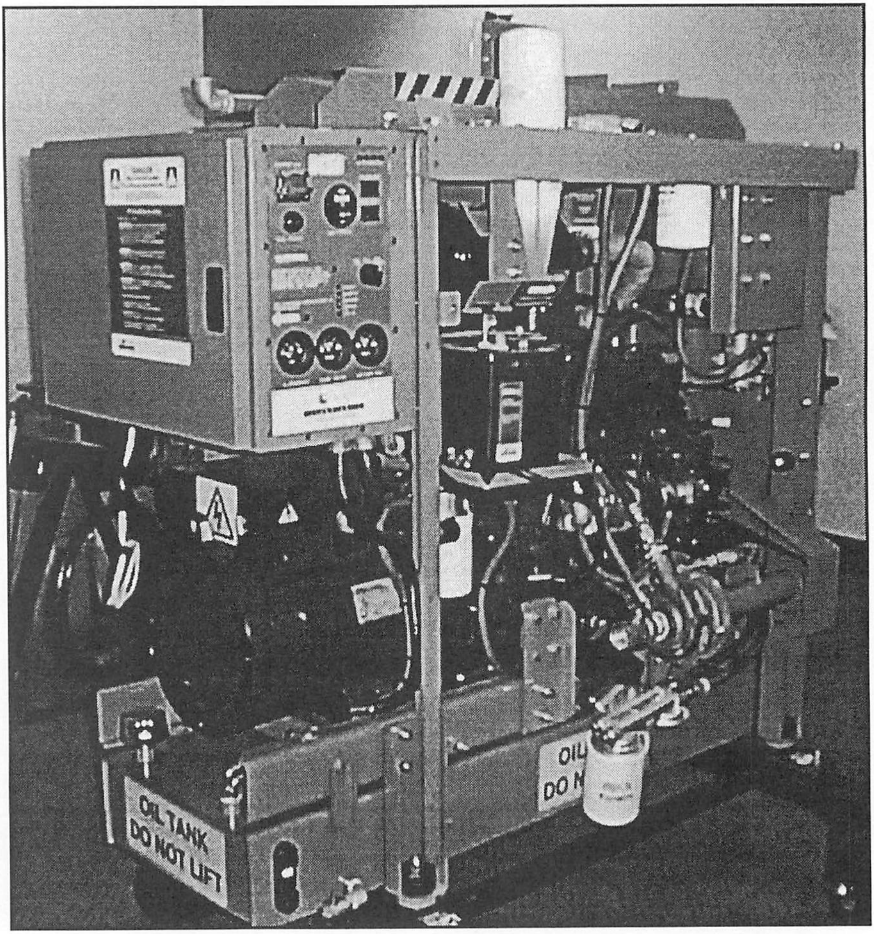


Figure 1
ECTOTRANS APU

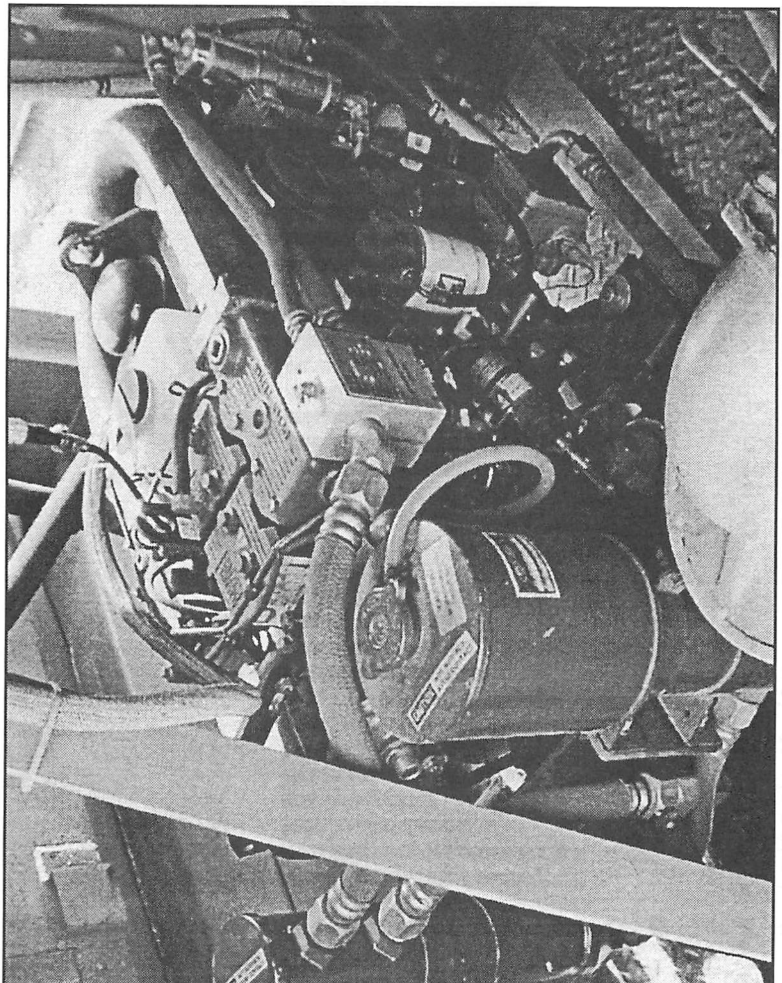


Figure 2 Kim DDHS

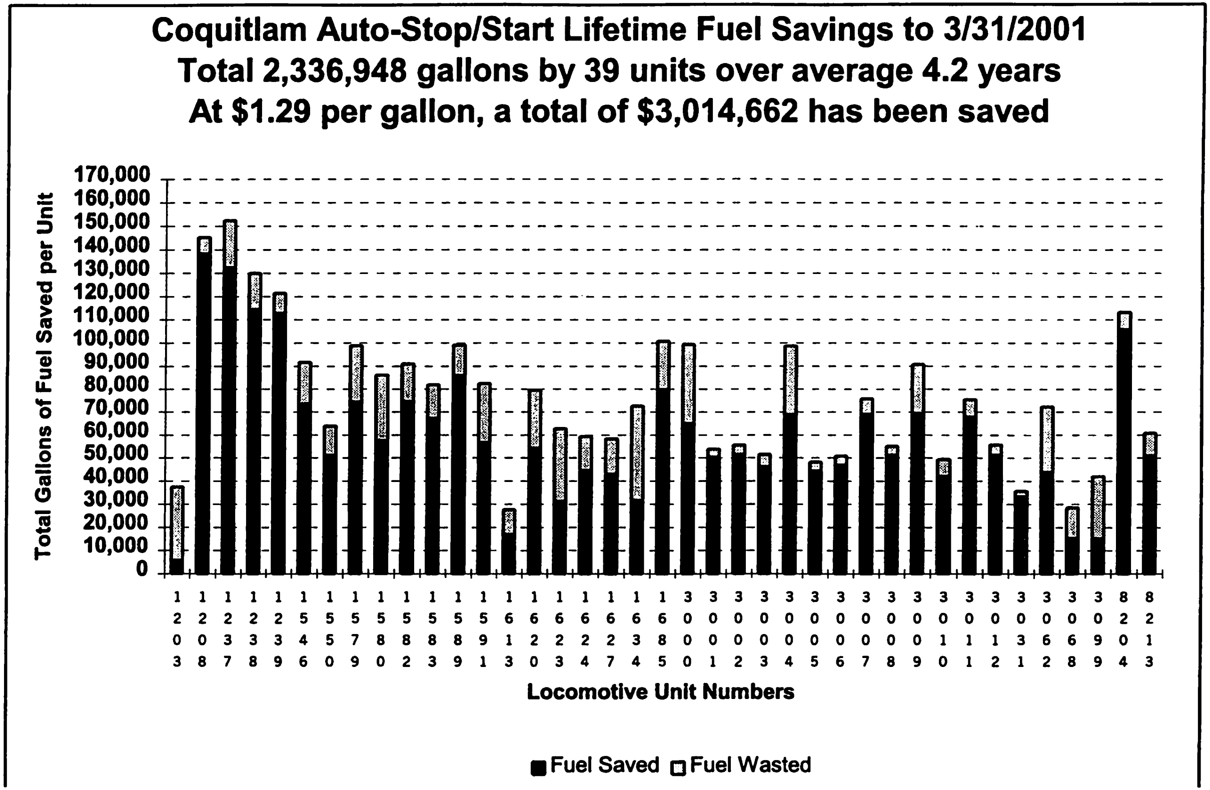

Coquitlam Auto-Stop/Start Lifetime Fuel Savings to 3/31/2001
Total 2,336,948 gallons by 39 units over average 4.2 years
At $1.29 per gallon, a total of $3,014,662 has been saved
Total Gallons of Fuel Saved per Unit
170,000
160,000
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1203 1208 1237 1238 1239 1546 1550 1579 1580 1582 1583 1589 1591 1613 1620 1623 1624 1627 1634 1685 3000 3001 3002 3003 3004 3005 3006 3007 3008 3009 3010 3011 3012 3031 3062 3068 3099 8204 8213
Locomotive Unit Numbers
Fuel Saved
Fuel Wasted

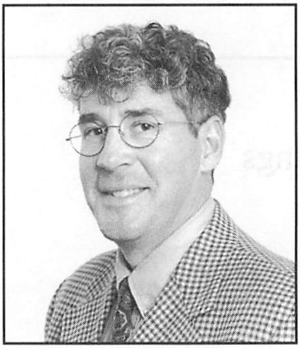
Figure 3

Customer	Union Pacific Railroad
Actual AESS Savings	$44,205.53
Number of Locomotives	32
Number of Locomotive Days	4515
Automatic Stop / Total Idle Time Opportunity	71%
Automatic Stop/Total Idle	43%

Figure 4

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

TUESDAY, SEPTEMBER 23, 2003
10:30 A.M.



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BENOIT GIRARD
Manager-Procurement-Locomotive
Canadian Pacific Railway
Calgary, Alberta

Vice Chairman
JOHN MINNIE
Materials Manager
BNSF Railway
West Burlington, IA

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G. Sumpter	Superintendent-Locos.	Florida East Coast	New Smyrna Beach, FL

PERSONAL HISTORY

Benoit Girard

Benoit Girard is the manager procurement - rolling stock at Canadian Pacific Railway Calagary, Alberta head office, with over 25 years of experience in the rail industry.

He began his career with Canadian Pacific in January 1978 at Angus shop in the Material department in Montreal. In 1992 he became senior material supply specialist when Purchasing and Material merged. During the summer of 1997 he transferred from Montreal to Calgary when CPR decided to move its head office. Finally, in January 1999, he was appointed to his current position.

He and Sylvie, who have been married for 22 years have one son, Pierre-Olivier.

I. JUST IN TIME DELIVERY: THE JUNIATA SHOP MATERIAL CONTROL PROGRAM

Prepared by Bob Harvilla, Triangle Engineered Products, and Pat Johnson, Norfolk Southern

Introduction

This report speaks to our committee's theme for this year, which is Strong Railroad and Supplier Relationships for Continuous Improvement.

The partnership we forge between the railroad material departments and the suppliers allow us to better serve our mutual customers - the diesel shops and mechanical departments.

Overview

Our report will discuss the concept of the JIT program and the thought process behind its inception.

We will discuss the criteria used to select the suppliers that were included in the program, and the commitment made by Norfolk Southern and the chosen suppliers to make the program work.

We will show you the information contained in the material fax order form, which is the working document for the entire program, and discuss the day-to-day workings of the document, and how it enables just in time delivery.

And finally we will share with you the payback that the NS Juniata Diesel Shop has seen as a result of implementing this program.

Concept

The idea is the brain child of John Tantanella, material manager for NS in Altoona. John came up with the idea when he was discussing a potential consignment arrangement with a supplier to reduce the inventory NS had to keep on the shelf.

Consignment has its own problems, such as keeping up with the amount of products on hand, issuing timely orders, and accounting for the inventory by the customer and supplier.

The idea was that if the railroad and the supplier had access to critical information, the supplier would be in position to fill the railroads needs on a Just In Time basis, and allow NS to reduce the amount of inventory in its warehouse. NS would give the supplier its average monthly usage for the chosen items.

It would give them the amount of inventory on hand and the quantity that was due out (shop picks already received).

And they would agree on standard packaging numbers to facilitate order and shipping efficiency.

Criteria

The first thing that John did in Altoona was to establish criteria for the suppliers that would be asked to participate in the JIT program.

The suppliers had to be willing to commit to keeping one month's usage of material on their shelves.

In turn NS would commit to keeping one month's usage in the pipeline (on the shelf, in transit, or

on the shop floor). All of the items that are part of the JIT program were already stock items for the Altoona shop; and all of the items that are part of the program were already assigned to the respective suppliers on the CAF (Contract Agreement File).

Implementation

In order to implement the program John and his people utilized the Microsoft Access based program NS already had available.

The program has three tables that were used to create the "Material Fax Order" form that is the day to day tool used to facilitate the JIT program.

The three tables are: Suppliers and their basic information; The CIC' (Class & Item numbers), Supplier I.D. number, and the Supplier part numbers; and the inventory table, which comes from the NS computer mainframe.

This information was melded together to create the Material Fax Order form.

Material fax order

The Material Fax Order form contains all of the information shared between the Norfolk Southern and the suppliers chosen to participate in the JIT program. The form has the following information supplied by NS each Monday:

- The class and item number of each part involved.
- The description of each part.
- The supplier part number.
- The agreed-to standard packaging quantities.
- The bin location of each the parts.
- Average monthly usage.
- The number of pieces on hand at Juniata.
- The number of pieces due out to the shop floor.
- The number of pieces on order from the supplier.
- And the number of pieces NS wants to order at this time.
- The supplier then fills in the following information, and faxes the form back to NS:
- The number of pieces it is going to ship to NS (based on the order to be placed and the number of pieces to go on back order (if it cannot fill the orders to be placed).

How the program works?

Each day of each week the JIT program is in process. This is how the program works from day to day:

On Monday NS faxes the Material Fax Order Form to each supplier. The suppliers fill out the required information and faxes the forms back to Altoona.

On Tuesday the suppliers receive their confirming orders via EDI.

On Wednesday the suppliers pick the material to be shipped to NS.

By Thursday all the orders placed that week are shipped by the suppliers.

On Friday the material is received by NS and put into the Juniata shop warehouse.

Obviously the program is not foolproof, and every order is not received by the suppliers, shipped to NS and received by Altoona on time every time, but the majority of the orders are, and the payback for the program has been substantial.

Supplier involvement

NS currently has 25 suppliers participating in the JIT program. It has been a new experience for most of the suppliers, and has helped form a much closer working relationship with NS.

Suppliers now have access to information they have never had before, such as how much material NS has on hand and how much it expects to need in the near future.

Due to the program and the information we now have, material availability is almost never a problem on the items covered by the JIT program.

And one of the biggest advantages of the program is that the suppliers have been brought into the fold by NS, and embraced as part of the team.

Side benefits

In addition to the advantages and improvements NS expected to achieve with the JIT program there have also been side benefits that were unexpected, such as:

- Reduced shipping costs, because the suppliers in most cases are now shipping once a week, and require only one transportation bill.
- Reduced shop labor time due to the fact that the supplier is now preparing only one bill of lading per week.
- And an expedited paperwork flow for NS because it now has only one invoice per supplier per week to contend with.

Payback

The biggest payback provided by the JIT program has been a significant decrease in on-hand material.

The program was created by John Tantanella with the intention of reducing inventory, and to date NS enjoyed a 50 percent decrease in on-hand material. This is a significant accomplishment, which is the result of the NS and its key suppliers working together to find ways to continue to improve our products and services for our joint customers.

II. THE CONTINUOUS IMPROVEMENT APPROACH

Prepared by Benoit Girard, Canadian Pacific Railway

The concept of continuous process improvement (CPI) is interesting; but it is a challenging technique that requires discipline and hard work. If successful however, the rewards that will be generated could be substantial.

What, exactly is CPI? As defined by the American Production and Inventory Control Society dictionary, it is "a never-ending effort to expose and eliminate root causes of problems; small-step improvement as opposed to big step improvement." The concept has been widely applied in Japan, where it is known as Kaizen. Kaizen is the Japanese term for improvements; continuing improvement involving every one - managers and workers. In manufacturing, Kaizen relates to finding and eliminating waste in machinery, labor or production methods.

CPI could be applied in the railway industry in various ways: internally to your own processes, externally with your customers and externally with your vendors or with your major contracts or services, or with your major service providers. The first step will be to determine the application and the creation of a plan of action.

The vision is one of the most important foundations: you need to recognize the performance gaps that you want to address, by creating or correcting actual processes. To track future progress, a number of goals have to be developed; these will have to be measurable and achievable. These steps will enable your CPI team to create a new behavior and lead to a culture that will be oriented towards success.

The next step will be preparing for the improvement. Some essential data will need to be researched. For example you might have to look at an existing contract application. A review of the contract will determine if some requirements are mandatory and need to be fulfilled by both parties, which will create a need for monitoring. A stakeholder analysis will have to be performed to assess and recognize the need for improvement. A prioritization of short and long term improvements will have to be established before we will be able to create the structure.

The selection of the improvement leader will be crucial; his level of power, his credibility, skills and personal motivation will be qualities required for future success. The team and/or sub team will also be selected following the same logic and will involve the same level of participation from the group who handle the contract as well as with the vendor who delivers the products or services. The team should lay down a comprehensive plan of action using a timeline, and will need to develop the required structures, reports and scorecards.

During the implementation, the

team will have to be sure to build support by communicating, showing common interests among themselves by using joint diagnostics or experimentation and developing the recognition of the need for improvement. I call this "coalition building."

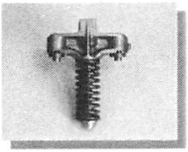
The team will also have to provide or develop capabilities by being willing to dedicate resources, time or money and even provide training when required. Finally, they will have to determine the technology to be used to diffuse the information.

The last task in the implementation is the goal setting. The goals have to be specific, difficult and accepted by all the participants. Remember, they also have to be measurable and achievable. A time frame also needs to be determined to monitor performance; the group will also allow time to re-evaluate the goals, not to lower them if not achieved, but to ensure that they are coherent with the need of improvement that has been set previously.

The major challenges after the implementation are to meet regularly, having the right resources and the leadership to meet the joint objectives, and create or maintain the discipline by ensuring continuity of new members or reconsider goals in the light of a changing environment. Other challenges like continued performance monitoring and fine tune re-aligned systems and showcase success are often encountered by many teams.

The rewards expected are the creation of a stronger customer/supplier relationship, a win-win situation for both parties who could share the benefits achieved, a streamlined, permanent process that can be applied to other projects. I strongly believe this approach has some merits and would bring added value if it is successful.

ROCKER ASSEMBLIES & VALVE BRIDGES



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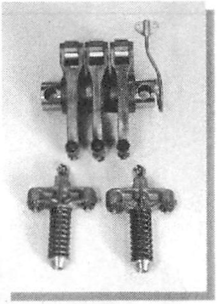
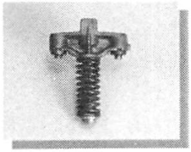
HEAVY VALVE BRIDGE



COMPLETE CYLINDER SET



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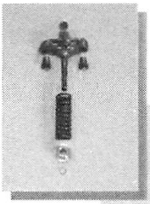
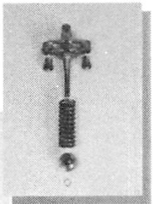
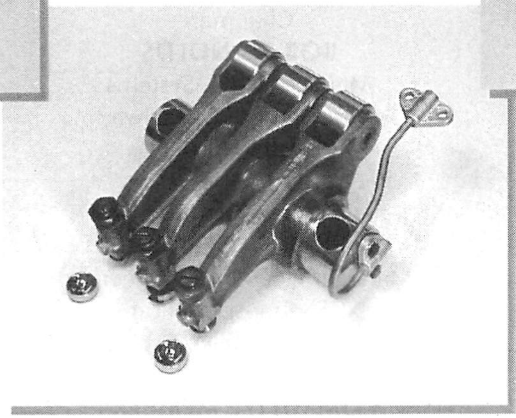
THIN VALVE BRIDGE







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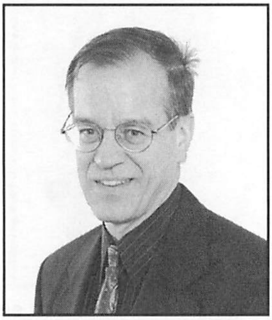
REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

TUESDAY, SEPTEMBER 23,2003
2:15 P.M.



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D. Smith	CMO-Locomotive	WATCO	Arvada, CO

PERSONAL HISTORY

Bob Reynolds
Manager Locomotive Systems
Canadian Pacific Railway

Bob was born in Montreal in 1951. He received a diploma in electronics technology from Dawson College in Montreal. After graduating he began work as an electronics technician with the Canadian Pacific Railway in 1972. His first position was working on the track geometry car, operating and maintaining various electronic instrumentation and computer equipment. He joined the Communication and Signal section in 1976 performing equipment tests on a variety of new equipment developed at that time.

In 1981 he joined the Mechanical department as an electronics specialist in the equipment engineering group. Since that time he has been involved with improvements and modifications to electrical and electronics equipment on the locomotive fleet. In recent years he has prepared specifications for new locomotives and worked with locomotive builders to ensure new orders met technical requirements and reliability standards.

Bob transferred to the new CPR headquarters office in Calgary in 1997, where he lives with his wife Mary and their three boys Andrew, Matthew and David. Bob was promoted to Manager Locomotive Systems in November 2000. His hobbies are electronics and hiking in the Canadian Rockies.

THE LMOA DIESEL ELECTRICAL COMMITTEE

WISHES TO EXPRESS THEIR SINCERE APPRECIATION TO THE FOLLOWING COMPANIES FOR HOSTING COMMITTEE MEETINGS AND SHOP TOURS IN 2003

NATIONAL RAILWAY EQUIPMENT
PADUCAH, KENTUCKY
FEBRUARY 2003

ZTR CONTROL SYSTEMS
LONDON, ONTARIO
JULY 2003

EMD-GM-CANADA
LONDON, ONTARIO
JULY 2003

I. DIESEL DRIVEN HEATING SYSTEM

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Introduction

Although U.S freight railroads have improved fuel efficiency by as much as 71% from 1980 to 2001 according to the Association of American Railroads, diesel fuel continues to be one of the largest operating expenses for railroads today. In 2002, for instance, BNSF used over one billion gallons of diesel fuel at an expense of more than $800 million. At these expenditure levels, even seemingly small fuel saving opportunities can add up when implemented consistently. If BNSF saves one penny on the price per gallon over a year, fuel expenses drop by $10 million. Needless to say, BNSF has many important initiatives to conserve fuel.

Like other railroads, BNSF has significantly improved fuel efficiency by implementing improved locomotive technology and other fuel savings measures, but much remains to be done. One of the key opportunities is reducing locomotive idling.

BNSF has tried many options to reduce idling, including manual shut down policies. Unfortunately, the success of these policies is dependent largely on the judgement and commitment of individual employees in complying with these policies. Automatic engine start/stop (AESS) systems maximize fuel conservation benefits by eliminating the human element. Onboard systems that monitor preset parameters and control engine start/stop functions ensure compliance with shutdown policies. AESS systems in use include those manufactured by ZTR, General Electric and Wabtec.

Despite all the benefits of AESS, the technology can do nothing to save fuel in freezing temperatures, since the diesel engine must be kept idling to prevent freezing damage to the engine, air compressor and other systems. Railroads like BNSF that have a significant portion of their rail system in colder climates would benefit greatly from a locomotive shutdown technology that would address cold weather issues and enable year-round fuel savings.

Cold weather shutdown

To shut down an unattended locomotive in cold weather, three mechanical concerns must be considered:

1. Coolant must be kept above 32 degrees to protect the engine, air compressor and cooling system from freeze damage
2. Engine oil must be warmed to ensure sufficient viscosity for easy re-start in freezing temperatures
3. Battery must be kept charged.

In addition, a technology that addresses crew comfort by heating the cab in cold weather will have enhanced buy-in and support by the crews who must ensure the system is operational. The system must also be reliable, operate as intended and have a backup system in event of malfunction. Return on investment also merits consideration. Since fuel conservation translates into dollars, rapid return on investment is to be expected.

The Kim HotStart layover system (reviewed in 1993 LMOA proceedings) is a technology that can and does allow for winter shutdowns. In general, this on-board system consists of tank heaters, pumps and motors that heat and circulate the locomotive oil and water. This system is powered by plugging into a remote power supply of three-phase 480-volt AC. While some railroads have successfully applied these layover systems, it may not be the optimum solution if an external power source is not conveniently accessible.

Stand-alone systems have been introduced over the years that allow locomotive shutdown without an external power source. Most of these systems use an on-board diesel generator set that provides auxiliary power for a variety of accessories including immersion heaters. Examples include the Microphor LTP (see 1998 LMOA proceedings) and the Ectotrans APU (see 2002 LMOA proceedings).

Kim HotStart recently introduced a stand-alone diesel driven heating system (DDHS) that will now be discussed in detail.

System overview

The DDHS is designed as a coolant and oil heating system for use in railroad locomotives, to allow engine shutdown in low temperatures without the danger of freeze damage. Unlike past stand-alone designs, however, the DDHS does not use a generator set to produce auxiliary power. Once the locomotive is shut down, the DDHS becomes operational, circulating and heating engine coolant and oil to target temperature of 120 F°. The system remains in operation until the locomotive is restarted either by automatic or manual methods.

The DDHS uses a direct-coupled centrifugal water pump to extract coolant from the main drain of the locomotive engine. Coolant is pumped through heat exchangers and electric heaters where heat is transferred to the coolant. Heated coolant is then injected directly into the locomotive engine water system at the top front of the engine, flowing through the cooling system and oil cooler in a reverse flow arrangement, (See Figures 1 & 2 for flow configuration).

Maximum heat is injected directly into the water through the mechanical energy of the pump, direct immersion heaters and a system of heat exchangers. The system is configured to operate at different speeds, automatically, to keep the water temperature between 100F° and 120F°. At the same time, the system charges the locomotive batteries and powers the cab heaters through a 72-volt, 80-ampere alternator. This system uses its own oil and antifreeze treated water supply.

The compact system is 32.6″ tall, 49.2″ long and 23.9″ wide, allowing it to be installed along the locomotive walkway or in the engine room.

The system can be used even on locomotives with limited space in the engine room, such as SW1000s and SD9s. This is significant, since these locomotive models are typically used in yard and switch engine service and idle to a much greater extent than locomotives in road service. (Figures 1 & 2 show typical walkway placement and system configuration on GP 9 model locomotives).

As the photo in Figure 3 indicates, walkway mount systems can be used on locomotive models with limited mounting space inside the carbody, further enhancing fuel saving opportunities. The photo shows example of installation on SW15 locomotive. Service points are fully accessible from the front of the enclosure. Exhaust from the DDHS is directed beneath the running board toward the frame. Installing the walkway mount system requires modification to main generator doors and reduces access, but service can still be completed from inside the carbody.

Heating capacity

In July 2002, BNSF purchased 3 DDHS units and installed them on GP 38 locomotives, which were assigned to switching operations at Corwith Yard in Chicago. The units' performance and reliability was closely monitored. To measure the system's heating capacity, a test was conducted on January 28-29, 2003. A data bucket with 45 channels and thermocouples measured temperatures at different points throughout the locomotive engine the DDHS and the ambient temperature. (Figure 4 summarizes the key data).

At the beginning of the test, the ambient temperature was 32°F, the locomotive oil temperature was 119°F and the locomotive water temperature at the dump valve was 119°F. The DDHS was manually switched from off to high speed. After 10.5 hours, the water temperature had increased to 195°F, the oil temperature was 180°F and the ambient was 29°F. At this point, the DDHS was switched from high speed to low speed. This test demonstrated the DDHS had the heating capacity to raise the water temperature by 166°F over ambient temperatures (195°F water temperature at 29°F ambient). Therefore, in subzero ambient temperatures, the DDHS has the capability to keep the water temperature above 100°F. This meets our requirements for our coldest BNSF yards such as Havre, Montana, and Northtown, Minnesota. As a sidenote, the Alaska Railroad has separately verified DDHS heating capability at temperatures down to -38°F in Fairbanks, Alaska.

HotStart "SmartStart" system

The DDHS starts and stops automatically when the crew starts or stops the locomotive engine. However, getting the crews to shutdown locomotives can be a challenge. Railroads have trained operating crews over many years to never shutdown a locomotive in cold weather. To address BNSF's concerns, Kim HotStart and ZTR Control

Systems worked together on an integrated "SmartStart-HotStart" system that would automatically shut down the locomotives and utilize the DDHS. The first integration was completed on BNSF 2133 in August 2002.

In a test of the SmartStart system, three locomotives were observed. Two locomotives had the standard Hotstart system, requiring manual shutdown to initialize the DDHS. A third locomotive, the 2133, had the SmartStart system that automatically initialized DDHS. The results appear in the chart below, with the number of recorded hours of DDHS "run time" indicating how long the locomotive was shut down. Clearly, locomotive idle hours were more significantly reduced on BNSF 2133 than on locomotives requiring manual shutdown to initialize the DDHS. It appears that, without the SmartStart integration package, previous training prevailed and locomotives were left idling when not used, thus prohibiting DDHS operation.

By automatically monitoring locomotive and DDHS parameters, SmartStart basically makes the decision to shut down the locomotive for the crews. SmartStart enhanced systems can also download a fuel savings report that documents exactly how and when we are saving money. Already available over laptop download, these reports may soon be available over the Internet, thanks to the efforts of ZTR, making it easy to manage a fuel savings program. After successful field-testing of the integrated system on 2133, BNSF purchased and installed five more systems in late 2002 for further testing.

The results in favor of the Smart Start system are compelling; however, the concerns about employee shutdown behavior may not be an issue on short lines or in smaller yards where crew rotations are smaller and behaviors may be more directly influenced.

Shutdown Test Summary

Road Number	Model	DDHS install Date	DDHS hr meter date	DDHS meter reading	SmartStart Hotstart
BNSF 2194	GP38	7/22/02	4/30/03	176.5	N/A
BNSF 2195	GP38	7/22/02	3/26/03	182.0	N/A
BNSF 2133	GP38	7/22/02	5/4/03	897.5	1514.5

Shutdown statistics also reflect the presence of certain parameters that inhibit the activation of the system, such as reverser not centered for brake pressure leaking (see download information for the BNSF 2133 in Figure 5). This information enables BNSF to repair defects or advise the work team of operator practices that may inhibit operation of the system. Fuel saving analysis and a summary are also provided on the download report to indicate realized savings as well as savings lost to defects.

Emissions

In 1998, under the Federal Clean Air Act, the Environmental Protection Agency (EPA) enacted exhaust emission standards for locomotive diesel engines. A primary focus was the reduction of NOx emissions. All existing locomotive models built from 1973 through 2001 must be made to comply with Tier-0 emission standards (that is, line haul locomotives must meet 9.5 gms NOx and switch engines must meet 14.0 gms NOx for compliance). New locomotives built from 2001 through 2004 are required to meet Tier-1 standards (7.4 gms NOx for line haul, 11 gms NOx for switch engines), and all locomotives built in 2005 must meet even more stringent Tier-2 standards (5.5 gms NOx for line haul and 8.0 gms NOx for switch engines.

In March 2000, the EPA introduced a voluntary initiative program to reduce emissions from older, dirtier diesel engines used in heavy-duty applications. This program would provide partnership opportunities among the EPA, state and local governments and related industry to address the engine exhaust and extended idle emissions.

In May 2003, under this initiative, the City of Chicago, EPA and Kim Hotstart formed a partnership with BNSF and the Wisconsin & Southern RR to conduct a locomotive idling emission reduction project. The purpose is to demonstrate the effectiveness of idle reduction technology in the switchyard in Chicago. The project will include measurements of emission output, fuel savings, noise reduction and the marketability of locomotive idle reduction technology. The project will benefit surrounding neighborhoods by minimizing exposure to exhaust emissions and reducing noise from idling locomotives in the yard. Seven yard-based locomotives were retrofitted with Hotstart DDHS and will be monitored throughout the test. The goals of this project are to:

- Reduce NOx and other air toxic emissions from switch yard based locomotives through control of engine idling.
- Conserve fuel by reducing idling hours.
- Reduce noise levels from idling locomotives.
- Analyze market acceptance and potential of engine shutdown technology for future application on locomotive road and switch engine.

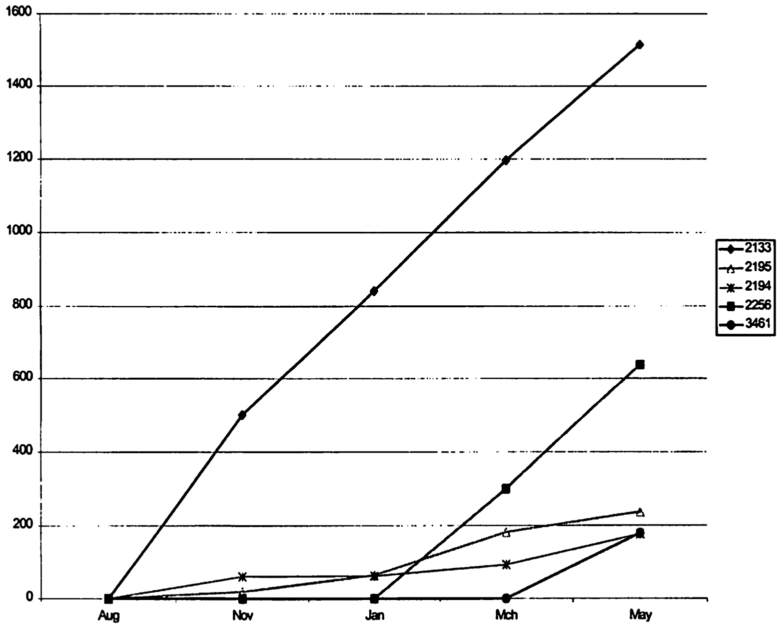


Fig. 6 the Cumulative Idle Hour Reduction report, indicating amount of idle reduction time accomplished to date.

Strategic deployment

Strategic deployment and placement of the integrated Hotstart-SmartStart systems on yard-based or captive locomotives will maximize fuel conservation as locomotives used in this capacity have certain payback advantages over line haul locomotives. Extended idle times occur with yard locomotives as they are generally associated with shift work. In some cases, they are not used more than twelve hours per day and not at all on weekends.

"Smart" applications would utilize the integrated DDHS system in the colder climates, whereas in the warmer climates only the SmartStart systems would be needed. Figure 7 compares average low temperature ranges between Houston, Texas, and Havre, Montana, with a 40-degree engine shutdown limit indicated. The following qualities demonstrate how yard-based locomotives would capitalize on maximum benefit and offer the quickest return on investment:

- Locomotives with extended idle times. Yard-based locomotives have a minimum of 28% more idle time than line haul locomotives (based on duty cycle averages).
- Ownership. Even though the crews rotate, it is easier to monitor yard engines to keep systems on line. Operating crews as well as area Mechanical forces becomes more aware of the systems and their operation.

- Strategic deployment. Systems can be configured and deployed in climates where maximum benefit is realized. Yard assigned or captive locomotives in colder climates would benefit from integrated DDHS systems and realize year-round fuel savings, while locomotives in warmer climates realize the same benefit using autostart systems only.

Benefits

Fuel savings are the primary consideration for railroads using AESS and SmartStart types of systems. Idling time for yard engines average 55% to 60% of their duty cycle (Figure 8) with a fuel consumption rate of 3-4 gallons of fuel per hour. Fuel consumption for idling locomotives increases significantly in cold weather, since most railroads, including BNSF, have winter idle policies that require engines to idle at notch 3 (no load) when temperatures reach 10-15 degrees. This practice allows engine temperatures to remain warm enough to protect the engines from freezing and to reduce oil out the stack issues due to cold engine operating temperatures. Fuel is consumed in notch 3 (no load) at a rate of 11-12 gallons per hour.

Many yard engines are not used in the evenings and weekends and are laid up idling until required for duty. Thus, a switch engine idling for one day would consume 72 gallons of fuel in a 24-hour period at a cost of $59.04 (24/hr. x 3/ghr. x $.82/gal). With winter idle policies in place, the switch engine would consume 264 gallons of fuel at a cost of $216.48 (24/hr. x 11/gal. x $.82/gal.). In remote locations where locomotives must be fueled by outside resources or DTL (direct to locomotive) fuel prices can reach $1.00/gallon, driving fuel costs even higher.

The DDHS unit, in contrast, consumes an average of 0.8 gal./hr. when in operation. This equals a fuel consumption rate of 19.2 gallons per day. So, by using a DDHS unit rather than idling the locomotive would reduce fuel consumption by 73% - 19.2 vs. 72 gallons per day. That's nearly one barrel (52.8 gal.) of fuel saved per day per locomotive, and over four barrels a day during winter idle practices.

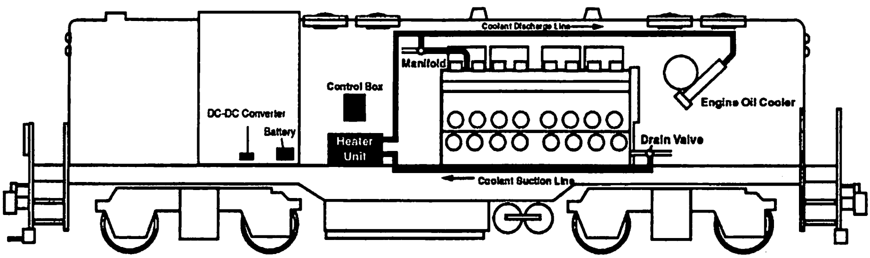
Emission reduction achieved by less engine idle time is equally important. With the introduction of strict Federal regulation regarding emission output, railroads must adjust operations to meet these requirements. Other collateral benefits include reduction of oil out stack problems.

Summary

Innovative thinking is needed to achieve ongoing fuel savings and to help minimize company exposure to fluctuating fuel costs. While diesel engine heating systems are not a new technology, the development of stand alone, on board heating systems coupled with electric monitoring has improved to allow the efficient, year-round use of this technology in all models of locomotives.

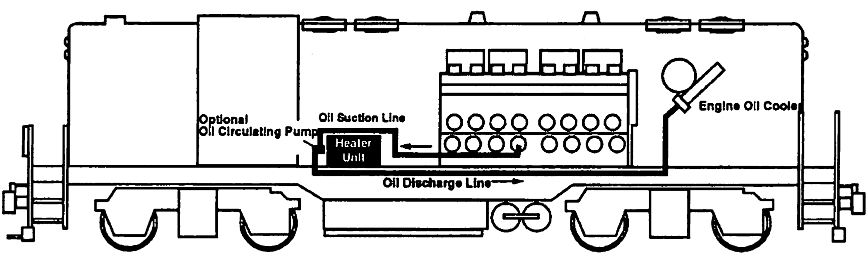
Engine shutdown systems offer

fuel conservation matched by no other means. Manual shutdown policies are subject to judgement or human error and often fall short of fuel conservation goals. Moreover, they are only effective and possible at temperatures above 40 degrees. With "Smart" application of DDHS and proper deployment, fuel conservation can be maximized. As mentioned previously, fuel savings become the primary consideration for railroads using automatic engine start/stop systems. But the accompanying benefits of emissions and noise reduction have important implications for the surrounding communities. It quickly becomes apparent that engine-heating systems should be considered to achieve these reductions year-round. Through innovative systems and aggressive developmental efforts, BNSF has demonstrated its commitment to a cleaner environment and improved fuel conservation, which could potentially benefit all of BNSF's constituencies, including our employees, customers, shareholders and the communities we serve.



Coolant Lines

Figure 1



Engine Oil Lines

Figure 2

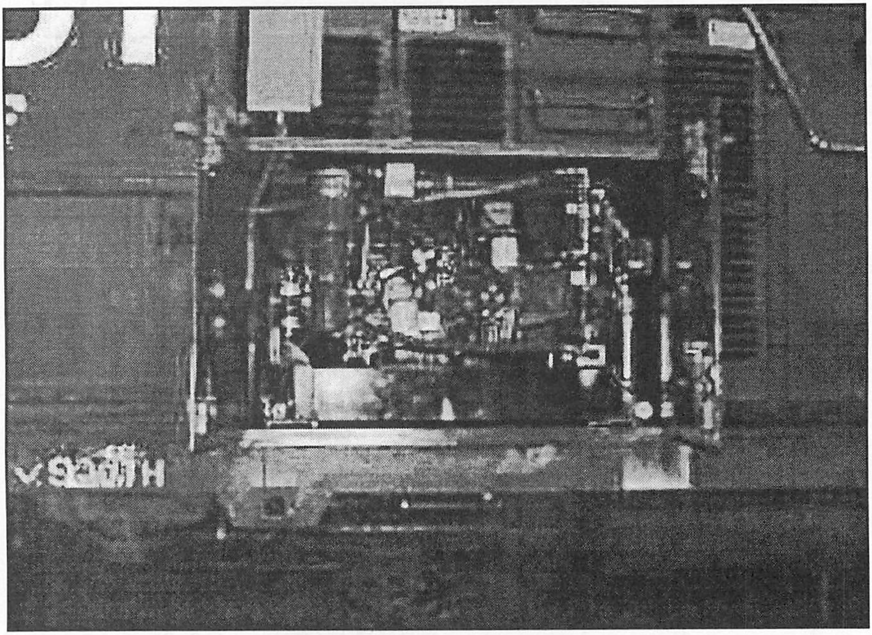
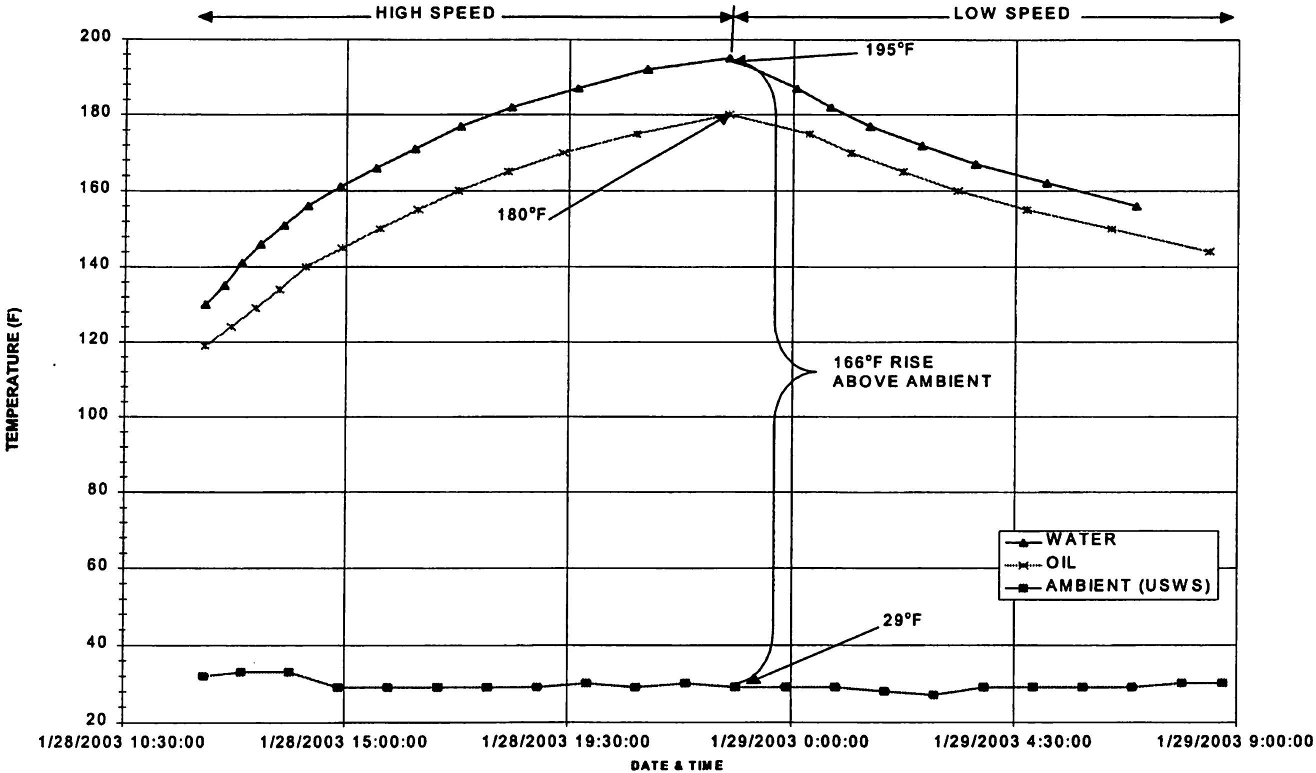


Figure 3

Figure 4 - BNSF 2133, DDHS Heating Capacity Test



Download report BNSF 2133 (5/4/03)

Condition	Since install	Previous report	Condition	Since install	Previous report
LOCOMOTIVE OPERATING STATISTICS (hrs)					
Engine Shutdown	2485.0	43.2	**Engine idling**	1913.3	100.8
Manual shutdown	970.5	0.0	Working idle	1147.0	87.2
SmartStart	1514.5	43.2	Parked idle	766.3	13.6
Engine Run	221.1	124.7	**Parked Idle**	766.3	13.6
Loading	317.8	23.9	Unavoidable Idle	343.8	0.0
Idling	1913.3	100.8	Manageable idle	422.5	13.6
Unsatisfied Parameters Preventing Shutdown (hrs)					
		Unavoidable			
Ambient temp	260.2	0.0	Water temp	37.2	0.0
Dump valve temp	70.9	0.0	High water temp	0.0	0.0
		Manageable			
Brake pressure	161.6	4.6	Battery voltage	0.0	0.0
Battery charging	50.8	0.0	Extended idle	10.5	0.0
Reverser not center	199.3	9.0	SS switch off	24.6	0.0
Reason(s) for Restart After SmartStart Shutdown (counts) - Hotstart Shutdown (counts)					
<<Brake pressure>>	*120*		Ambient temp	13	
Water temp	76		Battery voltage	0	
<<Reverser center>>	*366*	26	Dump valve	2	
SmartStart – Hotstart Shutdown Information					
Count	699	34	**Time**	1514.5	43.2
DDHS On	897.5	0.2	**DDHS high sp.**	27.0	0.0
SmartStart – Hotstart Savings Analysis					
	Savings realized by SmartStart-Hotstart			$6684.88	$174.85
	Additional savings NOT realized by SmartStart-Hotstart			$1454.46	$46.82

Road Number	Installation date	Previous report date	Current report date	Hours since install	Hours since previous report
BNSF 2133	7/22/02	4/27/03	5/4/03	5974.2	168

Fig.5

Doenload Summary for BNSF 2133

Summary	Time since install	Since last report	Hrs/Days
Service time in period:	4716.1	167.9	hrs
Unit was parked idling for:	766.3	13.6	hrs
Unit manually shut down for:	970.5	0	
Reduced manageable parked idling time:	78%	76%	
Unit was shutdown by SmartStart-Hotstart:	1514.5	43.2	hrs
No shutdown because reverser not centered:	199.3	9	hrs
Autostart switch turned off:	24.6	0	hrs
No shut down based on unsatisfied parameters:	422.5	13.6	hrs
Fuel Savings Summary			
Total hours this system shutdown locomotive:	1514.5	43.2	
Total gallons fuel saved:	7427.64	194.28	
Total dollar savings:	$6,684.88	$174.85	
Savings not realized due to unsatisfied parameters:	$1,454.46	$46.82	
Total possible savings potential:	$8,139.34	$221.67	

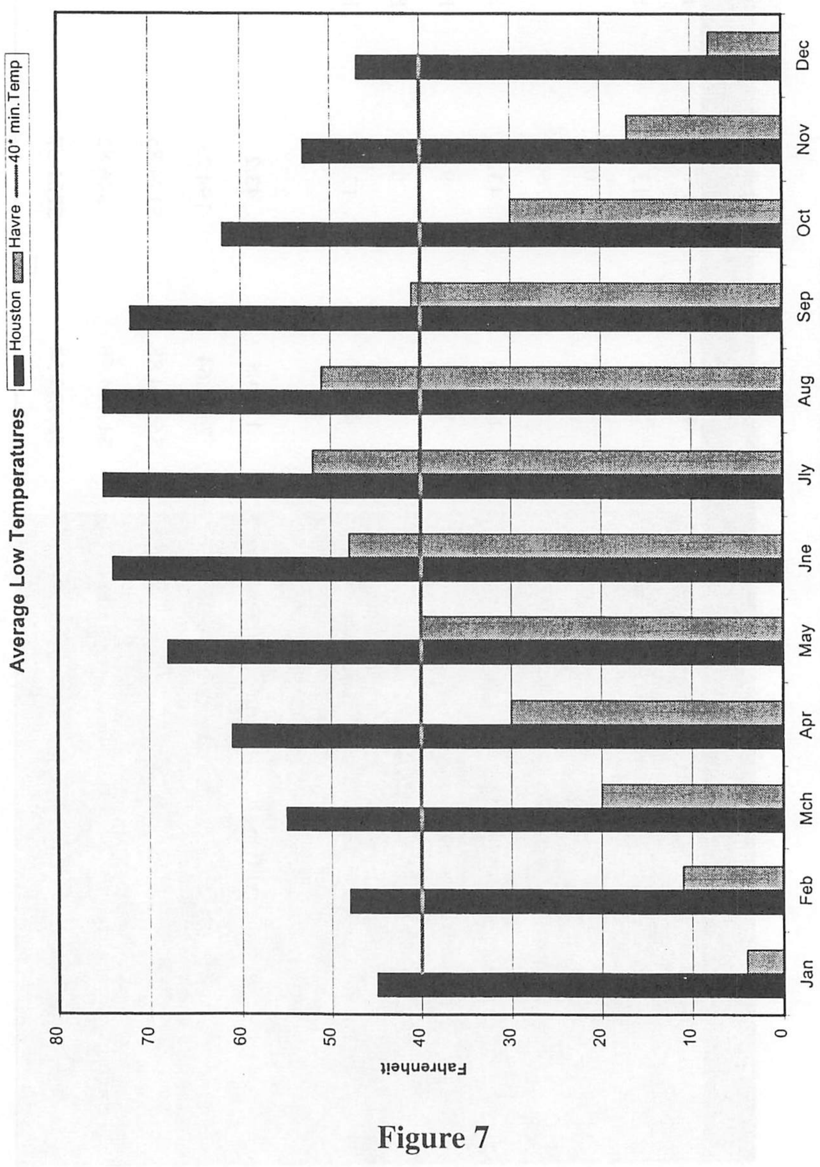

Average Low Temperatures
Houston
Havre
40° min.Temp
Fahrenheit
80
70
60
50
40
30
20
10
0
Jan
Feb
Mch
Apr
May
Jne
Jly
Aug
Sep
Oct
Nov
Dec

Figure 7

EPA Estimated Duty Cycles

(% Time in notch)

Throttle Setting	Line Haul Service	Switch Service
Idle	38.0	59.8
Dynamic Brake	12.5	0
1	6.5	12.4
2	6.5	12.3
3	5.2	5.8
4	4.4	3.6
5	3.8	3.6
6	3.9	1.5
7	3.0	0.2
8	16.2	0.8

Figure 8

II. TRAINLINK - ES TIBS, AS APPLIED TO CN/IC LOCOMOTIVES

Prepared by Bill Kirdeikis, Senior Reliability Specialist - Electrical, CN/IC Rail

Why Trainlink ES

The only way to remain competitive in today's rail marketplace is to do more with less. One way of doing this is to run longer and heavier trains, thereby maximizing the use of locomotives and running crews. It is not uncommon to see trains in the 10,000-foot plus range while 2-3 years ago a 5,000 foot train was considered a long train. These longer trains while achieving this have definitely created a brand new set of problems, not the least of which is the increased drawbar forces encountered during periods of braking (buff forces) or acceleration (draft forces).

With longer trains and using 1000 feet/second as the rate at which changes in air pressure are transmitted through a train's brakepipe, it will take a full 10 seconds to transmit a brakepipe reduction from the locomotives to the last car in a 10,000 foot train. Obviously, as the brakepipe reduction is taking place the cars toward the head end will start to retard the movement of the train as the brake cylinders apply prior to the trailing cars sensing the brake pipe reduction. This will cause the slack run in while equilibrium is being reached with the corresponding buff forces followed by the corresponding draft forces when it is necessary for the train to again accelerate.

One of the methods of reducing these forces during an automatic brake setup would be to apply all brakes on the car simultaneously. The only methods known of at this moment that can accomplish this would be ECP braking which would transmit barking requests through the train instantaneously. While this is obviously the best solution it is by far the most expensive, requiring dedicated cars for this purpose at a major expense. This is where Trainlink - ES comes in (Figure 1). To the CN and the IC (prior to being partnered with CN) Trainlink ES offered the best tradeoff of performance versus price. This coupled with the fact that many of our older SBUs were becoming due for replacement basically made the decision very easy. Another point is that Trainlink-ES IDU and SBU devices are completely compatible with all TIBS equipment used at CN. That is:

- Trainlink-ES IDU's (HOT or LCU) are fully compatible with all other SBU's used at CN
- Trainlink-ES SBU's (EOT) are fully compatible with all other IDU's used at CN

Maintaining compatibility with existing TIBS (Train Information and Braking System) equipment allows failed components to be replaced with conventional equipment in the field, should the need arise.

Trainlink-ES operation

The Trainlink-ES system provides all the features of standard TIBS equipment. For the most part, the

Trainlink-ES will operate the same conventional TIBS equipment until a locomotive engineer chooses to use the additional features it provides.

Over and above the basic TIBS operation, the Trainlink-ES system provides enhanced functionality that can be used to improve train handling, reduce in-train forces and reduce train stop distances. The Trainlink-ES system provides two important and useful features:

1. automatic initiation of end-of-train emergency brake command;
2. "ASSIST" or "ES" mode (EOT service braking).

The Trainlink-ES system will always assist "emergency braking" and will assist "service braking" whenever the "ASSIST" mode is engaged. By applying brakes simultaneously at the head and rear end of the train, whether for emergency or normal service braking, the Trainlink-ES provides the following two immediate benefits:

1. Train slack action is significantly reduced (conservative CN estimates) when train brakes are applied:
   a. 35-40% reduction in buff forces.
   b. 10-15% reduction in draft forces.
2. Train stopping distances are reduced (Figure 3)
   a. 2-5% reduction in emergency braking
   b. 10-20% reduction in service braking.

A graph of Rail Sciences data, based on the average of 336 simulations with random mixed train simulations is depicted in Figure 2.

Trainlink-ES ASSIST mode

To provide the ASSIST (also referred to as EOT) service braking function, the locomotive must be equipped with all three Trainlink-ES components:

1. Trainlink-ES IDU
2. Trainlink-ES SIU (Service Interface Unit)
3. Trainlink-ES SBU in position at the end-of-train.

When the locomotive engineer activates ASSIST mode, improved braking performance will result because the brake application propagation time is reduced. The end result is an improvement in train brake response time.

This is accomplished as follows:

- once the IDU is placed in assist mode the system will calculate the gradient on the train prior to indicating ready for assist mode.
- once ready for assist mode when the train brakes are applied with the automatic brake valve, the Trainlink-ES system will transmit a radio signal to the Trainlink-ES SBU based on the equalizing reservoir reduction.
- the Trainlink-ES SBU has its own brake valve that will, reproduce the brake application at the rear of the train by venting the brake pipe in response to service brake applications made at

the head end. The air is vented from the bottom of the SBU at an appropriate service rate.

Trainlink-ES does not provide any benefit in releasing a brake application, nor does it assist in recharging the train brake pipe.

The locomotive engineer has the ability to selectively enable / disable ASSIST mode as desired.

Modification for installation of Trainlink-ES equipment

The application of Trainlink-ES is a relatively straight forward modification (Figure 4). On the IC fleet this mod involved only the following basic steps.

1. Apply the SIU in the short hood area.
2. Using Hypalon 1/4" tubing route new lines from equalizing and brake pipe gauges to the appropriate fittings on the SIU.
3. One power plug and a serial data plug from the SIU to the LCU to apply and connect.
4. Apply new ES LCU (or retrofitted Trainlink II).
5. Test SIU operation using Wabtec supplied software and test function with ES SBU (EOT) unit attached to air supply simulating approximate pressure at the end of a train.

Note: if tail end pressure is higher than head end pressure by even 1 PSI, ES LCU will not go into assist.

When it came time for the CN fleet the following additional items were necessary:

6. Apply new odometer and power cables for the IDU (HOT/LCU). This was necessary as it was decided to standardize on the IC cable set for this application to ensure that at some point in the future there would be total interchangeability in the fleet. In addition to these cables the original CN cables were left in place to allow application of an older style CN IDU if required due to a failure at a location with no spare ES IDU.
7. Remove existing IDU mounting plate and apply a universal mounting plate. Again this was necessary as it was decided to standardize on the IC outline/case style on the ES IDU for this application to ensure that at some point in the future there would be total interchangeability in the fleet. This bracket was designed in Woodcrest to accept either style of IDU.

Installed Trainlink-ES equipment

To date the following Trainlink-ES equipment has been introduced into CN's Canadian operations:

- 198 Trainlink-ES SBU devices: CNQ 30110-30141, CNQ 31000-31165
- 108 Trainlink-ES fully equipped locomotives (i.e., IDU + SIU);
  GM SD-75's: -25
  GM Dash-9's: -83.

Additionally, the CN SD-70 locomotive fleet (CN 5600-5625) are being equipped with Trainlink-ES. At this time a number of SD-70 locomotives are equipped and some are only partially equipped. Thus, a CN SD-70 locomotive may be encountered with a Trainlink-ES IDU but without the SIU.

Additionally, on the IC side there are presently 174 units equipped which includes 40 GM SD-70 units (IC 1000-IC 1039) with the remainder on various main line locomotives (primarily GM SD40-2 or SD40-3 conversions).

As it stands there are no Trainlink-ES applications planned for 2003 on CN locomotives. Transportation is evaluating the units already in service with this equipment.

There are, however, plans for the next 30 GE locomotives purchased in the first quarter 2004 to come equipped with the ES system. Capital expenditures for 2004 in regards to ES are still to be determined. On the IC side the applications are still ongoing, although not at the same rate as previously.

Changes in ES as we go along and lessons learned along the way

One of the biggest hurdles we have had to cross has been that of purely education. Up until this point all CN head end units have been of the self-arming type; i.e. they were constantly armed to the tail end as soon as the tail end unit code was dialed in. But with Trainlink-ES it was decided to move to the style of head end unit that had to be actually armed to the appropriate tail end code by pushing the com test on the tail end unit to allow the head end unit to be armed. The change to arming style was again propagated by the desire to standardize on one set of rules for units south and north of the border and fully encompass the FRA requirements for arming. The change to a head end unit that required arming was, needless to say, a major change for transportation and equipment department personnel alike and continues to be one of the hurdles of this new system. One of the additional major concerns with this arming system is that if power is changed on a train, CN personnel must find their way to the end of the train to push the com test button on the SBU (EOT) to arm the new head end unit regardless of where the train is located. To this end Transportation is investigating with Wabtec some new methods of arming, which could be accomplished from the locomotive cab, at least on trains on the Canadian side.

Additional software changes to the IDU function which have been requested by CN and accommodated by Wabtec:

1. Change in the beeping routine of the IDU. Originally these IDUs would beep every three pounds increasing brake pipe pressure. That has since been changed to a series of beeps after a large brake pipe change and the 5 beeps on a Low Pressure Alarm.
2. Odometer function. As delivered these units would not allow the odometer

function to count until the 8T or 9T (forward or reverse) trainlines were high. This has since been changed to the CN standard that the odometer will count up unless a reverse signal is encountered.

3. With the relatively small fleet at present CN needed a sure way to let the crew on board the locomotive know that in addition to an ES head end device there was also a ES tail end device at the end of the train. The software has now been changed so that when armed to an ES tail end device a temporary message "ES Train" is displayed on the IDU for 5 seconds and repeats every 30 seconds thereafter to advise the crew that the required devices are in place for assist mode.

Overall on CN, Trainlink-ES is still a work in progress and as such will have both high points and low points as we go along. We do however believe that the journey will be worth it at the end,

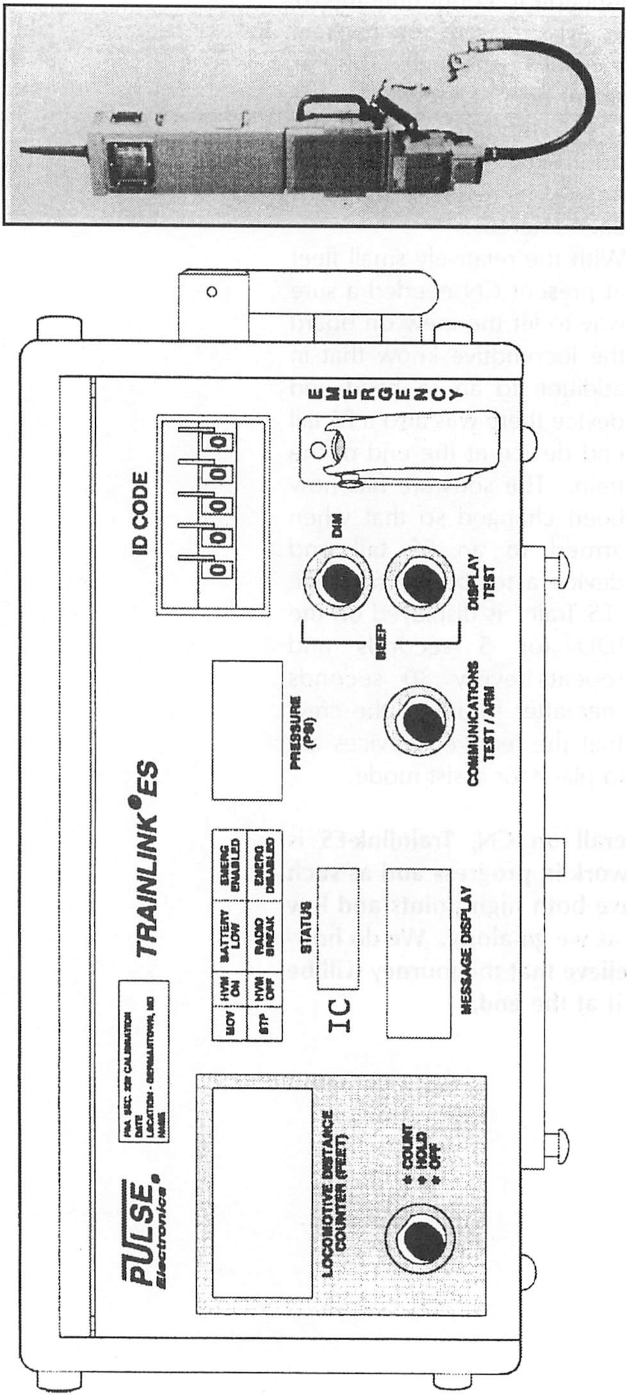

PULSE Electronics
TRAINLINK ES
ID CODE
0 0 0 0 0
EMERGENCY
DIM
BEEP
DISPLAY TEST
COMMUNICATIONS TEST / ARM
PRESSURE (PSI)
HVM ON
HVM OFF
BATTERY LOW
RADIO BREAK
EMERG ENABLED
EMERG DISABLED
STATUS
MESSAGE DISPLAY
LOCOMOTIVE DISTANCE COUNTER (FEET)
COUNT
HOLD
OFF

Figure 1

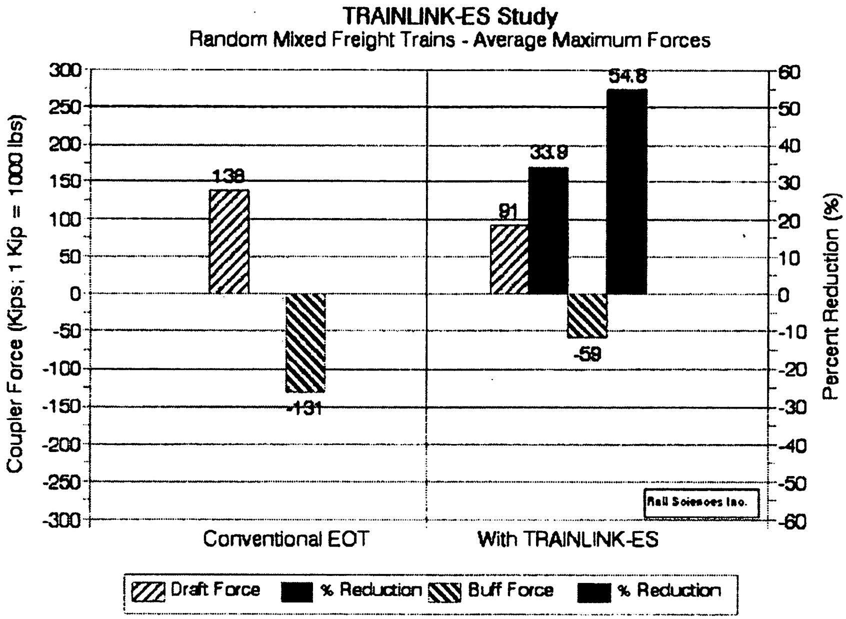


Figure 2

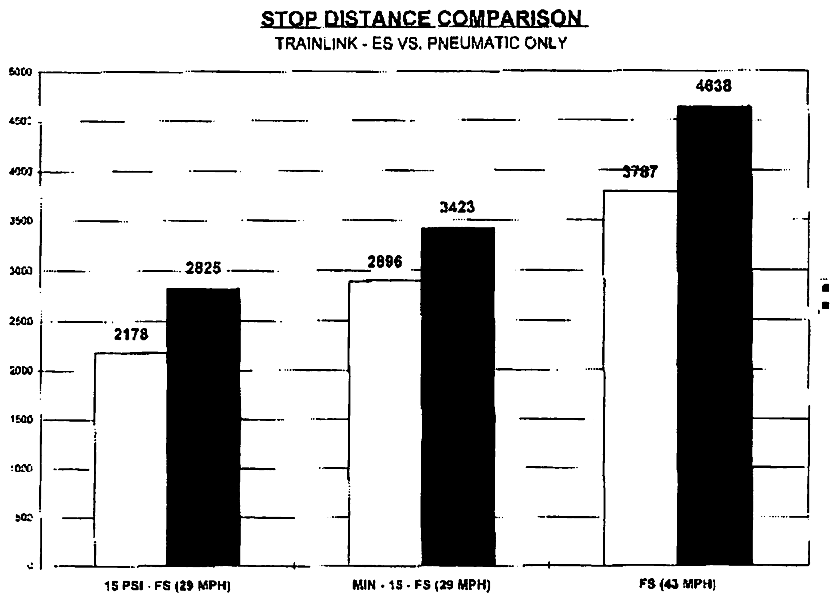
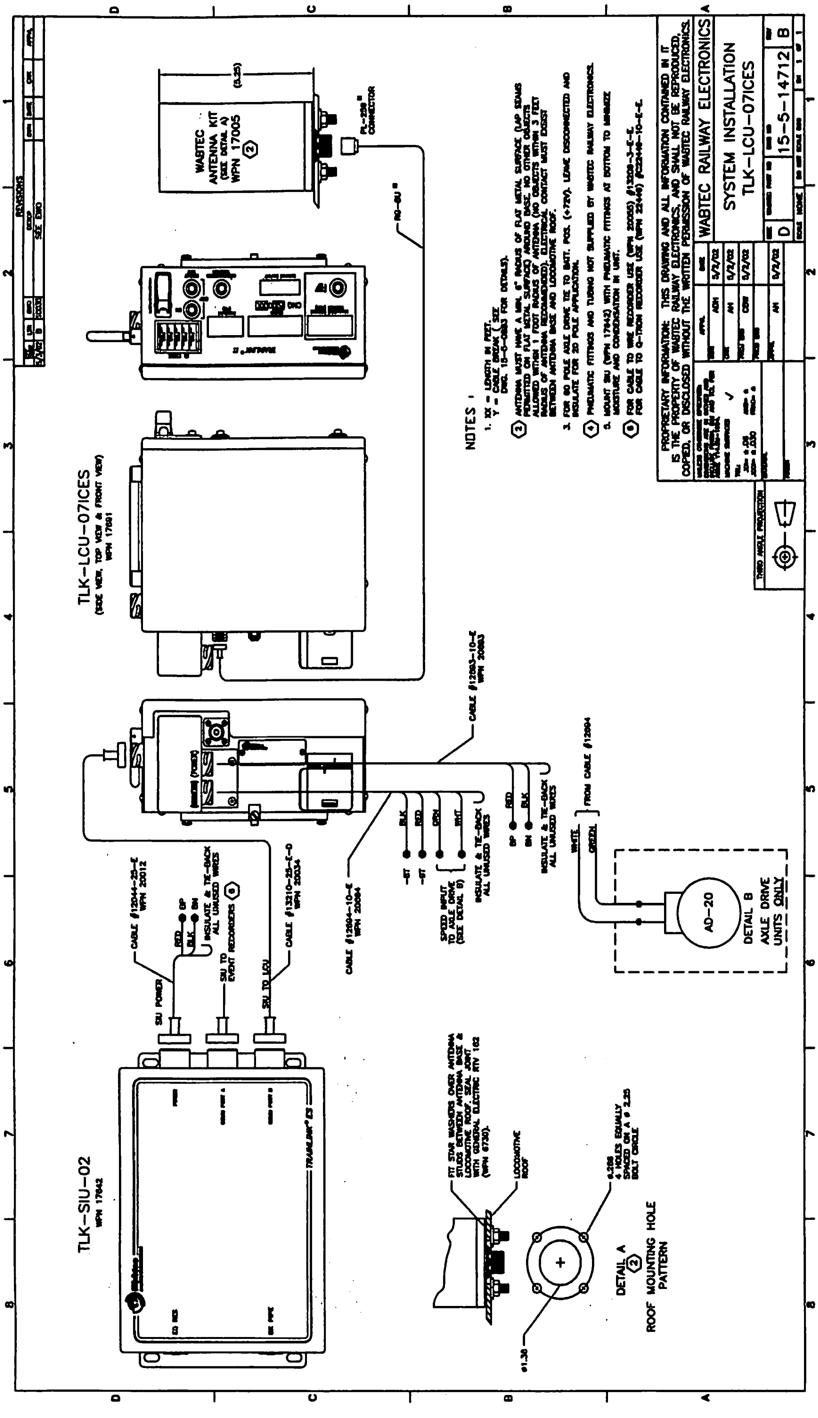


Figure 3

Figure 4



TLK-SIU-02
TLK-LCU-07ICES
WABTEC ANTENNA KIT
WPN 17005
NOTES:
DETAIL A
ROOF MOUNTING HOLE PATTERN
AD-20
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WABTEC RAILWAY ELECTRONICS
SYSTEM INSTALLATION
TLK-LCU-07ICES
15-5-14712

III. HEAD END POWER (HEP) SAFETY ISSUES

Prepared by Ron Bartels,
Manager-Electrical Systems
Via Rail Canada

1. Introduction

Any time we work with electricity or heavy equipment, it is important to understand that there are safety concerns. There are risks of electrical shock or electrocution or of physical injury. Head end power (HEP) systems involve both electricity and heavy equipment so when working with HEP, there are definitely safety concerns. This paper will give the necessary basic information for any railroad industry employee to understand what HEP is and how to work with if safely.

2. What is HEP?

HEP is the equivalent of hotel power on a passenger ship. It provides the electrical energy for passenger car loads such as heating, air conditioning, lighting, food preparation equipment, and various other convenience items and controls.

It begins with the generation of electrical power by an alternator, which may be located in a locomotive at the head end of a train (hence the name "Head End" Power) or in a stationary power generating plant. After the alternator will be protection circuits that will ensure the safety of personnel or minimize equipment damage in case of a major electrical fault. Following the protection circuits is the distribution system, which will ensure that all the loads receive their power safely and that they can be individually isolated without disturbing other loads.

HEP equipment can be found on:

- Locomotives, including alternators, controls,protective devices, and cabling;
- Between locomotives and cars, including receptacles connected together with flexible 3-phase HEP jumpers capable of carrying hundreds of amperes of current; and
- On cars, including cabling, a distribution panel with circuit breakers and transformers to adapt the voltage to suit the loads.

The voltage source is usually 480 VAC, 3-phase, 60 Hz in North America, although some railroads use a 575 VAC source.

When passenger trains are parked and still need to have a source of power, they will usually be connected to a wayside (or shore) power station, which distributes power from the local utility grid. This allows the train operator to shut off or disconnect the locomotive, thereby saving energy costs and reducing air pollution.

A very important safety aspect of the HEP system is the trainline complete (TLC) or integrity loop. It consists of:

- A voltage source, which is usually low voltage AC or DC and is located in either the locomotive or the wayside panel.
- A current path. The current from the source flows through all the HEP trainline jumpers and cables in series, provided they

are all connected. If even only one jumper in the circuit is not connected, no current will flow. The jumpers on the last car are looped back into the adjacent receptacle, providing a path for the current to return to its source location.

- One or more relays: The current returns to the coil of a relay (TLC relay) located in the wayside panel or locomotive where it originated. The loop is completed when all the jumpers are connected and the relay at the source is energized. Until this relay is energized, no 480 V power will be produced and the HEP system will remain non-energized in a safe state.

3. Safety concerns: Why do we have them?

Any time we deal with electricity we are dealing with a potential electrocution hazard. When talking about electricity, the terms voltage and current are frequently used. It is important to understand the difference between the two. Current is the flow of electric charge and it is the one that kills. A sustained current of 100 mA through the heart is enough to kill a person. The voltage is the "force" that pushes the current through the body.

For example, consider two power supplies capable of delivering 50 watts of power. A 5 V supply capable of delivering 10 A is not dangerous because the voltage is so low that it cannot push enough current through the body to be dangerous. However, a 500 V supply capable of supplying only 0.1 A (or 100mA) is definitely very dangerous and potentially fatal.

A frightening statistic from Labour Canada shows that 50% of electrocutions occur on 120 V, which is common household voltage. HEP voltage is typically 480 V. For the same circuit, the HEP source of 480 V will push four times as much current through it as a 120 V source. It is essentially four time as dangerous. It is critical to have respect for it!

The other main safety concerns when working with HEP are potential back injury or slipping and falling when connecting or disconnecting heavy jumper cables. These cables are sometimes difficult to mate and unmate, especially in cold weather or if they have deformed connector heads.

4. Safety concerns: What are the potential hazards?

4.1 Shock or electrocution while connecting or disconnecting a jumper - faulty trainline complete loop.

There are three causes for the trainline complete loop to give a false signal to the TLC relay:

(a) *One or more trainline jumpers is (are) short looped.* See figure 1. Looping a jumper part way through the train gives a trainline complete signal to the TLC relay while the HEP trainlines behind the short loop remain live with 480 V. This is a potential problem with a single bus system only. The split bus system would have no voltage on the HEP trainlines behind the short loop.

(b) *Incorrect train set-up with loco-*

motive and wayside connected. Under certain unauthorized locomotive set-up conditions with a train connected to wayside power, (i.e. a locomotive that is set-up for generating power when it should be set up as a trailing unit) the TLC relay in a wayside panel can be energized by a signal from the locomotive. This allows the wayside panel to produce power when live jumper cables may not be connected in their receptacles.

(C) *Grounds or short circuits in the TLC loop.* These could falsely compete a loop in a car that is not the last one, leaving all cars behind it unprotected by the TLC loop.

4.2 Shock/electrocution from damaged insulation on jumper or carbody cable.

This is not an uncommon accurrence in the railway environment. Flying debris can easily damage unprotected cables.

4.3 Injury from exploding plugs and or receptacles.

Water can enter into damaged or old style fabricated HEP connectors causing a short circuit which can be powerful enough to cause an electrical flash that resembles an explosion. Weak insulation in the connectors can also cause the same phenomenon.

4.4 Shock/electrocution while working on 480 V circuits.

Personnel working on HEP circuits may think they have turned the power off but have not taken the proper precautions to ensure their safety.

4.5 Personal injury while handling or connecting/disconnecting jumper HEP jumpers can be very difficult to connect, especially if they are cold or deformed. Back injury can result while forcing a jumper incorrectly. If the ground conditions are wet or slippery, one can quite easily slip and fall if pushing or pulling too hard on a connector.

5. How do we mitigate risk?

For each potential hazard, there are four approaches to take to mitigate the risk. It is virtually impossible to eliminate the risk because there will always be chances for errors in any system that is designed and built by humans and where humans must make decisions regarding their own safety. The approaches for mitigation are:

a. Common sense
b. Design
c. Procedures and training
d. Maintenance

5.1 To prevent shock/electrocution

a. Common sense:

- Make sure it is not live! Check the circuit, wires, or jumpers with a voltage sensing pen or voltmeter. It is critical to ensure that the testing device is working before using it, so test it first.
- Set up the train properly so that the TLC protection circuits can perform their function. This includes proper locomotive set-up and elimination of short looping.
- Don't allow jumpers to drag or be run over, as this will damage their insulation in the long run and create hazards for those who handle them.

- Don't go near live jumpers and cables if it is not necessary. Someone who is far away from the live circuits stands little chance of injury.

b. Design:

- Split bus vs. single bus. Split bus is almost failsafe regarding the TLC loop. It has two electrically isolated sets of power trainlines running down the length of each car and the TLC loop conductors follow the power cables on each set. Any power cables that are not protected by the TLC loop will not have voltage on them. The single bus system has both sets of power trainlines connected in parallel in each car while the TLC loop conductors follow the power cables on each set. By short looping a single bus system, a portion of the train is not protected by the TLC loop. See figure 1. The major differences between single and split bus systems are that the split bus system is inherently safer but it is more complex and, consequently, more costly. Also, split bus locomotives are not compatible with single bus cars. The single bus system is lower in cost due to its simpler power distribution, its power sources are compatible with both single and split bus cars, but the cars are not compatible with split bus locomotives.
- Create incompatible voltage sources for TLC loops on locomotives and wayside panels such that one source cannot energize the other. Even if a locomotive is improperly set up, it won't be able to energize a TLC relay in a wayside panel. Something as simple as DC/AC differentiation alone is not the solution because DC sources can energize AC relays and vice versa.
- Provide mechanical protection for carbody cables to shield them from flying debris which can damage the insulation. The secondary benefit is that, with protected cables, personnel cannot accidentally come into contact with the cables.
- Follow APTA standards for jumper design to ensure proper intermateability. Molded connectors with adequate insulation between the contacts will virtually eliminate the possibility of water ingress and short circuits between the contacts.
- Apply dead front panels as much as possible in electrical cabinets to minimize the chances of accidental contact with live circuits.

c. Procedures and training:

- Eliminate short looping. Unfortunately, in some railroad operations, short looping is reality. Communication of a short loop situation to all involved is the key to minimizing the risk of coming into contact with a live jumper.
- ISOLATE, LOCKOUT, TAG, TEST, otherwise known as a lockout, tag out procedure. This is a 4-step foolproof

process that must be followed before working on any electrical circuits. 1) Make sure all sources of 480 V power are off. 2) Ensure all power sources cannot be turned ON (Lockout). 3) Tag the locking mechanism so that anybody who approaches the mechanism knows who locked it. All personnel working on a circuit must apply their own locks and tags. 4) Test for voltage with a voltmeter or voltage sensing pen. If you follow these four steps, it is virtually impossible to receive electric shock while working on any circuits.

- Ensure that train set-up procedures on wayside are observed to avoid false TLC loop indications.
- If HEP cables or jumpers are unprotected, assume they are damaged and do not touch them unless no voltage is present.
- Instruct personnel regarding all possible hazards and to avoid the area surrounding live HEP jumper cables when the power is ON.

d. Maintenance:

- Ensure that all HEP trainline cables and connectors are in top shape to avoid need for short looping due to defective plugs or TLC loop conductors.
- Perform regular insulation (megohmmeter) and continuity testing of trainline complete circuits, including jumpers. This will detect short circuits or grounds which may other wise bypass the TLC loop of the train.
- Ensure protective panels/covers are in place as a regular maintenance task and also after maintenance and repair interventions, to prevent accidental contact with live circuits.

5.2 To prevent personal injury

a. Common sense:

- It is important to know one's own limits and physical abilities and even more important not to exceed them, especially when inserting or removing a stubborn HEP jumper.
- Ensure solid footing at all times when exerting forces.
- Don't allow HEP jumpers to drag or be run over so that they maintain their proper shape and don't require undue force to mate or unmate them.

b. Design

- When specifying HEP jumpers and/or receptacles, force the supplier to ensure that the tolerances are at the limits permitted by APTA to ensure easier mating/unmating. Although the tolerances are not wide in the APTA standards, with the outside diameter of the plug at its smallest allowed and the inside diameter of the primary seals at their maximum, mating and unmating forces are reduced.

c. Procedures and training:

- Instruct personnel on the correct and incorrect ways of handling jumper cables, including proper stance, specifically when mating and unmating HEP connectors.

- As a last resort, if a HEP connector is difficult to insert, sparingly spray a silicone lubricant on the mating areas of the plug only. It makes inserting the connector easier. Too much silicone can cause accumulation of foreign matter that can eventually make it more difficult to mate or unmate the connector or cause short circuits.

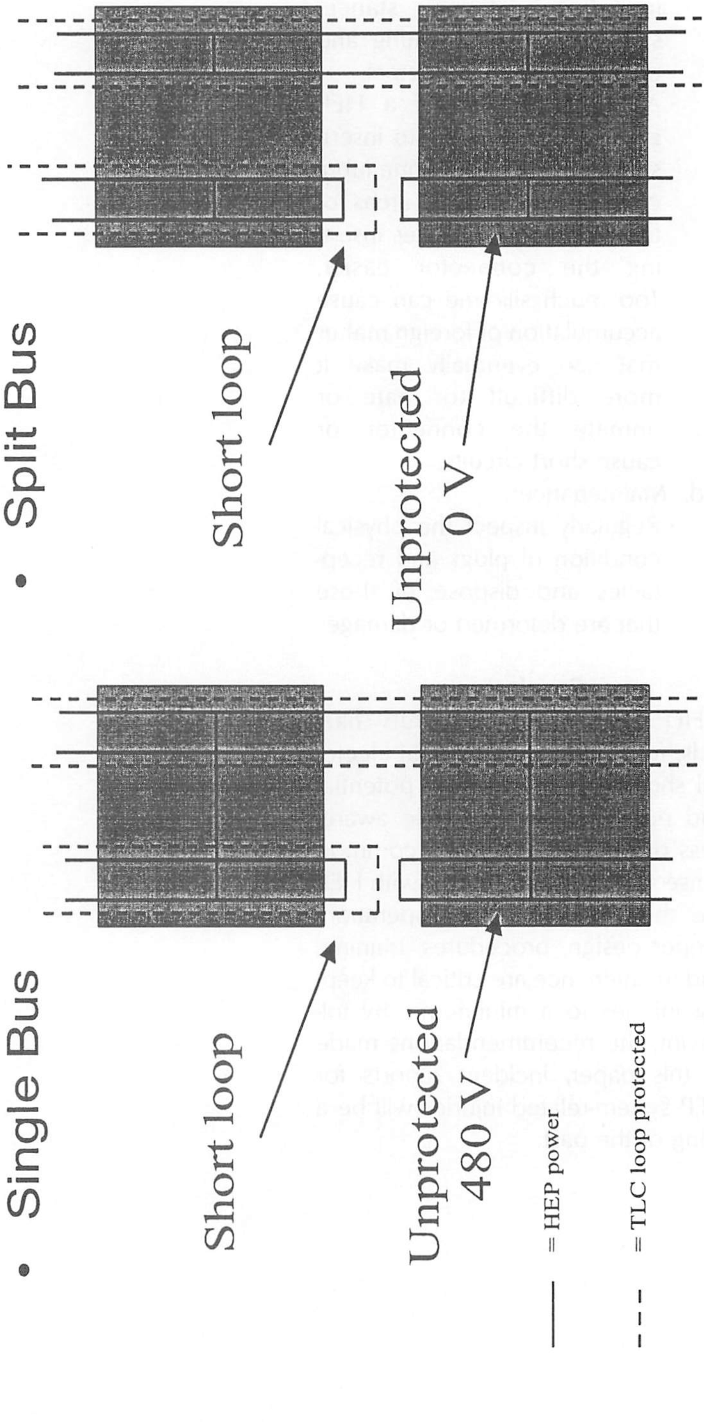
d. Maintenance:

- Regularly inspect the physical condition of plugs and receptacles and dispose of those that are deformed or damage.

Conclusion

HEP circuits present safety hazards, from the standpoints of electrical shock or electrocution potential and personal injury. While awareness of the hazards and a common sense approach to working with HEP are the keys to a safe operation, proper design, procedures, training, and maintenance are critical to keeping injuries to a minimum. By following the recommendations made in this paper, incident reports for HEP system-related injuries will be a thing of the past.

Fig. 1 Short looping: Single vs. Split Bus

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IV. FUEL SAVINGS USING LOCOMOTIVE CONSIST MANAGEMENT

Prepared by Randall Slomski, Customer Program Manager, General Electric Transportation Systems

Introduction

This paper provides an introduction and overview of the concept of locomotive horsepower management. This concept utilizes microprocessor technology to manage the horsepower output of individual locomotives with a consist, so as to maximize fuel efficiency of the entire consist.

The Basics

Freight trains are almost universally hauled by multiple diesel-electric locomotive ensembles or "consists" which may be placed together at the front or rear of the train, or distributed at intervals among the freight cars. A single crew on the lead locomotive coordinates the throttle and brake commands for the entire train. Locomotive throttles, for historical reasons, are set up to have 9 (Idle + 8) discrete settings, or notches, corresponding to different levels of horsepower output. The fuel efficiency of the diesel engine is different at the different notch settings, typically with higher fuel efficiency at higher notch settings. Figure 1 shows a typical fuel consumption curve for a diesel engine. On an individual basis, it can be seen that the diesel engine has a better fuel efficiency, i.e. consumes less fuel per HP-hr produced, at higher notches.

Considering the Consist "Total HP"

If we consider a multiple locomotive consist as one tractive-effort producing entity and combine the horsepower generated by each locomotive at each notch position, we can look at the total fuel efficiency for the consist. As conventionally coordinated, each locomotive in "trail" is operated at the same notch as the "lead" locomotive, set by the operator. As foretold by the individual engine fuel consumption curve, operating all locomotives in the same notch is almost always the most efficient at high power (notches 7/8). But when less than full power is required from the overall consist, e.g. notches 3-6, there is an opportunity to increase overall consist fuel efficiency by selectively operating the individual locomotives in the consist at different notches.

For example, with a consist of three 4400 HP locomotives, the horsepower generated by having all three locomotive in notch 4 is 4650 hp. The "un-optimized" fuel consumption for these three locomotive in notch 4 is approximately 0.3534 lbs/HP-hr. If we apply logic to select different notch setting for the individual locomotives in the consist, in this case notch 8, notch 1 and notch 1, we can still obtain at least 4650 hp from the consist, but at a fuel consumption of only 0.3350 lbs/HP-hr. This is an approximate 5.5% saving in fuel at this notch. Figure 2 shows one possible set of "virtual" notch combinations that could be selected to improve the consist fuel efficiency. Note the distinct savings in the intermediate virtual notch setting of 3-6.

Figure 3 is a plot of the efficiency curves for standard un-optimized and, optimized notch settings (as depicted in Figure 2) for a three locomotive consist. Integrating these instantaneous savings over an entire duty cycle provides an approximate 1% to 3% improvement in total efficiency.

Additional savings can be obtained when the consist is dispatched with extra locomotives (increased hp/trailing ton) to provide enough adhesion on the ruling (steepest) grade on the mission. When not on the ruling grade, the engineer will be operating at lower notch levels for longer periods. This provides additional opportunity for savings.

Consist Management System

However, operating the locomotives in a consist at different notch settings would be operationally difficult to implement without having each locomotive isolated and separate operators on each locomotive. Even then, coordination between operators would be difficult, to say the least.

To solve this operational problem, and therefore obtain the fuel savings, a microprocessor based consist management system can be added to the individual locomotives. This system uses various controls to independently set the notch position on each locomotive. This allows for the equivalent consist horsepower to be automatically divided between the operating locomotives in the most efficient manner so as to minimize operator intervention and maximize fuel efficiency.

Fuel and MWhr balancing

One situation that could arise from running separate locomotives in a consist at different notch levels is that fuel consumption, and therefore MWHr generation, may not be equal across all locomotives. MWHr balancing may be a long-term concern, but consist fuel balancing is a definite mission specific concern. A consist management system should employ algorithms that address fuel balancing across the consist. Basic systems balance fuel by the selection of notch setting on the lead versus trail locomotives across the locomotives' duty cycle. In some notches the lead is at higher horsepower and in some notches the trail units are at higher horsepower operation, thus providing a rough balancing function. Advanced systems might use two-way communications between the locomotives to obtain real time fuel measurements from the locomotive fuel gauges to ensure fuel balancing and optimize consumption.

Crew training

A definite requirement of any fuel optimization system is crew operational training. Untrained crews might think that there is a problem with a locomotive if the consist management system commands the lead locomotive to a different notch setting then what the operator called for. Once trained on how the system functions, operators will be aware that even though the locomotive that they are in is not operating at the called for notch, they are still producing the equivalent horsepower for the selected notch setting.

Conclusion

The concept of consist management shows definite potential to provide 1% to 3% fuel savings for railroads. On-board microprocessor technology is advancing rapidly to bring this concept into real time application.

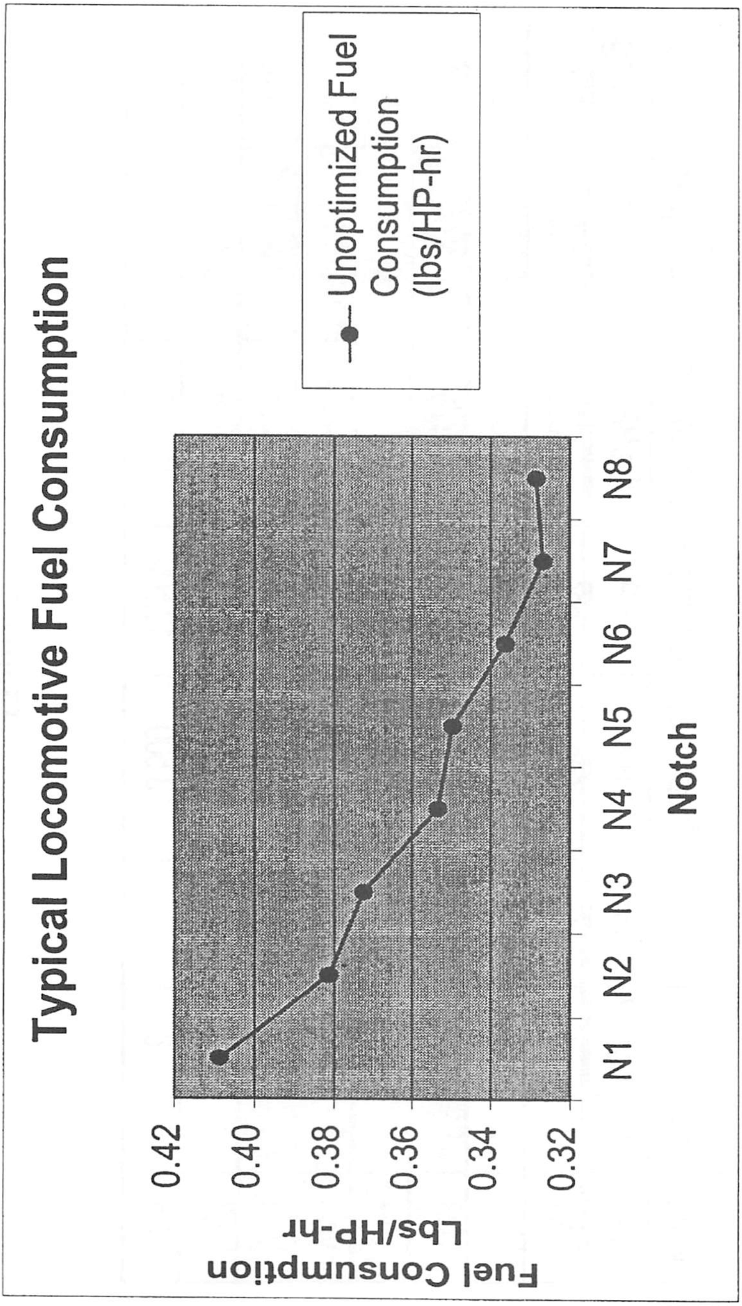
Typical Locomotive Fuel Consumption
Unoptimized Fuel Consumption (lbs/HP-hr)
Fuel Consumption Lbs/HP-hr
0.42
0.40
0.38
0.36
0.34
0.32
N1
N2
N3
N4
N5
N6
N7
N8
Notch

Figure 1

Virtual Notch	Loco 1	Loco 2	Loco 3	Unoptimized HP	Optimized HP	Unoptimized Fuel Consumption (lbs/HP-hr)	Optimized Fuel Consumption (lbs/HP-hr)	% Fuel Savings
VN1	1	1	1	600	600	0.4088	0.4088	0.0%
VN2	2	2	2	1,500	1,500	0.3813	0.3813	0.0%
VN3	5	2	2	3,120	3,220	0.3724	0.3595	3.6%
VN4	8	1	1	4,650	4,900	0.3534	0.3350	5.5%
VN5	1	7	7	6,660	7,520	0.3497	0.3288	6.3%
VN6	1	8	8	8,820	9,200	0.3363	0.3301	1.9%
VN7	7	7	7	10,980	10,980	0.3266	0.3266	0.0%
VN8	8	8	8	13,500	13,500	0.3284	0.3284	0.0%

Figure 2

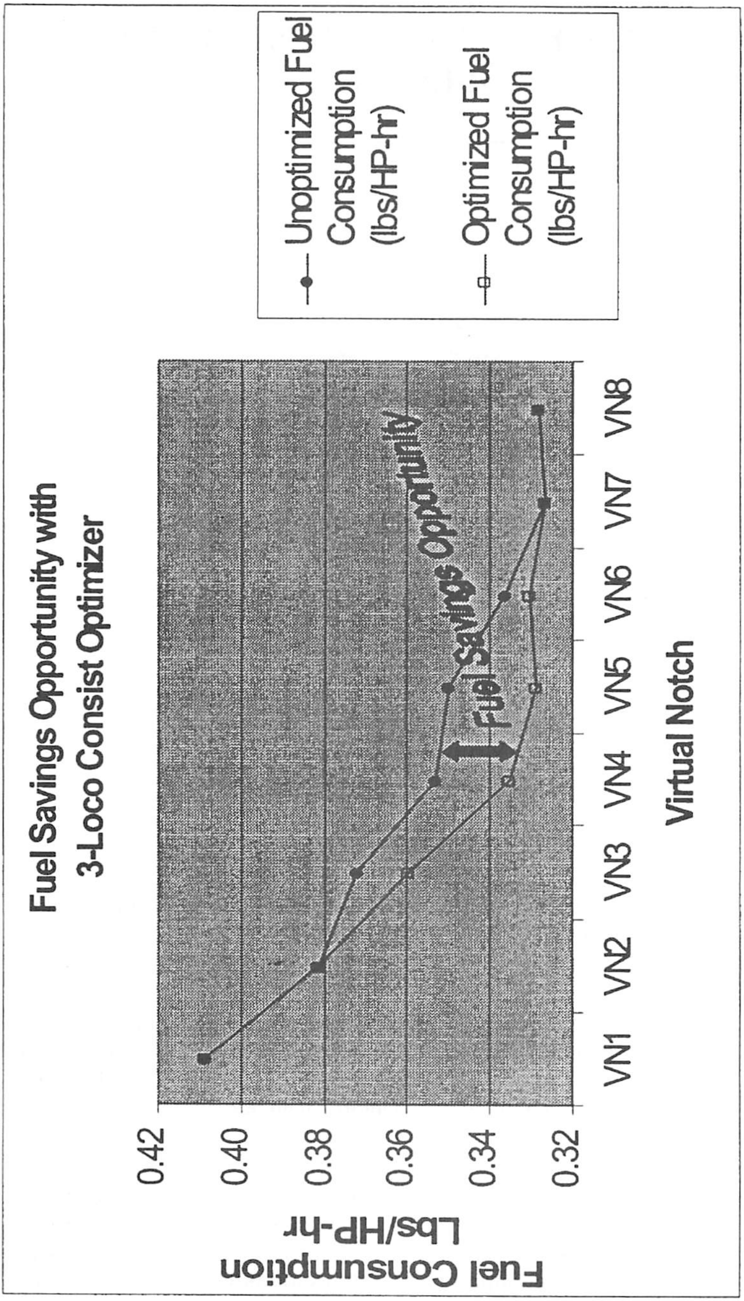
Fuel Savings Opportunity with
3-Loco Consist Optimizer
Fuel Consumption
Lbs/HP-hr
0.42
0.40
0.38
0.36
0.34
0.32
VN1 VN2 VN3 VN4 VN5 VN6 VN7 VN8
Virtual Notch
Fuel Savings Opportunity
Unoptimized Fuel Consumption (lbs/HP-hr)
Optimized Fuel Consumption (lbs/HP-hr)

Figure 3

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

TUESDAY, SEPTEMBER 23, 2003
3:45 P.M.

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Dennis Nott
VP - Sales & Marketing
Motive Power, Inc.
Boise, ID

Vice Chairman
Jack Kuhns
VP-Sales
JMA Railway Supply
Ponte Vedra Beach, FL

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PERSONAL HISTORY

Dennis L. Nott

Dennis L. Nott, Chairman of the LMOA Committee on Diesel Mechanical Maintenance, was born on March 26, 1951, in Charles City, Iowa. He is a graduate of Iowa State University with a BS degree in Construction Engineering.

Dennis began his railroad career with Morrison-Knudsen Co., Inc., in 1974. He has also worked at Conrail and the Denver & Rio Grande Western in his career.

Currently, Dennis is Vice President of Sales and Marketing at MotivePower, Inc., a Wabtec Company. In addition to his responsibilities for all locomotive sales and marketing at MotivePower, he is responsible for all locomotive contract maintenance and the service/warranty department.

Dennis joined the LMOA Diesel Mechanical Maintenance Committee in 1996. He received the LMOA "MVP" award for his services on the committee in 2001.

Dennis and his wife Sarah have been married for 29 years and they reside in Boise, Idaho, with their two children Maggie, 18, and Adam, 15.

THE LMOA DIESEL MECHANICAL MAINTENANCE COMMITTEE,

WISHES TO EXPRESS THEIR SINCERE APPRECIATION TO THE FOLLOWING COMPANY FOR HOSTING OUR COMMITTEE MEETING AND SHOP TOUR IN 2003:

METROLINK / SCRRA
LOS ANGELES, CA
FEBRUARY 2003

I. TRAINING 60/30 IMPACT NOW & BEYOND

Prepared by
George King,
Chief Mechanical Officer
St. Lawrence & Atlantic

60/30: What does it mean and what is its impact on railway mechanical operations?

Congress enacted and President Bush signed into Law the "Railroad Retirement and Survivors Improvement Act" on December 21, 2001. This legislation made sweeping changes to the existing Railroad Retirement Act both financially and in the context of retirement structure.

The aspect of the revised Act that affects railroad mechanical operations is the earlier retirement age at which persons can leave employment with full benefits. The prior requirement was 62 years of age with thirty years of service to be entitled to full benefits. Under the 2001 Improvement Act the age requirement has been lowered to 60 years of age.

What does this change mean to the railroad locomotive maintenance capability throughout the industry? Is there an impact with the passage of this legislation?

To start with we will look at the historical labor trends in the employment category by Class 1, 2 and 3 Carriers in the United States. In addition, we will review what percentage of the workforce would be eligible for retirement today.

Railroad Employment Statistics (Total):

1963	1,011,000
1981	503,000
2000	246,000

Total railroad employment declined (58%) during a 29-year period. A number of factors allowed for employment reduction.

The major influences were:

- Railroad mergers resulting in duplicate shops and staffing.
- Labor agreement changes.
- Advances in technologies throughout the industry.
- Increased productivity and operating efficiencies.
- Deregulation of the industry in the early 1980's.

Several dynamics were involved in the reduction of locomotive maintenance work force levels:

- Evolving technologies such as transistorized cards and modules.
- Improved oil engine and support system designs.
- Microprocessor application to locomotives.
- Changes in maintenance activities.
- Fleet replacement and downsizing due to improved tonnage movement capabilities.

During 1970's and early 1980's there was little new hiring, as a glut of personnel existed in maintenance of locomotive activities. The practice of apprenticing new hire trainees was drastically reduced or eliminated on many railroads during the 1980's. The effects of reduced hires and training would not show up for a decade or more in the industry. The 1990's saw a modest surge of shop based hiring on many carriers due to attrition and increased business levels. In many cases new hires with mechanical and electrical skills (non-locomotive) were brought on board to meet the maintenance demand.

The chart below shows statistics on railroad employment by age group and service life as gleaned from the most recent published reporting year (2000). These are Railroad Retirement Board 2000 statistics:

Age group	% Total labor
50-54	19.5%
55-59	12.3%
60-64	5.2%

Seventeen percent of all railroad employees have 30 years plus of service time. Thirty-nine percent of railroad employees have 20 to 29 years of service.

The average age of railroad employees is 47.

What can be seen from these 2000 labor statistics is that **a potential exists for 37% of the work force to retire under the new Act in the next six years.** That is a tremendous number to cope with in the maintenance environment.

What measures are being implemented to respond to 60/30?

- **Staff replacement.**

How does the industry attract new hires in the locomotive field? There have been many societal changes in the last 25 years that are impacting the traditional hiring process. A larger percentage of the population elects to purse higher education goals. The computer software and management industry has attracted many people who might have otherwise entered into railroad trades. Newer generations do not have the desire to work the off shifts or do without traditional weekends off. It is hard to attract a new hire with the thought of Tuesday-Wednesday off while working 15:00-23:00 on the service track. They can work cleaner and higher paying jobs in many instances. In the past the railroad industry has been an employer of several generations from within the same family. With the decline of employment opportunities and competing job markets, that has changed. The challenge is to attract the younger generation to jobs that are not appealing in nature to a great number of them.

- **Attrition based on synergies or efficiencies**

Locomotive fleet reductions have been achieved through increased availability and tonnage capability as demonstrated by the latest models. Improvements in that area would require less maintenance personnel in total to maintain the fleet. That in itself would go toward mitigating some worker loss but would not address the overall impact of 60/30 on staffing levels.

- **Increased training for the existing force**

In-house training through apprenticeship programs that have been reintroduced by the major carriers has been in place for the last seven to eight years. Also, the large railroads have expanded training at their respective education facilities to cope with technology. One major carrier has reduced outsourcing of its training centers to concentrate on improving skill levels of its own employees. Other methods of training include internet based instruction and plug-in software programs that assist the locomotive maintainer in the performance of duty.

- **Increased contract maintenance oversight**

Many railroads have entered into agreements with third parties to maintain locomotives. This tends to be based on reliability and availability guarantees that are agreed upon for the fleet designated. The contractor uses the existing locomotive labor staff, vendor supervision, maintenance policies and material sourcing to meet the contract parameters. In several of these agreements it is stipulated that the maintenance contractor must provide locomotive maintenance training for the crafts. That shifts the burden from the carrier to the vendor. Does shifting the responsibility do anything about the larger issue of retirement migration? At the end of the day there needs to be a sufficient number of well trained trades people to ensure customer satisfaction. Merely contracting out maintenance oversight does not necessarily ensure adequate locomotive maintenance.

- **Hiring Strategies**

Many roads are not hiring in any numbers today. In fact layoffs have been occurring on a periodic basis as the world economy slows, especially that of North America. Smaller railroads hire on a "just in time" basis, meaning that the retiree has left or is leaving employment before a replacement is on board. For the most part, short term economics dictate that approach. In the long run it is detrimental to locomotive performance. The larger carriers tend to look forward and judge when hiring must be done to ensure a smooth transition in the workplace. But they too are under the same economic constraints as the smaller employees.

Training

On the majority of railroads, no in-house, full time training facilities with instructors exist. This leads to either no formal training or to outsourcing for those type of activities. All too often locomotive assigned personnel make do with little or no training to perform tasks. Federal regulations require carriers to have qualified employees performing service. It is up to the railway to determine what constitutes a qualified employee.

- **Apprentice programs**

Apprenticeship programs result in short-term reduction of shop craft productivity. The pairing of a journeyman who mentors the trainee reduces overall production when staffing levels are reviewed. This changes after the trainee has completed the program and is promoted to journeyman level. A number of carriers have reintroduced the apprenticeship program in conjunction with formal education techniques to speed up the learning curve. Smaller roads generally do not have the human resources to implement an apprenticeship program of any substantial substance.

- **Third party contractor**

In the regional and short line world where funds are restricted and formal training is non-existent many choose to use third party instructional firms. There are several to choose from who can educate in all shop disciplines. Services are offered on site and at off site facilities dependent on the customer needs.

The Genesee & Wyoming system of railroads has a very aggressive mechanical training program in place using a third party training firm. The goals are to have all mechanical employees attend and pass programs during the next three years. The disciplines include air brake troubleshooting, diesel engine maintenance and repair, alignment of rotating equipment and electrical troubleshooting and repair. The costs involved (financial and resource allocation) are not inconsequential. However, senior management fully supports and funds training to improve safety and skill levels for all employees.

The Southern California Regional Rail Authority (SCRRA) utilizes a comprehensive training program developed in conjunction with a mechanical services contractor. The training program covers locomotive inspection, car exterior inspection, car interior inspection, air brake theory, Class 1 air test, single car air test, and automatic train stop (ATS). These modules demonstrate "hands on" training and classroom instruction. Random practical evaluations are conducted to validate the training requirements.

- **In-house programs**

Many railroads are turning to a team leader/lead man/technical assessment position to aid in diagnosing and troubleshooting defective conditions.

- **Correspondence courses**

The Railway Educational Bureau offers many correspondence-based courses that improve skill levels of tradesmen. This type of training involves independent study on the part of the employee. With this type of training there may be wage and or labor agreement issues that have to be worked through.

- **Fee for service training centers**

Several of the major carriers have in-house training facilities and programs, which at times may be offered to the industry for a set fee. Openings are dependent upon internal demand by the carrier. Many smaller railroads use this environment to enhance skill levels with their mechanical forces.

- **Cascading of locomotive types**

As the Class 1 railroads purchase the newest generation of locomotives they are releasing numerous locomotives that have been considered the standard to which other types are compared. Examples of this are the many EMD Dash 2 and GE-7 and -8 locomotives that are being released from Class 1 service and are now finding homes on the smaller roads. This poses training challenges for the roads acquiring these types of units, as this technology may be more advanced than the existing fleet make-up. The flip side of this is the challenge faced by the major carriers in retraining their forces to maintain locomotives equipped with the newest generation of microprocessors, electric fuel control, electronic air brake and AC traction motors.

"Is the Railway Industry ready for the challenge"

The mechanical service teams throughout the railway industry are looking for across-the-board solutions to the aging work force. What are your insights and suggestions as to how this matter can be best solved? Does the potential exist for an industry-wide standardization of training for shop forces?

60/30 has an impact on all of us. What we put in place today to address losing 33% of the workforce will decide if detrimental service issues arise.

II. CONDITION BASED MAINTENANCE, PRACTICAL APPROACHES AND TECHNIQUES

Prepared by David K. Miller, Manager, Mechanical Engineering I, Union Pacific Railroad

The cost of maintenance is one of the largest contributors to the life cycle cost of an asset. The maintenance cost can also be a significant opportunity to decrease the overall cost of operation, and thus create value by controlling and optimizing the utilization of material, manpower and the asset itself. The strategy that dictates the maintenance program determines the level of control that a company will have over its resources to maintain the asset. Maintenance strategy can be categorized into three approaches: reactive, preventative and reliability centered. Each of these strategies differs in their techniques as well as cost.

Maintenance strategies

A reactive maintenance strategy employs the principle of performing maintenance activity when the asset can no longer perform its desired function. Repair is essentially the only maintenance activity that takes place. There is not an effort to engage in activity that will preclude failure during the life of the asset. This approach will create a relatively low cost to operate the asset until failure occurs. Once this happens, the failure event can have a significant cost to repair, and have a significant, undesirable impact on the availability of the asset.

Preventative maintenance utilizes the execution of periodic maintenance events to decrease the likelihood of failure. Many of these activities are scheduled lubrication, filter replacements and visual inspections. The approach is the most widely used in maintenance today, and has shown to be effective in reducing failures and avoiding significant downtime events. The drawback to this approach is that it is no effort to actively manage risk and a majority of the resources expended are in low yield activity. The likelihood of finding a condition that is in need of repair is a low percentage of the inspections performed. Many of the components are replaced on a schedule. The risk at the time of replacement is not known or quantified. Much of the activity that does take place is usually at the manufacturer's recommended interval. The approach is effective in obtaining the desired result; however the cost to engage in such activity is high, and significant opportunity for improvement exists in that most components removed do have a relatively low risk of failure.

Reliability centered maintenance is quantifying and understanding the risk of failure and using this knowledge on an asset by asset basis to tailor the maintenance activity appropriately. The maintainer must determine what level of risk is acceptable or economically justified and the maintenance program must be designed to manage that risk.

There are a number of ways risk can be assessed. Developing risk of failure vs. age functions for each component or assembly is a common method. These models can be developed to determine the economic optimum for component replacement if the cost of failure and the cost of replacement are known. This method is explained by Nott in "Are We Ready for Reliability Centered Maintenance?" Another method that can be employed to assess risks is by engaging in condition-based maintenance. Condition based maintenance is a sublet of reliability centered maintenance in that it provides alternative techniques to assess risk. A periodic, non destructive risk assessment of the asset is performed, usually while the asset is under normal operating or test conditions to determine the risk level and decide if continuing operation is economically justified. The decision to perform maintenance, replace components or make adjustments is done only after the condition is assessed and the condition of the component(s) is known. This approach will allow the maintainer to optimize the replacement of the component only when the potential failure is identified. In the book "Reliability Centered Maintenance," John Moubray stipulates an important aspect for consideration when designing a condition based maintenance program: "A potential failure is an identifiable condition which indicates that a functional failure is either about to occur or in the process of occurring." For a condition based maintenance program to be successful, the potential failures must be identified and acted upon before the functional failure occurs.

To illustrate this difference in approach to risk assessment, consider the following example. A maintainer may determine that the economically optimal level of risk of failure for a particular component is five percent risk of failure. Using a purely risk vs. age base model, the component removal can be accomplished when the age of the component reaches the five percent risk of failure age. However, considering the overall population of the assets managed, this also means that ninety five percent of the components removed under this program will be removed with some usable life remaining in them. Condition based maintenance will allow the maintainer to determine the level of risk during the periodic assessment. This will allow the maintainer to discriminate the low risk components from the high risk components, provided the potential failure is identifiable. The low risk components could then be allowed to continue operation until the next periodic assessment when another evaluation and decision whether to continue operation will take place. This strategy will allow the maintainer to replace components only just before they have reached the end of their useful life. Economically, this approach will allow the user to perform significant maintenance activity only when it is needed and have a minimal impact on the utilization of the asset.

In reality, most locomotive maintenance programs will employ several, if not all of these strategies in executing their daily maintenance activities. In some cases there may be no potential failure that is detectable, or the time interval between the potential failure and the functional failure may be shorter than the interval in which the condition assessments take place. Therefore, the use of reactive and preventative programs should not be abandoned altogether. The suitability of a maintenance strategy must be assessed on a failure mode by failure mode basis to determine if that strategy will be appropriate for a given situation.

Reliability centered maintenance has found practical application because of improved failure reporting, risk assessment techniques, and an OEM effort to design and manufacture a product with a greater focus on reliability. This paper is a discussion of several available condition based maintenance techniques and processes in use today by several railroads.

The techniques used vary by the type of equipment being monitored and the available means to assess that equipment. The examples and techniques shown in the paper are intended to give a brief overview and provide some examples of how these techniques can be used to have a desirable effect on locomotive maintenance. These examples do not encompass all possible condition based maintenance techniques that can be used on locomotives. For the railroads that use these methodologies, there are slight variations in techniques and the systems used to collect and analyze the data.

Vibration analysis

One of the most widely used systems used to monitor rotating machinery is a vibration analysis system. Vibration analysis works because all rotating machinery vibrates. Even well balanced machines will create some form of vibration during their normal operation. These vibrations will take the form of complex periodic waveforms. In most machinery, these waveforms are produced from the sum of all the vibrations produced from the moving components within the machine. A relatively simple machine is capable of producing a complex vibration pattern. The vibration pattern can be captured in a number of ways. Sensors that are capable of measuring displacement, velocity or acceleration are commonly used to determine the vibration vs. time waveform. The output of the sensors is collected by a data acquisition system and displayed or analyzed using a computer. Analyzing the periodic, time vs. vibration waveform by itself is difficult because that waveform is the sum of all the vibrations coming from the machine. If a Fourier transform is performed on the time vs. vibration waveform, the components of the complex waveform can be determined. The Fourier transform will change the waveform from a vibration vs. time to amplitude vs. frequency of vibration. The amplitude vs. frequency function is referred to as a spectrum. If the running speed and the internal makeup of the machine are known, the vibration level of the various components can be determined from examining and interpreting the spectrum.

To use vibration analysis as a maintenance tool, acceptable levels of vibration at various frequencies must be determined. One way to accomplish this is to collect data in a similar fashion from several machines that are known to be in good working order and average them together. This average spectrum is then used on subsequent vibration readings to determine the amount of deviation from the average a vibration from a component is producing. This deviation from the average and its nature in amplitude and frequency can reveal the condition of the machine.

As components in the machine wear or conditions that predict failure materialize, the vibration levels will change. The amount of change can be determined by examining the vibration spectrum. Detailed knowledge of the machine is required to analyze and interpret the patterns found in the spectrum. The speed of operation, gear ratios, and bearing types must be known to determine at what speeds expected vibrations will occur. Changes in these patterns will show what components are experiencing wear or other conditions that would predict failure. The severity of the problem is determined by the amount of change between the measured spectrum and the expected or average spectrum. Many of the details of vibration analysis theory and methods of manual analysis, as summarized here, can be found in "Introduction to Machinery Vibration" by White.

The following is an example of using a vibration analysis system to determine the risk level in an EMD turbocharging system. The system used has a portable data collector, accelerator and software to store and analyze the data. The process to collect the data is simplified to work in a railroad operating environment. The user loads the data collector with the information necessary to perform the test. This information is organized into locomotive specific routes. The route contains all of the test setup information for the data collector such as what frequencies to collect data, how much data to collect and what locomotive is associated with that test. Once the data collector is loaded, the user then performs the test on the locomotive. To accomplish this the locomotive must be setup in a manner similar to that in which the average data was collected. For an EMD turbocharged engine, one way to analyze the turbo charger and associated gear train is to run the engine at throttle notch eight with no load applied to the main alternator. This configuration will adequately stress the gear train and will keep the turbo charger clutch system engaged. If the overriding clutch is engaged, the rotational rate of the turbocharger shaft and gears in the gear train can easily be determined by knowing the engine speed and the gear ratio between the crankshaft and the turbocharger shaft. Once the engine speed has stabilized, the accelerometer can be attached to the turbocharger and the data can be collected. After the data collection has been completed, the data collector is attached to the computer and the data is transferred to the software for analysis. Shown in Figure 1 are a typical test data and the average data for an EMD turbocharger.

Once the data is collected, analyzing it to determine if faults exist is the next step. Some programs require that a trained analyst examine the test data and determine the nature and severity of problems that may exist. Some vibration programs have automated analysis systems that will highlight and isolate faults and determine their severity. In this example, the software's expert system will use the spectrum in Figure 1 and an average spectrum to develop specific diagnostic information and repair recommendations based on the nature and severity of the deviation present. The output of a typical analysis system is shown in Figure 2.

The diagnosis and recommendations are tailored to specifically analyze an EMD turbocharger and provide the recommendations in a customized language specifically for this application. The output of the analysis references internal maintenance instructions as well as detailed tasks that need to be completed to further troubleshoot or repair a problem, as necessary.

Shown in Figure 3 is a spectrum from a test performed on an EMD 710 engine in an SD60 locomotive during a periodic inspection. Based from this spectrum, the computer system offered the recommendations as indicated in Figure 4.

In the case of this engine, the recommendation was to replace the turbocharger because of a significant imbalance in the rotor shaft. This turbocharger was removed from service and a detailed teardown was performed. As shown in Figure 5, a failed turbine blade was found.

If this condition had been allowed to persist, the imbalance would have accelerated the rotor bearing wear rate and a premature failure of the turbocharger shaft would have resulted. That failure would have caused an in service failure event as well as an unscheduled repair event of the locomotive. Instead, the turbocharger was removed during the scheduled periodic inspection in which the test was performed, and the unscheduled repair event and catastrophic failure of the rotor shaft was avoided. The net result is that utilization of the locomotive was optimized and the failure event was avoided altogether.

Engine analysis

A method that can be employed to assess the condition of an engine is the use of engine analysis. Engine analysis can be best described as a performance assessment of each cylinder in the engine. Conditions that predict failure can be determined and the overall performance of the engine can be assessed. To accomplish this the in-cylinder pressure and cylinder head vibration are measured in phase with the crankshaft rotation. Measuring the in-cylinder pressure vs. crankshaft angle will allow the user to determine the peak firing pressure, peak firing pressure angle relative to top dead center, and an in-cylinder pressure vs. crankshaft angle curve for each cylinder can be obtained. The cylinder head vibration measurement will allow the user to determine and quantify the injection timing, the valve timing, the condition of the lash adjusters, presence of liner scuffing, piston ring performance and if bearing wear is present in the connecting rod bearing or the wrist pin bearing. The performance of each cylinder is independently collected and analyzed. Using all of these parameters together will allow an assessment of the overall condition of the engine to be performed. A typical engine analysis program consists of periodically testing all the cylinders in an engine and determining if conditions exist that would predict failure. Examples of these conditions and how they are manifested in an engine analysis program are contained in "Diesel Engine Analysis with Recip Trap" from Dynalco Controls. The equipment needed to perform this analysis technique consists of a crankshaft position instrumentation system, a data collection system, and a computer program to store, organize and analyze the data collected.

The crankshaft position instrumentation system is needed to provide crankshaft rotational position information to the data collection system. The crankshaft position input data is important because all of the measurements are phased relative to top dead center for the cylinder being analyzed. There are several methods by which the crankshaft position can be determined. Magnetic pickups, encoders, and light sensitive sensors are commonly used instruments to establish a once per turn reference for the crankshaft. This signal is then communicated to the data collector via a wireless data radio or a hard-wired cable.

The data collection system consists of a data collector and the various sensors. The data collector is capable of multiple input channels and the crankshaft reference. The pressure transducer, accelerometer, and ultrasonic microphone input signals are simultaneously sampled by the data collector. Most systems used for engine analysis provide a screen in which a signal vs. crank angle graph can be viewed while data collection is taking place.

The pressure transducer must be exposed to combustion gases that reside in the cylinder while it is under typical operating conditions. To accomplish this, the pressure relief needle valves are removed and temporarily replaced with an indicator valve. An indicator valve fits into the pressure relief valve housing and provides a petcock arrangement that can be opened and closed outside of the engine. There is also a threaded adapter that has matching threads on the pressure transducer. Once the indicator valve is installed in the engine and the pressure transducer is attached to the indicator valve, the flow of combustion gases to the pressure transducer can be controlled by the petcock on the indicator valve. This will allow the user to apply the pressure transducer, expose it to combustion gases by opening the petcock, collect the necessary data, close the petcock, and safely remove the pressure transducer.

Two separate vibration sensors are used to collect vibration data in several frequency ranges. A standard industrial accelerometer is used to collect vibration in low, mid frequency ranges, and an ultrasonic microphone is used to collect vibrations in a higher frequency range. The accelerometer can be attached to the compression relief valve housing by a magnet or a clamp and the ultrasonic microphone is firmly held against the pressure transducer.

To standardize the data collection procedure and make valid comparisons between different engines a standard test configuration is used. A typical configuration is testing an engine during a standard load test.

The data that can be collected using this system is used to assess individual cylinders as well as the engine as a whole. To assess the overall engine, all of the cylinder pressures must be considered and analyzed to determine the pressure balance of the engine. The balance of the engine has a direct impact on the torsional loading the crankshaft experiences. A wide variation in cylinder pressures will result in a large crankshaft torque variation from cycle to cycle. This variation will increase the cyclic stress that the crankshaft is subjected to and potentially decrease the life of the crankshaft because of higher cyclic stress loads. The pressure variation can also be used to infer the temperature variation between cylinders. A larger temperature variation can cause uneven cylinder head temperatures and create a situation where a power assembly failure is more likely in one cylinder than another cylinder in the same engine. An example of assessing the combustion performance of an engine is shown in Figure 7. This plot represents the pressure curves from all the cylinders in an engine in firing order. This plot can be used to determine which cylinders are in need of adjustment or repair.

The vibration vs. crankshaft angle graphs, Figure 8, illustrate the various mechanical events that take place during an engine cycle. Events like the opening of intake ports, closing of exhaust valves, and the combustion event can all be determined from examining the various vibration graphs.

The cylinder head vibration vs. crankshaft angle graph is particularly useful in diagnosing valve and lifter problems in EMD engines. This example illustrates the case of a collapsed lifter and a dropped valve on an EMD 710 power assembly. In this case the valve closing event occurs much earlier then expected and creates a large vibration when it closes relative to the other exhaust valve closure events in the same engine. Figure 9 shows the phased vibration graph for a collapsed lifter and dropped valve. Upon visual inspection, it was found that a hydraulic lifter on the #9 power assembly had collapsed and the exhaust valve associated with it had began to drop. This condition was corrected by replacing cylinder and the valve bridge/lash adjuster assembly. This replacement avoided the failure of the component and the subsequent unscheduled maintenance event. Had this condition been left uncorrected, the valve might have dropped into the combustion chamber during operation and caused power assembly failure.

Another example of using engine analysis to diagnose engine problems is the use of the pressure data to balance an engine. In this case the engine was found to have a significant imbalance between several cylinders. The highest measured pressure in this engine was 1900 psi, the lowest measured pressure was 1300 psi. The difference in pressures amounts to a difference of 38,000-lbs. difference between the highest and lowest pressure cylinders. The pressure curves for this engine are shown in Figure 10. This difference in pressures will cause higher wear rates and shorter life on the cylinders that are experiencing higher peak pressures and decrease crankshaft life as previously discussed. Reviewing the engine timing and maintenance history for this engine showed that several injectors had been replaced due to failure. The replacement injectors were not properly set and a gross error occurred in the injection timing of the engine.

Electrical / Control Systems

Condition based maintenance for electrical systems can be done using remote monitoring or an automated fault log analysis program. This approach uses fault and operational input data to assess a locomotive. The data is communicated back to a central data analysis hub. This is accomplished by manual fault log downloads, cell phone, data radio, or satellite. The transfer of information occurs either periodically, on demand, or if preprogrammed criteria are met. Either trained analysts or an automated analysis tool then analyzes the fault and operational data. Repair recommendations are then developed. This methodology provides the opportunity to develop customized recommendations that are tailored to a specific problem. The severity of a problem is also determined to prioritize the repair and determine the scope of the facility where the repair can be accomplished. In some cases, this degree of customization greatly streamlines the repair process and focuses the maintenance resources to obtain an optimal maintenance and repair strategy. Messrs. Estes and Chessario have extensively covered this subject in a recent LMOA presentation "RM&D - What it is, What it does."

Challenges

Implementing condition-based maintenance is not without its challenges. The technical and operational challenges are difficult, but can be accomplished. The economic aspects of this approach provide the greater degree of difficulty. Mechanical departments determine their budgetary requirements based largely from traditional scheduled maintenance programs. Overhauls and larger scale project work scopes can be defined and planned with a reasonable amount of lead-time.

Changing the maintenance strategy to a condition based approach will have both a positive and negative effect on a maintenance budget.

Positive effects include improvements in asset utilization and a reduction in associated damages that accompany failures. When these techniques are performed during scheduled maintenance events, the repair can coupled with scheduled maintenance activity. This results in a repair event, which is an unscheduled activity, taking place simultaneously with the planned maintenance event. Overall, this will decrease the number of shopping events over the life of the locomotive without having a negative impact on the operational availability of the locomotive.

Negative effects of moving to a condition-based approach include budgeting concerns, most notably with respect to overhaul planning and financing. Incorporating a condition-based approach should extend average overhaul intervals. However, a shift of work should take place, moving more work from the overhaul shop to the field repair shop. Traditional approaches to overhaul programs have also been planned project work. Overhauls planning can take place more than a year in advance of the actual event. Funding and the scope of these programs are usually determined well before overhaul work takes place. This shift creates some challenges in planning and funding locomotive repairs and overhauls. One possible way to manage this shift is to change the scope of the overhaul work into a fragmented approach. The various sub-systems that would normally undergo a major refurbishment at an overhaul are done in the field on condition. This would decrease the cost of the overhaul but shift the cost to the repair environment. Another approach would be to enter a long-term parts and overhaul agreement with an OEM or after market parts provider. This way the costs of the overhaul and repairs could be spread out over the life of the asset and the burden of cost variability can be shifted from the operator to the parts provider.

Condition-based maintenance will find its way into locomotive maintenance programs where appropriate. The need to provide an acceptable return on investment requires locomotive maintenance programs to optimize the life cycle cost and utilization of the asset. The challenges of using these technologies is implementing them into a railroad environment where they can be effective, and creating a cost structure that is capable of meeting challenges of this approach, especially as they pertain to overhaul planning.

References

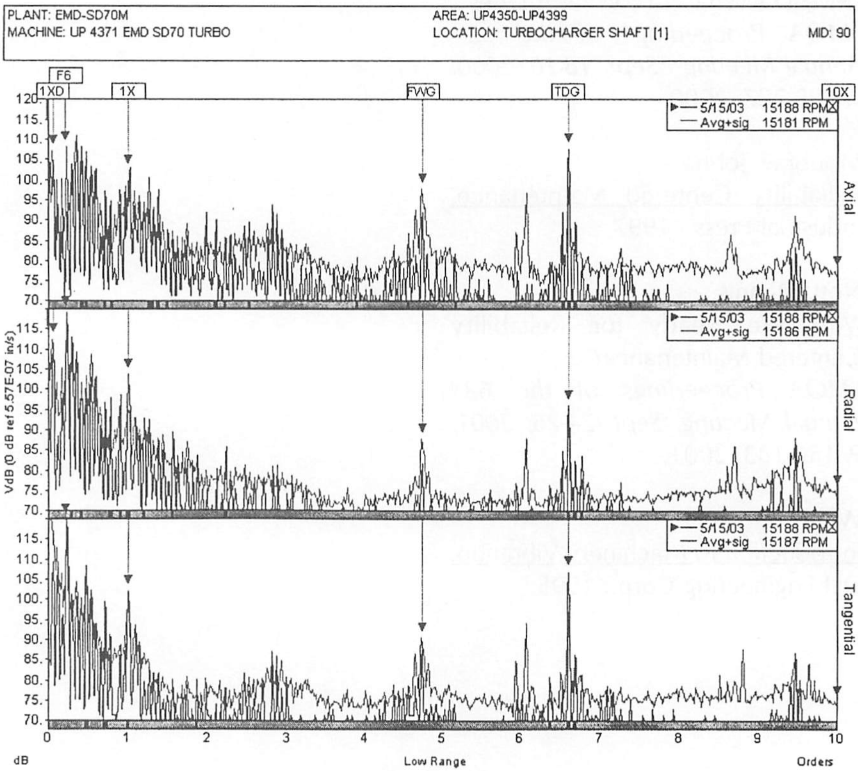
Dynalco Controls. Diesel Engine Analysis with Recip Trap.
Date unknown.

Estes & Chessario.
"RM&D - What it is, What it Does".
LMOA Proceedings of the 62nd Annual Meeting. Sept. 18-20, 2000.
P. 198-207. 2000.

Moubray, John.
Reliability Centered Maintenance.
Industrial Press. 1997

Nott, Dennis.
"Are We Ready for Reliability Centered Maintenance?".
LMOA Proceedings of the 63rd Annual Meeting, Sept. 24-26, 2001.
P. 156-183. 2001.

White, Glenn D.
Introduction to Machinery Vibration.
DLI Engineering Corp. 1995.



- Figure 1 -
Average and Typical Spectra of an EMD Turbocharger

- Figure 2 -
Typical System Report

UP 4371 EMD SD70 TURBO

Report generated on: 5/17/03 10:20 AM
Acquired: 5/15/03 10:41 AM 1xT = 15179 RPM Averages: 35

Maximum level: 119 (+0) VdB at 0.22xT on 1T in low range

RECOMMENDATIONS:

DESIRABLE: SIGHT OR MODERATE VIBRATION FAULTS MAY EXIST, CONTINUE IN SERVICE IF POSSIBLE
DESIRABLE: --

DIAGNOSES:

MODERATE TURBOCHARGER ROTOR IMBALANCE

```
    102 (+2)  VdB at 1xT    on 1A in low range
    104 (+10) VdB at 1xT    on 1R in low range
    102 (+4)  VdB at 1xT    on 1T in low range
```

MODERATE TURBO DRIVE GEAR MESH PROBLEM OR WEAR

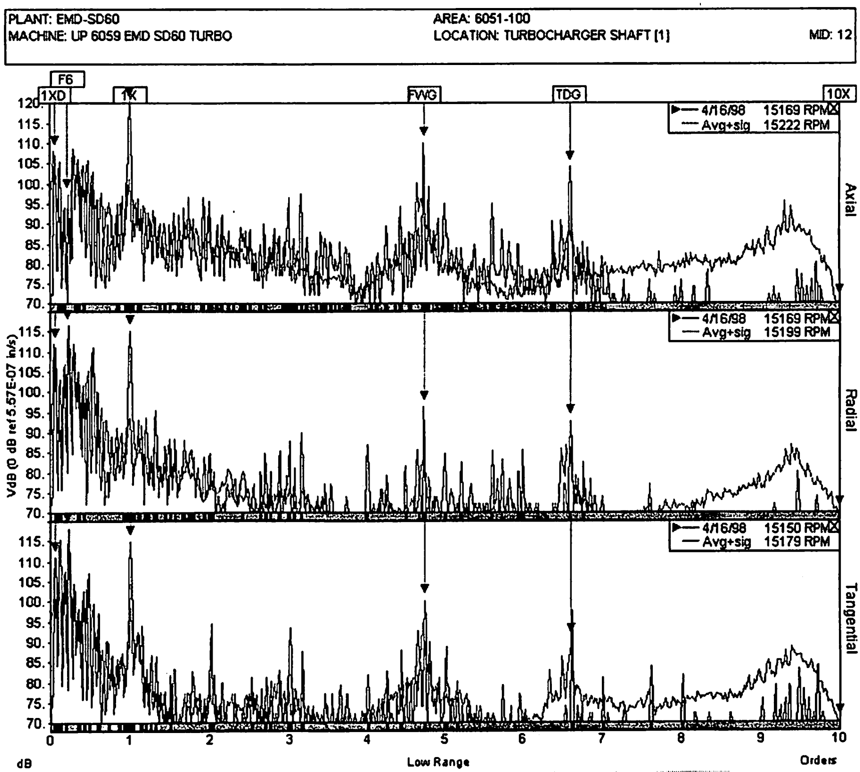
```
    108 (+11) VdB at 6.6xT  on 1A in low range
     96 (+2)  VdB at 6.6xT  on 1R in low range
    107 (+10) VdB at 6.6xT  on 1T in low range
     85 (+11) VdB at 19.8xT on 1R in high range
```

SLIGHT COMPRESSOR IMPELLER OR GUIDE VANE PROBLEM

```
    100 (+5)  VdB at 17xT   on 1A in high range
    102 (+10) VdB at 17xT   on 1R in high range
```

POSITION LEGEND:

POSITION 1 IS: TURBOCHARGER SHAFT



- Figure 3 -

SD60 Turbocharger spectra showing a problem at 1X.

UP 6059 EMD SD60 TURBO

Report generated on: 11/11/99 07:28 AM
Acquired: 4/16/98 10:54 AM 1xT = 15138 RPM Averages: 15

Maximum level: 120 (+16) VdB at 1xT on 1A in low range

RECOMMENDATIONS:

MANDATORY: REPLACE TURBOCHARGER
MANDATORY: NOTIFY PLANNER AND/OR MANAGER THAT TURBO NEEDS C/O USE LMI1502
MANDATORY: FOR QUESTIONS CALL D K MILLER, 8-271-5846

DIAGNOSES:

EXTREME TURBOCHARGER ROTOR IMBALANCE

```
    120  (+16) VdB at 1xT    on 1A in low range
    115  (+20) VdB at 1xT    on 1R in low range
    115  (+13) VdB at 1xT    on 1T in low range
```

SLIGHT TURBO DRIVE GEAR MESH PROBLEM OR WEAR

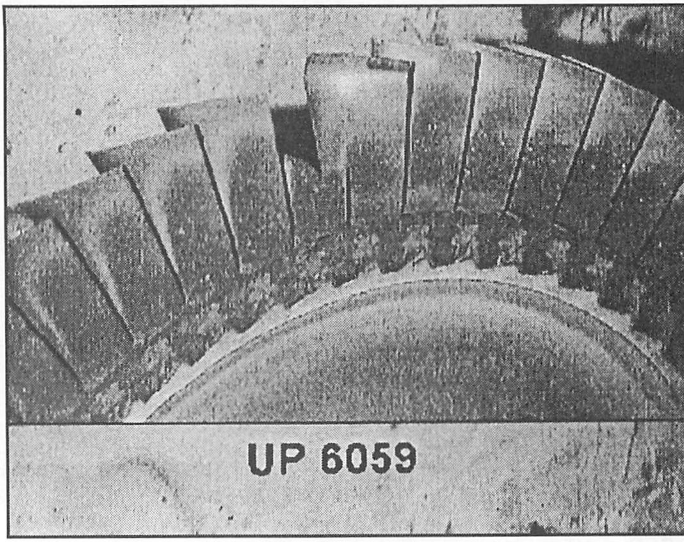
```
    104  (+8)  VdB at 6.6xT  on 1A in low range
     98  (+3)  VdB at 6.6xT  on 1T in low range
```

SLIGHT FLYWHEEL DRIVE GEAR MESH PROBLEM OR WEAR

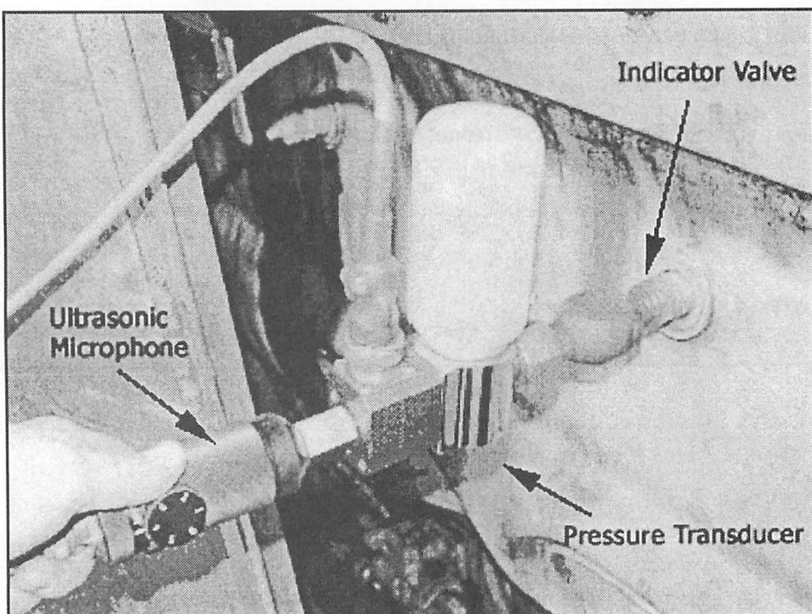
```
    110  (+8)  VdB at 4.74xT on 1A in low range
     96  (+6)  VdB at 4.74xT on 1R in low range
     81  (+10) VdB at 19xT   on 1A in high range
     94  (+5)  VdB at 19xT   on 1T in high range
```

POSITION LEGEND:
POSITION 1 IS: TURBOCHARGER SHAFT

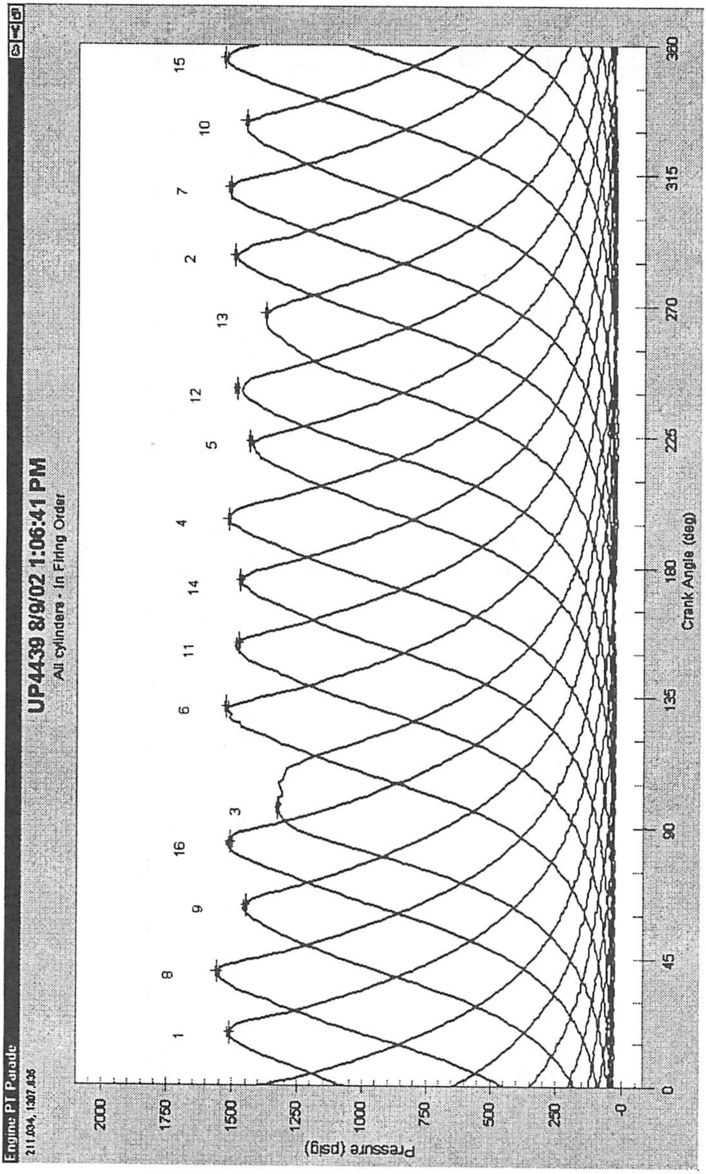
- Figure 4 -
Expert System Recommendations
Based on Spectra of Figure 3



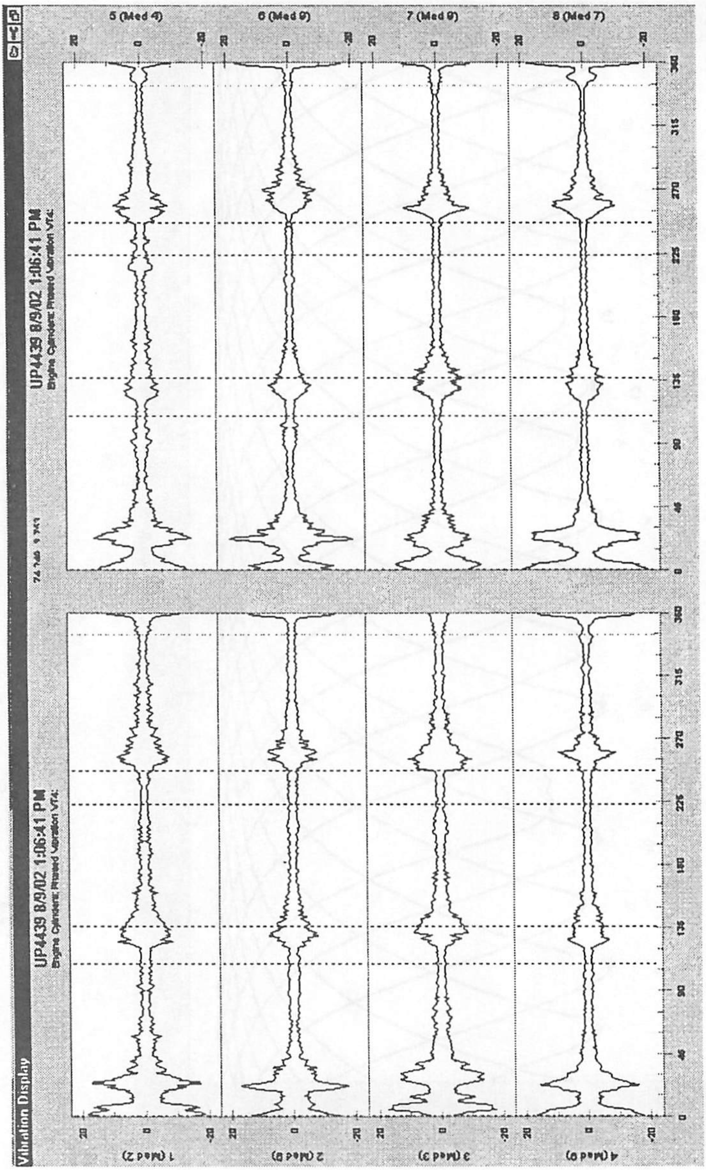
- Figure 5 -
Turbine from Spectra in Figure 3



- Figure 6 -
Typical Indicator Valve, Pressure Transducer, and Ultrasonic Microphone arrangement

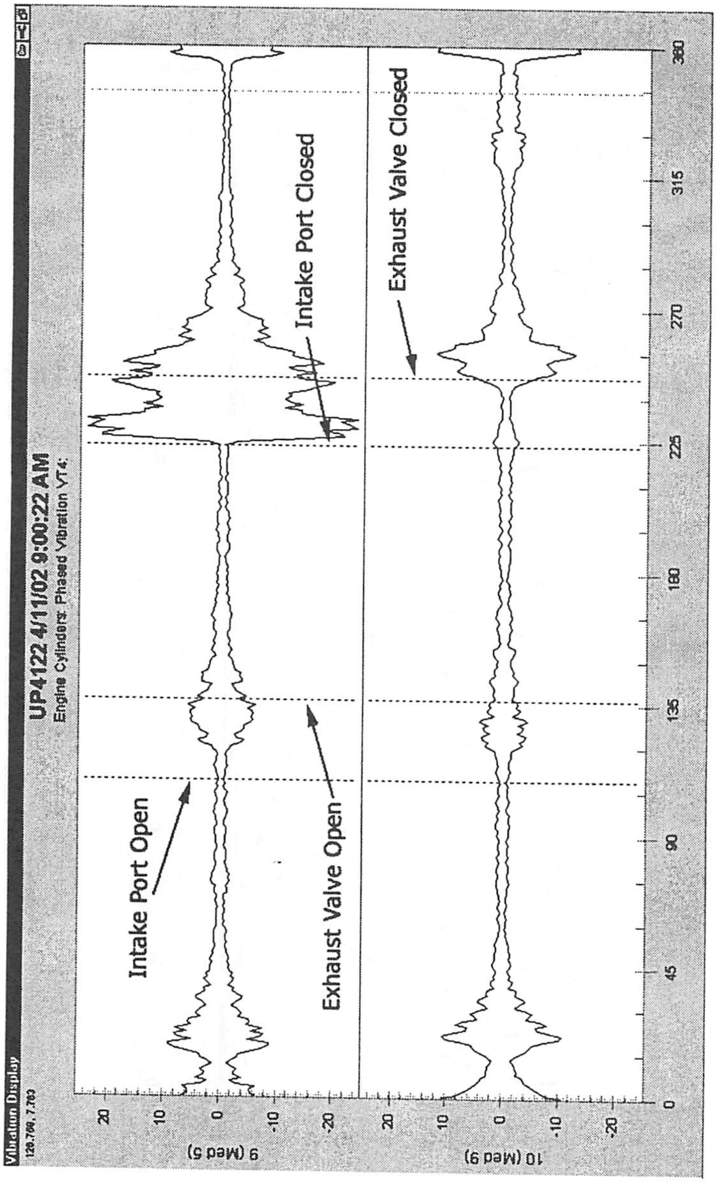


- Figure 7 -
Typical Engine Cylinder Pressures in Firing Order.

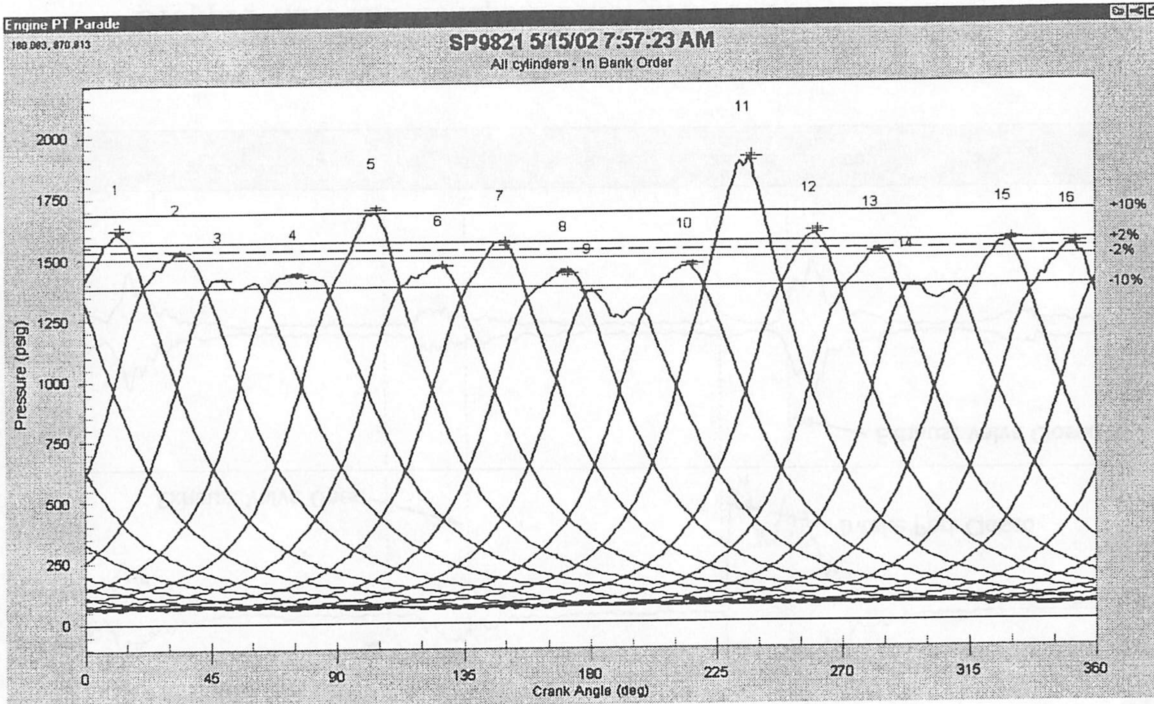


- Figure 8 -

Cylinder Head Vibration, Phased to the Crankshaft.



- Figure 9 -
Dropped Valve and Collapsed Lifter in a 710 Power Assembly.



- Figure 10 -
Imbalanced Pressures in a 710 Engine.

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 1 - Active Railroad Membership shall be composed of persons employed by a railroad company and interested in locomotive maintenance. Mem-bership 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, and shall have the 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 service, he may continue to serve until the end of his term, and, if he chooses, continue to serve as an executive officer and be allowed to elevate through the ranks as naturally occurs, to include the office of President.

Section 2 - Board of Directors: There shall be a Board of Directors composed of the President, Vice Presidents, and all Past Presidents in active 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 activities.

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 will 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 active 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 repre-sentations 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.

DIESEL MECHANICAL MAINTENANCE COMMITTEE TWENTY-TWO YEAR INDEX

2002

1. Detrimental Effects of Locomotive Engine Idling
2. Emissions Standard Compliance for the GE Dash 8 Locomotives
3. Tier 0 Emissions Compliance for the GE Dash 8 Locomotive
4. Locomotive Inspection Training - A Preview of CFR 229/238
5. Computerized Record Keeping to Improve Performance and Reduce Maintenance Expense for Shortline and Regional Railroads

2001

1. Troubleshooting Electronic Fuel Injection on GE Locomotives
2. Troubleshooting Electronic Fuel Injection-EMDEC Electro Motive Division Two-Stroke Engine
3. How to Maintain ALCO Locomotives in the 21st Century
4. Catastrophic Engine Failures: Shortlines & Regionals (Best Practices)
5. Are We Ready for Reliability-Centered Maintenance?

2000

1. 2000 Emissions Review - GE Perspective
2. 2000 Emissions Review - EMD Perspective
3. EMD Diesel Engine Crankshaft Main Bearings Edge-Load Condition (Description, Detection and Resolution)
4. 2000 - LMOA Best Practice Series: Locomotive Truck Overhaul Procedures

1999

1. Vibration Analysis
2. EMD Power Assemblies Change Out Practices for Regional and Shortline Railroads
3. Improved Access to GE7FDL Engine Intake Manifold for Cylinder Inlet Port Cleaning
4. What's Ahead in Plastics for Locomotive Applications
5. Cast Iron, Composition Brake Shoe Arrangements vs. Type-J Relay

1998

1. LMOA Best Practices Series: GM Engine Crankcase Pressure Troubleshooting
2. Union Pacific's New EMD Diesel Engine Rebuild Line At Downing B. Jenks Locomotive Facility-No. Little Rock, Arkansas
3. GE Turbo Rebuild Procedures
4. Mechanical Impact of Locomotive Emissions Regulations
5. Locomotive Engine Bearing Developments

1997

1. LMOA Best Practices - GE Water Leaks
2. Locomotive Update - MK 1200G LNG Powered Switcher
3. Proper Use of Gaskets and Seals

1996

1. Air Brake Trouble Shooting-Where We Are Now
2. Best Practices - Internal Water Leaks on EMD Locomotives
3. Best Practices - Oil Out Stack

1995

1. General Electric New 7HDL 6000 HP Diesel Engine
2. LMOA Best Practices Series - Low Oil Pressure Trouble-shooting Procedures for EMD Turbocharged Locomotives
3. How Can a Regional or Shortline Justify a Wheel Truing Machine?
4. EMD SD60M Natural Gas Locomotive Development

1994

1. Electronic Fuel Injection.
2. ICAV - The Physical Affects on Instantaneous Crank Shaft

Angular Velocity Technology.
3. Maintenance Practices Com-parison Between Regionals and Class I Railroads.
4. Amtrak Document Manage-ment.

1993

1. EMD's Three-Axle Radial Steering Truck
2. The Natural Gas Locomotive at BN RR
3. Locomotive Waste Oil Reten-tion
4. Fragmented Maintenance

1992

1. Mechanical Quality Progress Developing on Major Railroads.
2. Coal Fuelled Diesel Locomotive Development.
3. 18:1 Upgrade for the 645E Engine
4. Automatic Stop and Start Control System
5. Acquiring Locomotives for Regionals and Shortlines.

1991

1. Recommended Practices for upgrading 567 to 645 Design.
2. Conversion of SD40 Loco-motives to SD 40-2 on CSX.
3. Update: Diesel Engine Emission Controls.
4. Stationary and Dynamic Test Procedure for Locomotive Fuel Efficiency Measurement.
5. Personnel training on New Technology.

1990

1. Caterpillar Power in Reman-ufactured Locomotives.
2. The EMD 710G3A Engine
3. Improving Performance of Traction Motor Friction Sus-pension Bearings.
4. Fluid Leaks on GE 7FDL Engine.
5. Rebuild of the EMD F3B Fuel Injector.

1989

1. Wheel Axle Gear Wear/Impact on Traction Motor Life.
2. 710 Engine - Operational and Overhaul Update.
3. GE Power Assembly Improvements on Welded Head-to-Liner
4. Assembly Rework Procedures.
5. EMD Engine Oil Leaks. Secondary Air Filtration - Barrier vs. Impingement.

1988

1. Low-idle Operating Costs vs. Fuel Savings.
2. Rebuilding GE's EB Liner.
3. The Extended Maintenance Truck
4. Flange Lubricator Update.
5. Permaspray II - Cylinder Liner.

1987

1. EMD Water Pump Rebuilding.
2. On Board Flange Lubricators.
3. Gear Case, Bull Gear and Pinion Gear Longevity in the 1980's - Gear Cases - Canadian National Experience.
4. Maintenance of Locomotive Fueling Systems for a Spill Free Operation.

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 Requirements: 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 MATERIAL CONTROL COMMITTEE
TWENTY-TWO YEAR INDEX

2002

1. "Mentored Champion Process" - CSX Supply and Service Management

2001

1. RAILMARKETPLACE.COM - The Industry's Market Exchange

2000

1. GE Global eXchange Services
2. My.SAP.Com

1999

1. Composite Floors and Doors for Locomotives
2. Packaging Standards

1998

1. Tighter is Not Better
2. Are Vending Machines the New Wave for Safety Items?

1997

1. Raising Our Standards for Safety
2. The Rail Industry's Electronic Parts Catalog Exchange Standard (EPCES) - A Better Way

1996

1. Technology Transfer-The Hot Process of the 90's-Condition Based Maintenance
2. Warehouse Automation

1995

1. Warranty and Reliability Man-agement
2. Railroad Industry Group (RIG) Exchange Standard for Parts Catalog Information

1994

1. Material Consignment.
2. The Next Step in Electronic Information Management - Interactive Technical Manuals.
3. Electronic Catalog Alternatives.

1993

1. Technology Transfer
2. Electronic Cataloging from a Material Perspective
3. Computerized Reordering from the Mechanical Employee's Point of View
4. Electronic Catalogues: OEM /Supplier Point of View

1992

1. Warranty Overview and Issues
2. Recycling - 1992
3. Bar Coding
4. Material Packaging

1991

1. The World of Recycling.
2. Problems with Solutions.
3. Problems with Opportunities.

1990

1. Waste Minimization.
2. Hazardous Materials End Cost
3. The Role of the Suppliers.

1989

1. Packaging and Containerization for Today's Railroad.
2. Innovations in Material Dis-tribution Resulting from Shop Consolidations.
3. Outsourcing! Does Anyone Really Understand the Difference Between UTEX and Repair and Return and the Affect on the Budget?
4. "Stuff" Happens! - A Skit About the Necessity of Feedback from Suppliers - Suppliers to the end User.

1988

1. Communication - The Vital Link in Materials Acquisition.
2. Quality Assurance Through Communications and Feed-back.
3. Paperless Requisitions.
4. A Practical Application of Bar Coding in the Railroad Industry.

1987

1. Suppliers Selection for Component Failure Analysis.
2. Vendor Performance or Service Level.
3. Bar Codes.
4. Bar Coding - Railroads
5. Material Handling Innovations by the Airline Industry.

1986

1. The In-House Electronic Re-quisition System.
2. Electronic Data Interchange.
3. RAILING and Electronic Pur-chasing.
4. Quality Evaluation of Material Sourcing Decisions.

1985

1. Evaluating Locomotive Maintenance Projects.
2. Reconditioning Material: In-House vs. Vendor.
3. Identification and Disposition of Surplus Material.
4. Cost of Carrying Surplus.
5. Evolution and Future Directions of Material Handling Equipment in Railroad Use.

1984

1. Bar Coding of Material.
2. Forecasting Material Requirements.
3. a. Fuel Security - Are You Getting What You Pay For?
   b. Fuel Oil Is Expensive.
4. Pros and Cons of Material Purchasing Contracts (Single Source - Just In Time Inventory).

1983

1. Improved Locomotive Produc-tivity 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 AND PROCESSESCOMMITTEE TWENTY-TWO YEAR INDEX

Suspension Bearing Replace-ment Equipment and Pro-cedure.
3. Locomotive Component Re-placement 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 Equip-ment.

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 Tech-nolo-gy.

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 Re-gula-tions on Locomotive Finishing.

1984

1. Shop Tools.
   A. New Tools.
   B. Shop-Made Tools.
2. Traction Motor Shop Equipment Up-Date.
3. 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 equip-ment.

1981

1. Training Aids.
2. Testing Devices Inspired by New FRA Laws.
3. Tools and Training for Pro-ductivi-ty.
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

DIESEL ELECTRICAL MAINTENANCE COMMITTEE
TWENTY-TWO YEAR INDEX

1992

1. Nickel-Cadmium Batteries as an Alternative
2. Overview of Locomotive Microprocessor Based Controls
3. Locomotive Air Conditioning
4. Testing Traction Alternator Fields on EMD Locomotives
5. Flange Lubricators

1991

1. Locomotive Rebuilding - Something Old - Something New. Standardization of Elec-trical Equipment.
2. Locomotive Batteries
   a. Storage Handling Proced-ures.

   b. Recommended Maintenance Procedures.
   c. Recommended Repair Procedures.
3. Amtrak's AC Traction Locomotives.
4. Modern Tooling for Electricians Recorders.
3. Why Can't We Have One Central Computer?
4. EPA and Regulation Driven Cleaning.

1990

1. Modern Tooling of Electrical Troubleshooting.
2. Maintaining Solid State Event Recorders.
3. Why Can't We Have One Central Computer?
4. EPA and Regulation Driven Cleaning.

1989

1. Modern Tooling for the Troubleshooting Electrician: a) test meters available (single function); b) test meters available (multiple functional); c) analysis and diagnostic tools.
2. Sound Electrical Repairs and Practices for: a) traction motors; b) grids and fans; c) wire and cable solderless termination.
3. Guidelines for Preparing Electricians for the 1990s.

1988

1. Utilizing Magnetic Tape Event Recorders for Locomotive Maintenance.
2. Solid State Locomotive Data Recorder.
3. Improved Utilization of GE DASH 8 Data Recording Systems.
4. Locomotive Health Data and Its Uses To The Railroad.
5. Improved Data Acquisition From EMD's 60 Series Display Computer.

1987

1. Proper Maintenance of Electrical Fuel Savings Options.
2. Preliminary Report on AAR Traction Motor Study.

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
4. Electrical Modifications.
5. Performance of Locomotives After Storage.

1983

1. Ground Relay Trouble Shooting.
2. Specification for remanu-factured 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.

NEW TECHNOLOGIES COMMITTEE
TWENTY-YEAR INDEX

2002

1. On Board Rider - A Remote Locomotive Condition Monitoring System
2. Cool Your Jets: A Low Cost High Performance Rooftop Air Conditioner

2001

1. Performance and Economic Aspects of Various Environmentally Friendly Coatings for Rolling Rail Equipment
2. Non-destructive Testing: Crack Detection Technology - EMFaCIS

2000

1. FIRE: EMD Turns up the Heat on Railroad Electronics Integration
2. Put the Chill on Air Condition-ing Costs
3. Do Not Get "Steamed" Over Fuel Tank Repairs
4. Industry Responses to Emission Regulations
5. Improved Adhesion Through the Use of Individual Axle Inverters

1999

1. Locomotive Filteration-Where are We Going?
2. EMD Markets a New Line of Switchers

1998

1. Expert Systems
2. EMD SD90MAC 6000 HP Locomotive - Where Are We Today? GE AC6000CW Locomotive - Where Are We Today?

1997

1. An Overview of the Electro-pneumatic Train Brake
2. Locomotive 6724, Where Are You? GPS, Mobile Telemetry and GIS Technologies in a Railroad Environment
3. Runout Measurement Using Non-Contact Sensor Tech-nology
4. Common Rail Fuel Injection

1996

1. Activities Toward New Safety Standards for Passenger Equipment
2. SP-3 Thin Sensor Technology for Variable Force Measurement
3. Top-Of-Rail Lubrication
4. Traction Motor Vibration and its Effects

1995

1. Beltpack Locomotive Control System
2. The MK1200G Switching Locomotive
3. Advanced Traction Motor Testing

1994

1. Electronic Fuel Injection Sys-tems.
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 Develop-ments Retrofittable to Older Model Locomotives
3. Locomotive Applications of Catepillar Engines.
4. Wheelslip Control for Individual Axles.

1987

1. Electronic Fuel Injection Sys-tems.
2. Update on Electronic Gover-nors.
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.
4. Locomotive Cab Develop-ments.

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.

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE TWENTY-TWO YEAR INDEX

4. Partnership in Development.

1990

1. The Responsibility of Railroads and Facility Managers in the Handling and Disposal of Hazardous Materials.
2. Update on Diesel Fuel Regulations.
3. Diesel Exhaust and Worker Exposure.
4. Field Experiences with Multigrade Railroad Locomotive Oils.
5. Conrail Wheel/Rail Lubrication Update.

1989

1. Field Test Data Follow-Up and Description of "Generation 5" Locomotive Crankcase Oil.
2. Diesel Emissions: Regulations and Fuel Quality.
3. Petroleum Storage Tank Regulations - Guest Speaker - George Kitchen, International Lube & Fuel Consultants.

1988

1. Used Oil Analysis and Condemning Limits.
2. Review of A.A.R. Procedure RP - 503, "Locomotive Diesel Fuel Additive Evaluation Procedure."
3. Update on Improved Oils - Multigrade.
4. Wheel Flange Lubrication Update - Lubricants Being Used.
5. Survey of Disposable Practices or Locomotive Engine Lube Oil and Lube Oil Filters.
6. Speaker on Overview of Environmental Requirements for The Use of Petroleum Products in The Railroad Industry - Peter Conlon - AAR.

1987

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