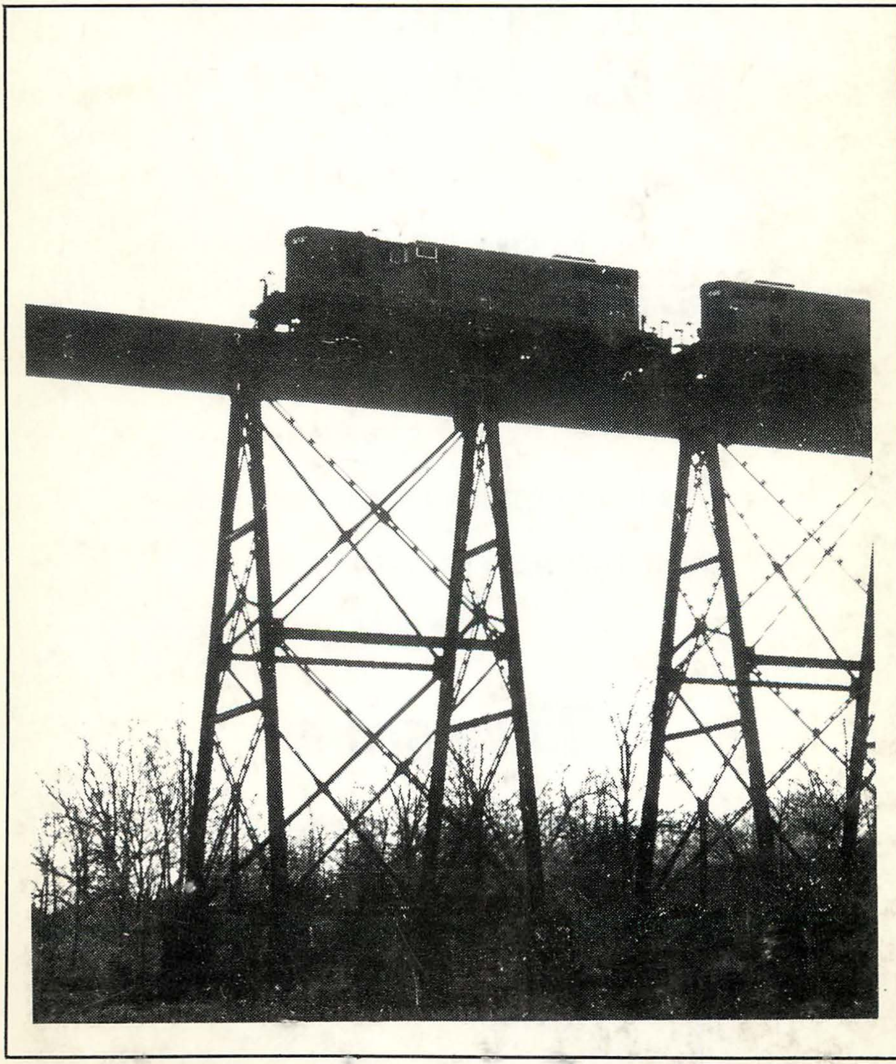
LMOA

Locomotive Maintenance Officers Association

Proceedings of the 58th Annual Meeting
Chicago, September 16-18, 1996



1996 ADVERTISERS INDEX

LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

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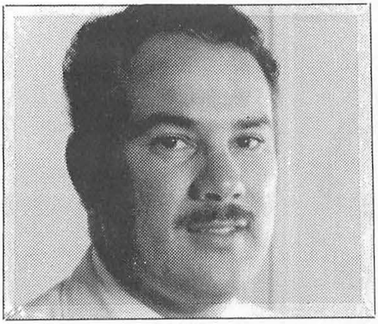

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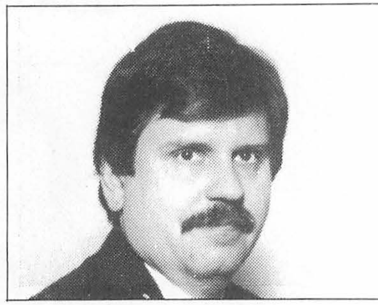

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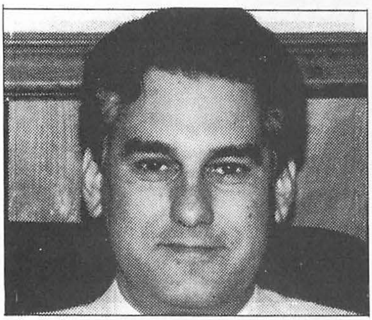

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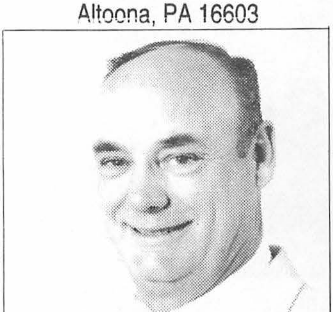

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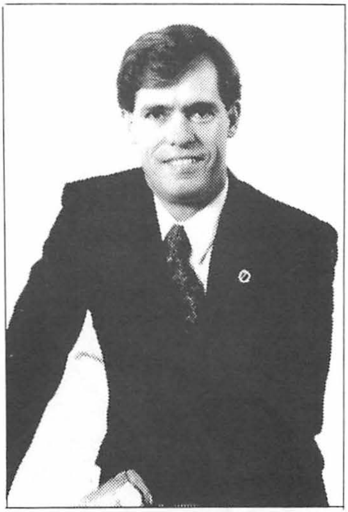

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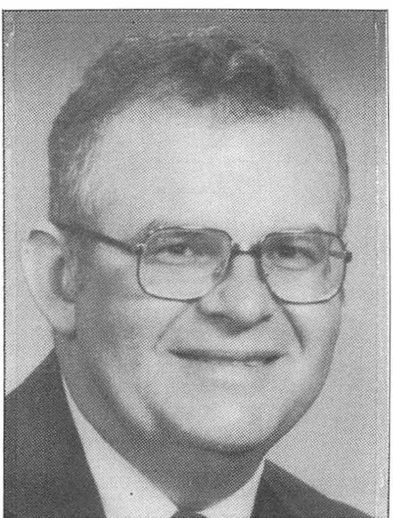

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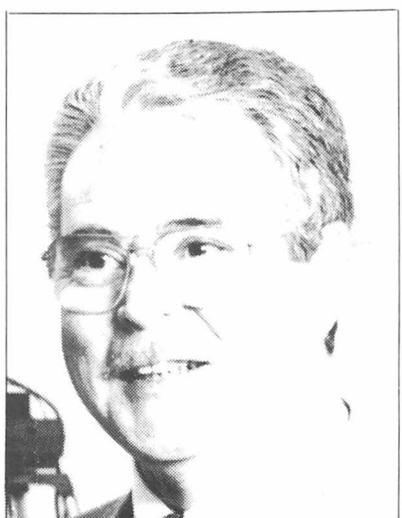

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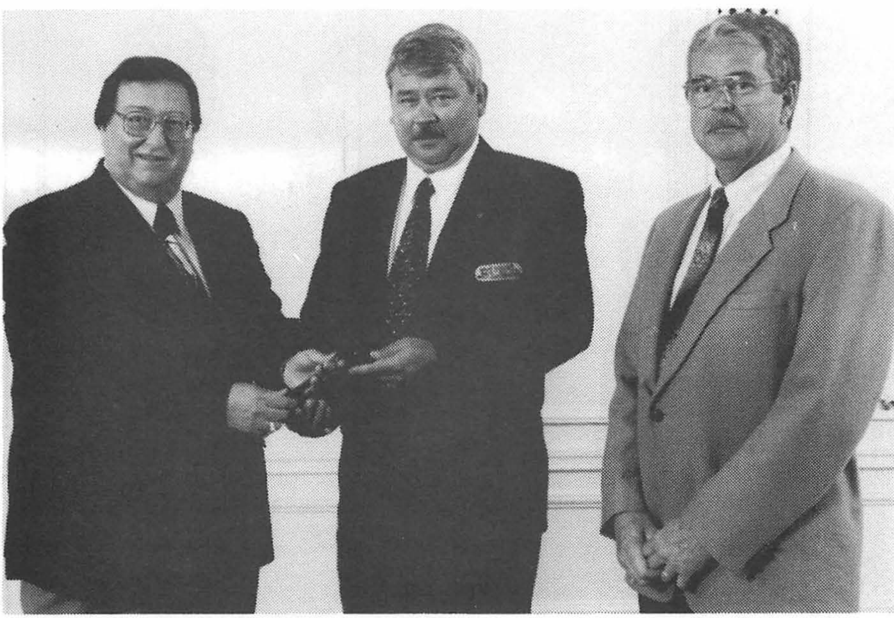
Norfolk Southern Corp.
Atlanta, GA 30315

Chairman of the Board, Mark Coles, Union Pacific, presents Past President's Pin to President Charlie Miller, Union Pacific. Past President Tom Harley (retired) was in attendance.



Outgoing President Charlie Miller, Union Pacific, presents gavel to new President Gil Bruno, Amtrak-MetroLink, which was witnessed by Past President Bill Brown, Montana Rail Link.

Past President Darrell Walker, Norfolk Southern, presents "General" Desk Set to President Charlie Miller, Union Pacific. Past Presidents Dale Propp (retired) BN and Paul Hoerath (retired) Conrail, far right, witness the ceremony.

New President Gil Bruno, Amtrak-MetroLink, assists new 3rd Vice President Doug Corbin, Norfolk Southern, with his new LMOA blazer. New 1st Vice President, Dave Wetmore, CSX, gives his approval.

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1954 & 1955 - F. D. SINEATH, Retired Chief of Motive Power, Seaboard Coast Line R.R., 1061 Nelson Ave., Jacksonville, FL 32205
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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, Retired Asst. Chief Mechanical Officer, Missouri Pacific R.R., 523 Hidden Harbor, Houston, TX 77079
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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, Retired Chief Mechanical Officer, Elgin Joilet & Eastern Ry. Rt. 1 Box 28010, Albia, IA 52531
1968 - T. W. BELLHOUSE (Deceased) Supt. Mechanical Dept., S. P. Co., - St. L. S.W. Ry.
1970 - G. R. WEAVER Retired Director Equipment Engineering, Penn Central Co., 516 Bryn Mawr Ave., Bryn Mawr, PA 19010
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1990 - P. F. HOERATH, Retired Sr. Mech, Engr. Shops, Conrail, Box 134, R.R. 4, Hollidaysburg, PA 16648
1991 - D. D. HUDGENS, (Retired) Sr. Mgr. R & D, Union Pacific, 16711 Pine St., Omaha, NE 68130
1992 - K. ALLEN KELLER, Supt. Loco. Maint., Reading, R.R., 241 E. Chestnut, Cleona, PA 17042
1993 - W. R. DOYLE, Mgr.-Maint. Control Systems Union Pacific RR, 1416 Dodge St., Omaha NE 68179
1994 - M.A. COLES, Director Loco. Technical Services, Union Pacific RR, 1416 Dodge St., Omaha, NE 68179
1995 - C.A.MILLER, Mgr.-Loco. Plng. Stds. & Programs - Maint. Opns, 1416 Dodge St., Omaha, NE 68179

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

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

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

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT

MONDAY, SEPTEMBER 16, 1996
10:45 A.M.

Pre-Convention Presentation

July 15, 1996
Marriott Hotel
Altoona, PA

BILL PETERMAN, Chairman
Consultant
BP Rail Systems
Montreal, PQ

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

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M. Scaringe	Mgr-Loco. Overhaul	Amtrak	Beech Gove, IN
T. Stefanski	Mgr.-Loco. Maint.	EMD	Alliance, NE
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LMOA wishes to express its thanks to Conrail for hosting the Pre-Convention Presentation in Altoona, PA.

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

1. LOCOMOTIVE PAINTING

Prepared by:
Ron G. Yartin
Conrail

With the advent of AC and other larger locomotives, modifications to both the physical paint booth and our painting procedures were necessary.

I. Automatic Mixing System - Conrail's Juniata Locomotive Shop paint booth is equipped with the Graco automatic P-Mix system, equipped with a PC for controlling the paint mixture and amounts. This eliminates the guess work on how much paint is required for each unit, and eliminates disposal of residue in the pressure pot. It also prevents any improper mixing which could affect the finish and cause possible D.E.R. regulation violation. D.E.R. Regulations state that V.O.C. Volatile Organic Compound, cannot exceed a reading of 3.5 parts per million. We eliminated the need for installation of a costly filtering systems as our new system now brings us into compliance with these standards.

2. D.E.R. Emission Standards/Paint Consumption - Our PC controls, use of a new paint, and new spray equipment has reduced our paint usage by 50%, along with reducing environmental risks. Our original paint was DuPont Imron 333 line, 4 x 1 mix, with a V.O.C. of 3.5, which of course is unacceptable. This paint, even though it has served Conrail well has its limitations concerning finish texture, along with being a source of concern over D.E.R. emission. We tested the Imron 5000 line, 3 x 1 mix and found that it could be applied much smoother than the Imron 333 line. It also has a lower V.O.C., 3.22, which makes it more environmentally friendly. We then tested several paint spraying systems and found that the Graco PRO03500HC paint guns allowed us to apply the 5000 Imron with less over spray and a finer atomization of the paint. As a result, we have reduced our paint cxonsumption from 12 gallons of blue Imron per locomotive to 6 gallons using both the new paint and new equipment. It previously required one hour to apply the blue paint on an average using air assisted airless electricstatic guns with Imron 333 line.

For an A/C Locomotive, it takes 1.5 hours to apply paint using the new system. But, even with this additional time, a locomotive (cab, engine room, primer, blue and black) is still being painted in one trick, using only two painters. The 1/2 hour time increase is more than offset by the savings on paint and the environmental exposure.

3. Modifications and Problems/ Solutions brought on by AC Locomotive Length: The purpose of this section is to help point out potential problems that may arise should you find it necessary to make modification to your paint facility to accommodate the length of the AC locomotives. It is hoped that our experiences will save you time and money as you make your changes. Our first problem was to extend the working length of the existing mancarriers in the paint booth. This was necessary to be able to reach the full length of the SD80MAC units (80 feet). This was done by converting the work platforms to a dual paint spraying platform, which allowed the painters to reach 3 feet farther on both ends of the paint booth. The east end of the mancarrier system was restricted in movement by the paint system paint line festoon system. This restriction was reduced by converting the festoon system from seven hangers to a four hanger system which allowed mancarriers

to travel 6 feet farther east.

After making these modifications to the mancarrier system it was still necessary to move the locomotive farther west in the paint booth to have it centered in the working range of the mancarriers. In doing this, we discovered that the air make up intake blower was causing problems for the painter during painting. The forced air coming into the booth was interfering with the spray gun atomization. We eliminated this problem by modifying the air make up system to a balanced air drill system, and installing a filtered intake panel below the forced air inlet duct. This allowed the inlet blower to be shut off during the paint spraying operation, thus allowing only the same amount of air to be drawn into the booth as was being exhausted by the exhaust fan, and creating the necessary negative pressure in the paint booth. After the paint spraying is completed, the heated forced air system is turned on, speeding up drying time. Special thanks to Chuck Medovich, General Manager Manufacturing Assets; Ron Osmolinski, General Superintendent Juniata Locomotive Shop; John Baranko, Assistant General Superintendent Juniata Locomotive Shop; and Francis (Bud) McClellan, General Foreman at Juniata's painting facility for their assistance and expertise in preparing this paper.

2. DROP TABLE TOOLING FOR NEW EMD AND GE LOCOMOTIVES

Prepared by:
Joe Muench - CSX

The April edition of Railway Age magazine, in an article on research and development, stated that more than 500 locomotives equipped with radial trucks are currently in service. The magazine additionally quoted one estimate that 1,400 to 1,500 A.C. equipped locomotives would in service by the end of 1996.

There are several benefits in these new traction motor and truck designs including improved performance and reduced wear. However, these newly designed locomotive trucks, marketed by major locomotive manufacturers, have features that necessitate tooling and process changes when their traction motors are removed during running maintenance. The arrangement of EMD's Radial Trucks and GE's High Adhesion Trucks and Steerable Trucks, while different, can have certain similarities, such as A.C. powered traction motors, traction motor nose suspension linkages instead of spring packs, coil springs located outboard of the axle bearing housing rather than above and oil filled gear cases.

New Training Video from EMD

An instructional video has been recently produced by EMD featuring the removal and application of a traction motor from one of its radial trucks. The video highlights both procedures and tooling including:

- Collar Cutter - to remove the Nose Link fastener
- Suport Stand - to align the Axle Traction Rod
- Retaining Bar(s) - for Coil Spring support
- Pry Bar or "Come Along" - to achieve Nose Link clearance
- Application Gun - to apply Nose Link fasteners

Spring Saddle Stablizer for GE Trucks

A Spring Saddle Stabilizer has been designed and manufactured for use on GE High Adhesion Truck journal boxes as an alternative to supporting coil springs with retaining straps. The stabilzer allows for the journal box and coil spring assemblies to be removed from and applied to trucks with the traction motor, safely on a single motor type drop table, minimizing the possible imbalance of components.

Other Tooling Available

One manufacturer of railroad equipment tooling features lanyard equipped hand tools that, when used to install and remove GE Traction Motor Sensors, limit potential for tools to be dropped into equipment. This manufacturer additionally supplies a gear case bolt torque kit, including torque motor, reaction arms, sockets and adaptors, and also installation and removal kits for an alternate style nose support fasteners. This fastener is equipped with a twist off drive which detaches itself upon achieving desired torque.

Summary

The evolution of design has been accelerated by locomotive manufacturers to provide our employers greater capabilities and efficiencies. We in the railroad shop environment must likewise accelerate our ability to maintain and repair our newly gained assets, safely and cost effectively.

REPORT OF THE COMMITTEE ON NEW DEVELOPMENTS

MONDAY, SEPTEMBER 16, 1996
1:45 P.M.

Pre-Convention Presentation Amtrak

TIM FREDERICK, Chairman
Mgr.-Loco. Mech. Sys.
Conrail
Philadelphia, PA

June 20, 1996
Wilmington, DE

COMMITTEE MEMBERS

B. Begole		General Electric	Erie, PA
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W. Jacobs	Mgr-Locomotive	Union Pacific	North Little Rock, AR
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L. Sopol		BC Rail	Prince George, BC
T. Stewart	Engr.	CSX Transp.	Jacksonville, FL
C. Wills	Sr. Engr.-Maint. Support	BN/SF	Topeka, KS

PERSONAL HISTORY

Timothy A. Frederick

Timothy A. Frederick was born in Pittsburgh, Pennsylvania on Sept. 1, 1954. After his high school education he studied at Pennsylvania State University where he received a Bachelor of Science degree in Mechanical Design Engineering Technology in 1976.

He began his railroad career as a trackman with the Penn Central Railroad in Pittsburgh while attending college. Later he was hired by Consolidated Rail Corporation as a Management Trainee in October 1977. In Sept. 1978 he was transferred to Altoona as a Supervisor of Quality Control. In Dec. 1980 he transferred to the Mechanical Engineering Department. He served as the Resident Mechanical Engineer at the Altoona Locomotive Shop thru October 1987.

Timothy was promoted to Sr. Mechanical Engineer and transferred to corporate headquarters in Philadelphia. He was promoted to Assistant Manager - Mechanical in August 1988 where he supervised five fellow engineers. In March 1994 he was transferred to the Mechanical Department as Manager Mechanical Systems, the position he now holds.

Timothy's hobbies include golfing, hunting, sporting clays, reloading, motorcycling, and masonry.

Timothy and his wife Joyce Renee, have four children: Timothy Jr. 22, Cheryl 19, Steven 18, and Jennifer 15, and one grandson, Andrew 8 months old. They currently live in Glenmoore, Pa.

I. ACTIVITIES TOWARD NEW SAFETY STANDARDS FOR PASSENGER EQUIPMENT

Presented by:
Craig R. Prudian
Electro-Motive Division

New safety standards for passenger locomotives. Why is this topic an issue? Who is affected? What was wrong with the old standards, anyway?

To those even tangentially connected with passenger and commuter train operations, this is a topic that will be prominent in the coming few years. There are near-term Congressional mandates that must be met. Organizations are realigning to meet the demand of passenger rail standards development and maintenance. There is a new tier-based definition for passenger and commuter trains that will be instituted. In short, many important changes are now in the works for the passenger and commuter industry. It is a good time now, for everyone involved, to become conversant with the new changes now coming down the rails.

1. What's the Problem?

The passenger rail industry is unregulated! An overstatement for sure, but it does reflect the battle cry of some "surface view" observers of intercity passenger and commuter rail. Industry overseers see what they think are glaring shortcomings in passenger safety strategy, and look to the FRA to provide rail passenger safety through new regulations.

The traveling public, therefore, gets an unrealistic view of what's really going on. When thousands of passenger trains arrive on time each day, that's not news. But when the public does tune in for news, it is bombarded by sensational scenes and stories.

How do we sort this all out? What's true, and what's an exaggeration? Let's take a look.

Over the years, there's been constant activity in the arena of passenger-specific equipment standards, yet few regulations are on the books today. As we know, Federal safety standards for freight equipment have been around awhile. Passenger standards, however, exist mostly through practices and procedures maintained by the passenger roads themselves, and overseen by the FRA. This "state of the industry" tends to agitate Congress, the National Transportation Safety Board (NTSB) and others. When passenger rail accidents occur, these groups find no Federal regulations to use for investigation. Furthermore, they find no "vehicle" to use as a document to advance the cause of safety in an environment of continuously changing operations and technology.

This absence of Federal regulations is the most *visible* shortcoming relating to passenger rail standards. Yet, another factor looms...

This "other" factor, not immediately evident to the casual observer, is namely, "Who provides the standards and recommended practices" to team up with the Federal regulations? Nobody is coordinating the effort to maintain and catalog standards that the industry has already so painstakingly developed.

On the freight side of the rail industry, the Association of American Railroads acts in partnership with FRA regulations to set standards for the design and maintenance of freight equipment, providing for safe operations. However, over the years, the AAR has discontinued the development and maintenance of passenger equipment standards. The standards that *are* in place come as a result of early efforts, combined with operator-

specific rules developed over decades of operation and collaboration with other industry members. The picture is complicated by the fact that there is no common "quelle," or source that exists as part of the Federal library. The only Federal point of reference are operating rules designed for freight trains!

Passenger equipment safety covers countless aspects of passenger and commuter operations, maintenance and manufacturing. The bulk of the rule-making that will emerge in the coming few years will target passenger car structure and appointments, and passenger train operation. Some aspects will directly impact locomotives and multe-unit powered cars as well. The purpose of this paper is to briefly treat the central issues, and touch a bit more on the power vehicle issues involved.

2. How Did it Happen?

So why are we facing the regulation issue now? What's different about the present climate that served to cause such a critical and immediate need for new Federal rules?

Worldwide, passenger equipment operating speeds are increasing. In the United States, Amtrak is now working with the team led by Bombardier to develop new equipment for operation at high speeds on the Northeast Corridor. In California, rolling stock is in place today to provide passenger service at 110 mph, with eventual capability for 125 mph operation in selected corridors.

Add to this picture the many new operators that are only now appearing. These new agencies are in urgent need of the wisdom of the more experienced organizations gained in running safe passenger service over long periods of time.

But there's a bigger reason that there were no Federal passenger safety regulations sooner. Quite plainly, there was no urgency. The passenger and commuter railroads were going just fine, thank you, by utilizing self-regulation with FRA oversight. However, despite the relatively safe record that rail passenger service has maintained, accidents still occurred, most frequently as a result of factors beyond the passenger railroad's control, as equipment failure was not a factor in most of these incidents (for example, highway vehicles that fail to clear a crossing in time). FRA data compiled by the AAR for 1995, shows that 94% of rail-related fatalities involve either grade crossings or trespassers.

Yet, with each accident and subsequent investigation, areas were discovered that could either reduce the possibility of similar reoccurrences, and/or limit the risk of injuries in such an accident. As a result, the affected agencies, in conjunction with the Federal authorities, would map out new strategies to ensure safe operation. But these results often have no place to reside in the realm of Federal Regulations. With the high visibility of passenger train accidents in the past number of years, those calling for formal safety regulations are getting pretty loud, especially in the halls of Congress. *That's* more likely the real reason we are developing regulations now.

<u>What Our Government Sees</u>

With the high visibility of passenger train accidents in the past number of years, the lack of formal safety regulations has become increasingly prominent. The government sees the need for formal safety rules to:

(1) provide for the continuing safe transportation that the rail industry has traditionally been known for,
(2) make passenger travel desirable

to potential customers,
(3) provide for cost effective operations and
(4) catalog the extensive efforts that have already resulted in the standards that are in effect through voluntary compliance today.

The General Accounting Office (GAO) recognized the need for comprehensive safety standards and regulations in Report GAO/RCED-93-196, entitled AMTRAK Should Implement Minimum Safety Standards for Passenger Cars. In addition, the NTSB has been vocal in this process, issuing numerous recommendations to the FRA and to the railroad industry concerning the crashworthiness of locomotives.

Locomotive Crashworthiness

The NTSB's interest in locomotive crashworthiness dates to 1970, and NTSB has made several safety recommendations to the FRA and the industry concerning increased protection for crew members in a locomotive cab, based on a number of accidents, mostly freight related. Those documented in the latest Federal notice include:

1. 8 Sep 1970 A collision between an Illinois Central (IC) and an Indiana Harbor Belt (IHB) train in Riverdale, Ill. which caused the IC caboose and two other cars to override the underframe of the IHB locomotive.
2. 8 Oct 1970 An incident involving a Penn Central freight train and a passenger train near South View, Conn. again demonstrating the weakness of the locomotive crew compartment.
3. 6 Jun 1975 Collision of three freight trains near Leetonia, Ohio, once more prompting the NTSB to reemphasize recommendations for increased cab crashworthiness, including consideration of a readily accessible crash refuge.
4. 18 Sep 1978 Louisville and Nashville freight train collided head-on with a yard train inside yard limits at Florence, Alabama. The lead unit of the yard train overrode the freight train lead unit.
5. 11 Aug 1981 A Boston and Main freight train and a Massachusetts Bay Transportation Authority commuter train collided head-on-near Beverly, Mass. The lead car of the commuter train overrode the freight locomotive.

NTSB's investigations of the above accidents resulted in four recommendations to the FRA regarding crashworthiness protection to the locomotive operating cabs.

6. 13 Apr 1983 Rear-end collision of two Burlington Northern (BN) freight trains near Pacific Junction, Ia. The operating cab of the lead locomotive on one train was overriden and crushed by the caboose of the other train.
7. 10 Jul 1986 A Union Pacific (UP) freight train struck a standing UP freight train near North Platte, Neb. at a speed of about 32 mph. Three locomotives and eleven cars from both trains derailed, and the cab section of the moving train was destroyed on impact.

Accident/Incident Data

A 10-year history of passenger equipment incidents that railroads have reported to the FRA was compiled. These were grouped in the following categories:

"Train accidents" include all collisions, derailments, or fires involving passenger trains that resulted in more then $6,300 damage to on-track equipment, signals, track, track structure, or road bed.

"Grade crossing accidents" include all reported impacts of a passenger train with cars, trucks, busses, farm equipment, or pedestrians at grade crossings.

"Non-accident passenger train incidents" include all reports of injuries or deaths of passenger train accident or grade crossing accident.

Recommendations of the NTSB

As a result of investigations of numerous accidents involving passenger trains over the past 20 years, NTSB has made recommendations to the FRA or the passenger railroad industry, which include:

- provide for emergency escape from passenger cars, with appropriate emergency lighting and back-up emergency power;
- require that passenger cars have secured seats and luggage retention devices;
- require that rail passenger equipment be fitted with roof escape hatches;
- initiate studies to determine the relationship between passenger car design and passenger injuries;
- establish minimum design and construction standards for the interiors of passenger cars, to provide adequate crash injury protection;
- establish minimum safety standards for the inspection and maintenance of railroad passenger cars, and;
- amend the power brake regulations to provide appropriate guidelines for inspecting power brake equipment on modern passenger cars.

Efforts to Date to Develop Regulations

Work has been afoot for some time to develop comprehensive regulations for the passenger industry, though not without numerous barriers.

In the 1980's freight railroads progressively withdrew from the business of hauling passengers. As a natural consequence of this movement, the AAR (whose committee members were largely from the freight roads) stopped maintenance of the passenger standards that existed until that time. The AAR's "Specifications for the Construction of New Passenger Equipment Cars", S-034-69 was orphaned, left to languish in the memory of its 1938 roots. Congress then took action, directing the FRA to look into assuming responsibility for ongoing passenger car safety standards. In a 1985 response, the FRA concluded that "passenger operations had compiled an excellent safety record and a major regulatory effort was not necessary...,"and declined to act to formalize the then present rules and regulations.

In 1992, Congressional agitation was evident. This resulted in a directive to the FRA to "review of the Department of Transportation's rules with respect to railroad power brakes, and, not later than December 31, 1993...revise such rules..." The process has been long and exhaustive. On December 31, 1992, the FRA published an Advanced Notice of Proposed Rulemaking (ANPRM) relative to this issue. An NPRM followed in 1994. Subsequent discussions involved so many parties and drew such intense response that soon after, the FRA withdrew the NPRM and has only this year reissued a new version of the original ANPRM, as part of the larger Passenger Safety Standards effort. Another NPRM will surely follow before the rule becomes final.

Congress was not pleased. So with all this as a backdrop, the Federal Railroad Safety Authorization Act of 1994 (title II, Pub. Law No. 103-440; Nov. 2, 1994) was enacted. Section 215 of the Act amends 49 U.S.C. 20133 to require the Secretary of Transportation to prescribe "minimum standards for the safety of cars used by railroad carriers to transport passengers."

Given the breath of the specific items listed in the Act, it is evident that the intent was to have the safety of rail passenger service considered as a whole, determining the extent to which existing regulations should be supplemented or strengthened. New passenger safety regulations will include standards for equipment crashworthiness, power brakes, train control and signal systems, track safety, employee testing and training and hours of service for safety-critical personnel. Locomotives specifically fall within the scope of the Act, especially when passenger transportation is viewed from the broader systems standpoint.

The Act gives the FRA a sizable task; it requires the FRA to:

(1) develop *initial* rail passenger equipment safety standards by November 2, 1997 and,
(2) develop *final* regulations by November 2, 1999.

People are becoming increasingly fearful about rail safety. Congress is ticked off that needed regulations still don't exist, even after some mandates for action have passed. The FRA wants to show that this *appearance* of chaos does not really reflect the true state of the passenger and commuter industry.

Yet, the FRA is on the hook for these new safety regulations. The pressure to act is mounting. The timetable is short. Traditional avenues for rulemaking won't work, because they would take too long. The charge is becoming quite difficult...

3. How Do We Fix It?

The prescription of what needs to be done must then deal with the two questions previously introduced:

(1) How do we make these new Federal regulations appear?
(2) How do we maintain standards and recommended practices to partner with these new regulations?

Development of Federal Regulations

So how do we make these new Federal regulations appear? The work presently underway holds great promise to overcome the numerous delays experienced thusfar.

Some industry voices believe that we should begin by looking to the broad experience base in Europe. The UIC standards in effect there are a result of much collective wisdom and experience of how to handle increasing speeds with commensurate growths in safety. They indicate that many sound guidelines can be acquired as a result of this activity.

It would be indeed short-sighted, not to exploit the great body of effort put forth to develop the expertise that the UIC standards embody today. The shortcoming with this approach is that European trainsets do not meet the structural or operating standards that are common practice for current North

American equipment. The North American railroad operating environment requires passenger equipment to operate along side some of the heaviest and longest freight trains ever assembled, often over track with frequent grade crossings used by heavy highway equipment. Thus, not all European passenger equipment design standards are appropriate for the North American operating environment. A unique set of North American standards is needed, to maximize the safety of future passenger rail operations and to facilitate continued sound planning.

A passenger-specific Power Brake Law is also needed. This activity arises out of a 1992 mandate that had stirred up "dust" on the path toward a proposed rule. The lessons learned from the freight roads must be adapted to the unique operating conditions that face passenger and commuter operations. The safe practices of existing operations need to be consolidated and then augmented with new regulations that take into account emerging new technologies.

The degree of difficulty involved with developing new safety standards was not lost on those who penned the Act. To achieve this new landmark in Federal rulemaking, the FRA has "consulting" privileges, to deal directly with Amtrak, public authorities, passenger railroads, passenger organizations, and rail labor organizations without being subject to the usual cumbersome regulations.

The Working Group

The FRA established a Passenger Equipment Safety Standards Working Group (working group) to provide for the bulk of this consultation. This working group first met in June 1995, and continues to meet to help develop these new safety standards. As well, other working groups were formed to apply specific expertise toward development of these standards. These include the Emergency Preparedness Working Group and the Power Brake Working Group. The FRA uses these and other interested parties, to provide information and views pertinent to the rulemaking effort.

This main working group, informally known as PRESS (Passenger Rail Equipment Safety Standards), is diverse in its representation. Along with its private sector members, an FRA representative chairs the group. Staff members from the FTA and NTSB are involved, as well as others, including technical personnel from the Volpe National Transportation System Center. Passenger rail equipment suppliers, designated by the RPI, are also included, as associate members.

The working group will focus on developing safety standards for rail passenger equipment, including cars and locomotives, by applying a fact-based system safety approach to:

(1) determine and prioritize safety risks;
(2) determine steps or corrective actions to reduce risks, and optimize safety benefits.

The working group will also recommend future research or test programs when a technology appears to have the potential for a safety benefit, but is not yet mature enough to be applied with confidence.

The working group will provide advice to the FRA on all phases of the rulemaking process, to include:

(1) recommending what issues or requirements must be covered by Federal regulations, and which ones can be effectively handled outside the body of Federal regulations by industry standards or

some other means;

(2) reviewing the oral and written comments received, as the proposed rule progresses through the required phases toward a final version;

(3) providing cost information and other pertinent advice to support the FRA's economic analysis of the proposed rule;

(4) providing information and advice on the potential benefits of the proposed rule and its individual elements;

(5) reviewing and critiquing drafts of the proposed rule, as it progresses through the required phases toward a final rule;

(6) recommending actions to take to respond to any petitions for reconsideration received as a result of the final rule.

With all that the working group must accomplish, there are many questions that arise anew, out of the course of action. What keeps this working group together to provide an effective continuing industry voice for passenger regulations? What vehicle can be used to ensure that applicable UIC standards are considered in the rulemaking process? What about being able to catalog the collective wisdom of the industry through standards and recommended practices?

In the working group, the American Passenger Transit Association (APTA) has come to the fore. This group has accepted a tremendous responsibility for the passenger and commuter industry to date, maintaining an organization that promotes continuing dialog for safe, efficient operations. As well, they are keenly aware that the expertise they provide could be an effective force in the realm of safety standards. Using this activity as a launch, APTA has offered its organization to coordinate many of the diverse efforts into a cohesive force for effective rulemaking activities.

Maintenance of Standards and Recommended Practices

With the AAR discontinuing the practice of maintaining passenger equipment standards, a new structure is urgently needed to meet this significant challenge. As standards activity becomes further focused, APTA would also be willing to take on the same role for passenger equipment standards definition and maintenance that the AAR now exercises for freight equipment.

APTA has developed an initial pass at a standards committee structure that will effectively address the ongoing concerns, relative to maintenance of standards and recommended practices. Sub-committees would be established and overseen, so the same degree of rigor enjoyed by the freight concerns would be practiced for passenger equipment standards. The arrangement, shown in Figure 1, will be subject to further review by parties directly involved, and by industry regulatory agencies.

Commuter Rail Standards Committee Structure

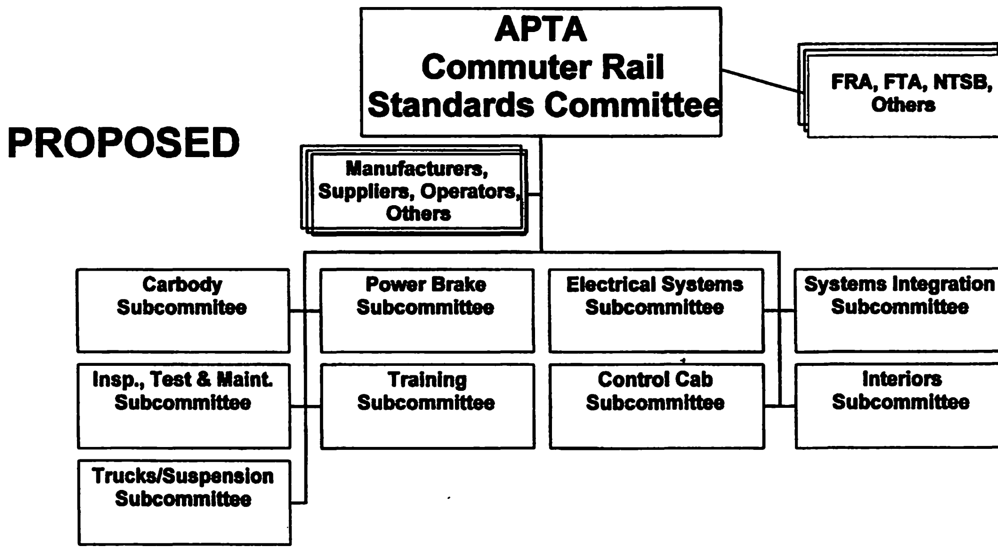


Figure 1.
APTA Proposed Committee Structure

4. What Will it Mean?

The rulemaking effort will deal with several specific topics, including:

(1) system safety programs and plans;
(2) passenger equipment crashworthiness;
(3) inspection, test and maintenance requirements;
(4) training and qualification requirements for mechanical personnel and train crews;
(5) excursion, tourist and private equipment;
(6) commuter equipment and operations;
(7) train make-up and operating speed;
(8) tiered design standards based on a system safety approach;
(9) fire, safety; and
(10) operating practices and procedures.

As a way to approach the above topics within the diversity of passenger and commuter operations, passenger equipment will be segmented into three tiers:

The first tier will involve conventional equipment and will be operated at maximum speeds of 110 mph or less.

The second tier will be reserved for more specialized equipment designed for higher speeds.

A third tier for museum or tourist equipment is also contemplated, but is now envisioned to be covered as a result of a separate effort.

<u>**The Bottom Line for Motive Power**</u>

How is this activity likely to affect those with the responsibility for operating and maintaining mainline passenger locomotives and multiple-unit (MU) equipment?

Although the bulk of the new regulations will be specifically focused on passenger and control cab cars, a number of areas are targeted for application specifically toward motive power. These include:

(1) Locomotive crashworthiness
(2) Operating cab structure
(3) Fuel tanks
(4) Safety inspection requirements
(5) Maintenance program requirements
(6) Personnel qualification.

New power-brake rules for passenger equipment are also being developed. Previously, this was handled through a special subcommittee. Due to time and logistics constraints, it was decided to include passenger equipment power-brake activity within the scope of this effort. Freight equipment power-brake regulations and standards will be developed separately.

<u>**Locomotive Crashworthiness**</u>

To fully treat locomotive and cab car structural requirements, a symposium was held in June, to discuss potential crashworthiness strategies. The agenda included finding ways to maximize survivability for passengers, while optimizing locomotive and control cab car survivability. Energy absorption and deflection models were treated. Findings are aiding in completion of structural standards, part of the rulemaking activity now underway. Among expected changes are increased strength corner posts. Others will be coming, as well.

The NTSB calls for improvements in locomotive crashworthiness, pointing to the results of many freight train accident investigations. A question at hand is. "How applicable are these data to train collisions?" This issue is complex, as there are many different types of collisions to consider. Can these past collisions be an effective predictor of the type of damage to be expected in future incidents?

Structurally, locomotives built to AAR S-580 crashworthiness standards fare relatively well in collisions with highway vehicles and even control cab cars. For example, a near head-on collision occured between an Amtrak and a MARC train in Silver Spring MD., in February. With an impact speed of more than 50 mph, the Amtrak crew escaped with only minor injuries, using a locomotive built before the S-580 crashworthiness standards were in place. Control cab cars, however are a completely different matter, as their history of crashworthiness is not nearly as promising. The MARC car demonstrated this weakness in the same incident, as the forces from the collision lopped off the entire left side of the car's control cab, allowing it to be carried away with the locomotive.

This all being said, locomotive crashworthiness measures alone do not ensure the integrity of the cab compartment. On February 9, 1996 in Secaucus, NJ, a New Jersey Transit GP40 locomotive collided nearly head-on with a cab car. The locomotive structure survived well, but the roof cant rail of the cab car entered the locomotive cab through the windshield, killing the engineer. Again, the cab car operating compartment was decimated, as is typical in this type of crash.

Cab Survivability

Cab survivability was also analyzed and reviewed in the June symposium. Along with the concerns over glazing, and cab attachments, the NTSB cites a disturbing reality that when a locomotive strikes a caboose or a lighter rail car, the lighter vehicle typically overrides the locomotive, often destroying its operating cab. NTSB first issued a recommendation to the FRA to initiate and/or support a design study to provide a protected area in the locomotive operating cab for the crew when a collision is unavoidable (NTSB Recommendation R-83102). Later, after no action was taken, the NTSB issued Safety Recommendation R-87-23, which recommended that the FRA promptly require locomotive operating cabs to provide crash protection for their occupants. This issue is still open, but is being addressed by the task team for the upcoming rule. Expect more changes to come.

Fuel Tanks

At this time, the plan for passenger locomotive fuel tanks will closely follow existing AAR RP-506 recommendations. New regulations for structurally integral fuel tanks will also be written, in recognition of the success of the tanks employed on GE's Genesis series locomotives.

Power Brake Rule

The new power brake rules will take the sound practices that are in place today and launch these into the special cases of modern passenger service. For instance it rarely makes sense to stop a train full of passengers at a next repair point for defective brakes, when they can safely be transported to the next station. The new rules will also address the modern realities of electronic air brake control and new style parking brakes.

Maintenance and Personnel Issues

There's universal concern about maintenance and inspection issues, likewise, for personnel training and qualification. The new rules will establish minimum requirements for these criteria, using the best practices of the member roads as a point of reference. Amtrak has been extremely helpful to the group here, with many formal practices in all of these areas.

Cost

The issue of cost cannot be ignored. If cost were no object, full train control and other safety devices would be installed everywhere and cab cars would be as strong as locomotives. The sky would be blue, the grass green, and there would be no hole in the ozone layer. But the real world isn't like that. What we are trying to do is put the limited resources where they will likely do the most good.

One of the side benefits of the rulemaking effort underway, is that new arms of the government will learn of the true financial situation that faces many of the roads that operate with government funding. Maybe extra funding can come out of this new knowledge in order to institute some of the safety measures that would be in place now, but for lack of the funds to provide them.

5. Summary

The issue of rail passenger safety is as visible now as it has ever been. When the lags in rulemaking and upkeep of standards are overlaid on a rising count of passenger rail accidents, industry credibility suffers.

Using APTA, the industry has once again developed a creative solution, effectively addressing the Federal agencies, Congress and ultimately the traveling public. Yet, the passenger rail community must offer a continuing commitment to this new responsibility.

An historic point? The past few decades have seen passenger and commuter rail service in the United States relegated to mostly a second-class mode of travel. The view is only more solidified with the latest questions of safety in the industry.

The new safety regulations now being developed can help reverse this trend. Although rules alone will not ensure long term viability of this industry, they are a crucial initial volley. If we can stay this course, rail transportation will have its fair shot proving itself as strongly viable among transportation modes in the United States.

Who knows? Maybe new funds *can* come, as a result of our government's heightened awareness of the plight of the passenger and commuter roads. This would ease the burden of operation, often now on a shoestring. Each road would benefit.

And, more importantly, so would the US transportation industry.

II. SP-3 THIN SENSOR TECHNOLOGY FOR VARIABLE FORCE MEASUREMENT

Presented by:
Keith Challenger
National Electric Carbon

Traction motor and generator performance is key to the successful operation of major railroads. To ensure optimum performance and reliability of direct current (DC) traction motors, a comprehensive maintenance and overhaul program is usually operated, allowing motors in particular to be replaced and repaired prior to costly failures which may otherwise occur away from the maintenance facility. One of the most critical factors in the successful operation of a DC traction motor is the electric current transfer system which comprises the copper commutator, the carbon brushes and brush holders. The electromechanical interface between the carbon brush and the commutator surface is extremely important, since most electrical motor problems manifest themselves in this area, whether or not the brush and commutator are actually at fault. The objective of the carbon brush and commutator interface is twofold:

(1) To facilitate the transfer of electric current from conductors on the stationary frame of the motor to the rotating armature (or vice versa); and
(2) To enable current reversal in the magnetic coils of the armature - a process known as commutation.

To achieve these objectives efficiently, the carbon brush must be capable of maintaining a firm, intimate contact with the rotating commutator. The brush is therefore held firmly in position by a closely-toleranced fit within the brush holder, and a mechanical spring device which is an integral part of the brush holder but applies force to the top of the carbon brush, thereby pressing the brush firmly against the commutator surface. This force is usually not adjustable on a DC traction motor brush holder. The brush holder manufacturer will build the holder with the appropriate spring to exert the contact pressure specified by the brush manufacturer or motor designer. If the contact pressure is excessively high or low, problems can result which compromise the performance of the motor and can lead to excessive maintenance costs.

Problems caused by heavy contact pressure

When excessive force causes the brush to be pressed too hard against the commutator surface, the result is an increase in friction. This causes excessive heat to be generated, as well as an increase in carbon brush and commutator surface wear. Heavy contact pressure will also lead to loss of the graphite/oxide film which is deposited on the commutator by the carbon brush. This film, which is essential to good brush performance and comprises layers of copper oxide, water vapor and graphite, reduces surface friction and stabilizes contact voltage drop at the brush/commutator junction. Without this film, and particularly if contact pressure between brushes is variable, unequal current distribution can take place, causing some brushes to wear even more quickly or severely overheat.

Problems caused by light contact pressure

It is not difficult to see why too much

force acting on the brush would present a problem, however light spring force can present an even *more* significant problem. When contact pressure is too low, the physical relationship between the brush and commutator becomes unstable. Even minor surface blemishes on the commutator can disturb the brush causing momentary loss of contact which of course produces sparking at the brush face. This in turn increases the electrical erosion which significantly increases brush wear (see Figure 1). Rapid radial movement of the brush also creates an abnormal level of noise, often referred to as brush "chatter," and results in an abrasive condition that can cause commutator surface damage, as well as chipping/damaging the brittle carbon brush material, fraying the copper shunt wires, and other damage.

Relationship between contact pressure and brush wear

At this point, it is worth mentioning that carbon brush wear is caused by two different, though often related phenomena. The first is mechanical friction, which causes wear between two surfaces that are constantly rubbing against each other. Because the brush is softer and more brittle then the commutator copper, the brush is expected to wear more quickly. This is of course desirable since the brush can be replaced far more easily and cheaply then the commutator. The second phenomenon is wear caused by the transfer of electric current and is known as erosion. This electrical erosion can have a far more dramatic effect on the rate of carbon brush wear than the frictional wear caused by high spring force. This is Illustrated in Figure 1 which shows a much steeper curve in the area of light spring force compared to the more gradual curve in the heavy spring force section. This suggests that in conditions where the spring force is adjustable but cannot easily be measured, it is generally better to set higher, rather than lower spring force.

Measuring spring force

Force can be defined as "the exertion of physical strength" and may be measured directly using some form of pull scale, similar to that illustrated in Figure 2. As you might imagine, the use of such a device (or its electronic counterpart) is very difficult in the limited space available under a locomotive. It requires conviently-located inspection covers (an uncommon luxury!) and adequate illumination. Due to the position of the brush holders, it is physically impossible to check certain springs using this method. Furthermore, the readings from this device are produced by lifting the spring upward, which is the opposite direction to that which is producing contact pressure, thereby leading to some inaccuracies. In order to allow brush manufacturers to specify the required force regardless of brush size, carbon brush applications are specified in pressure, the force acting per unit area, rather than force. Therefore, having obtained a reading from this or a similar device, the force measurement must be converted into pressure by using the carbon brush dimensions in the following equation.

$$\frac{\text{Force in lbs (reading from measuring device)}}{\text{Area in square inches (thickness x width of the brush)}} = \text{Pressure (psi).}$$

Contact pressure

It can easily be seen that calculating the contact pressure, using a less-than-ideal measuring device and relying upon calculation with the attendant possibility of human error is a far from ideal situation. Add to that the fact that we are measuring upward force at the *top* of the brush and assuming there is no additional force caused by the mass of the brush and that no force is negated by friction between the brush and brush holder. Clearly, what we are assuming to be contact pressure is really nothing more than a rough approximation. This is reflected in the wide range of "acceptable" pressures specified by brush manufacturers. National Electrical Carbon Products for instance, specifies pressure for transportation applications of 6 to 10 psi.

It would clearly make far more sense to measure the force directly under the brush by placing some form of load cell between the brush face and the commutator surface. The problem with this approach is that the space available for placement of such a load cell is extremely small. Most reference sources recommend that the gap between the bottom of the brush holder and the surface of the commutator should be between 1/8" and 3/16". A device recently advertised as "the world's smallest load cell" has a total height of 1/4" *without* making allowances for any form of protective enclosure.

The breakthrough

After much research, National Electrical Carbon Products, Inc., was able to form a strategic alliance with a technology partner to solve the problem by using this film resistance sensor technology.

A semi-conductive junction is formed by taking two layers of substrate material such as polyester or polymide film and depositing a layer of conductive material to each substrate. A layer of special pressure-sensing resistive material is then placed between the two conductive surfaces and the whole junction is aligned and bonded together with adhesive in such a way that force applied to the substrates causes an inversely proportional change in resistance between the two conductive layers (see Figure 3). Typically, the resistance range of a sensor made in this way will be from several megohmas to about 20 k-ohms. This technology yields flexible sensors with an actual sensing area thickness of around 0.003".

The next step in the development process involved the design and creation of a hand-held control device, which would be battery-operated for maximum portability, with the capability of converting the resistance changes in the sensor and displaying these data as force readings on an LED display. It was decided that the device should be called SP-3.

SP-3

Whilst creating a design specification for the SP-3, it was realized that by adding numeric functions to the handset, the brush thickness and width dimensions could be entered, thus allowing the SP-3's processor to automatically calculate and display contact pressure. Other added functionality included the ability to read and display temperature by using a thermistor-based sensor in place of the force sensor, and selecting either American or metric units for pressure, brush size and temperature in order to make SP-3 easily available to export markets.

Force Sensors

The force sensors were designed to be small and flexible enough to be placed under the carbon brush by lifting the brush slightly, then lowering it gently onto the sensor. A small positioning clip is supplied to assist with locating the sensor under brushes in difficult-access areas. Also, the sensing area is covered with a small rubber disc which spreads the applied force more evenly over the entire sensing area which is approximately 1/4" diameter (the SP-3 sensors cannot be used on a brush whose smallest dimension is less than 1/4"). Each sensor is individually calibrated for maximum accuracy, and the calibration number, along with manufacturing batch information is printed on a small white label which is integral to every sensor.

SP-3 temperature measurement capability

Like most resistive devices, the SP-3 force sensors can be affected by temperature extremes. SP-3 is designed as a shop maintenance instrument for use at or near room temperature and should never be used on a commutator which is still hot from operation. The operating temperature range for the SP-3 force sensors is currently 40° F to 110°F, although higher temperature sensors are presently under development. A small thermistor-based temperature sensor is supplied with the SP-3 and can be inserted in place of a force sensor to measure the temperature of the commutator *before* taking force readings. This temperature sensor would typically be placed under a carbon brush, between the brush face and the commutator. The SP-3 handset will indicate the temperature in either Fahrenheit or Celsius depending upon whether the handset has been set to American or metric units. When the temperature reading stabilizes (typically under a minute), the ENTER key on the handset is pressed to register the temperature value. The temperature sensor can then be replaced by a force sensor and all subsequent pressure indications in the LED display will automatically be temperature-compensated. No further temperature measurements are required unless the commutator temperature changes by more than 1 degree, at which time the simple procedure can be repeated.

Force sensor capability

There are three different sensor types available for the SP-3 which are color-coded as follows:

Sensor Color Application	Force Range at... 68°F	100°F
Green Small industrial drives	3.0 lb.	1.3 lb.
Yellow Medium/large industrial	8.0 lb.	3.5 lb.
Red Transportation	24.0 lb.	10 lb.

The rated accuracy of the sensors is +/-10%

Although the sensors are relatively robust, it is unrealistic to expect them to receive delicate handling in a railroad maintenance environment. Therefore, a significant amount of development effort was devoted to creating a process which allows the sensors to be manufactured at a modest cost, allowing them to be replaced frequently. It is recommended that each sensor be used for no more than one hundred measurements unless it becomes damaged or defaced in some way when, of course it should be discarded sooner.

The handset is supplied with a padded canvas carrying pouch for protection during use. However, if the handset should receive unexpectedly rough treatment, it can be checked for correct operation by using a small resistor plug which is supplied with the unit. This plug is used in place of a force sensor, and by following a routine specified in the user's manual, correct handset operation can be verified.

Conclusion

The SP-3 measuring instrument (Figure 4) is designed to make carbon brush contact pressure measurement simple. The sensors provide appropriate accuracy and repeatability for the maintenance environment in which they will be used and are capable of satisfying the need for an extremely thin, economically-priced force sensor. Future development efforts will address the need for force measurement capabilities in other applications at a wider range of forces and temperatures.

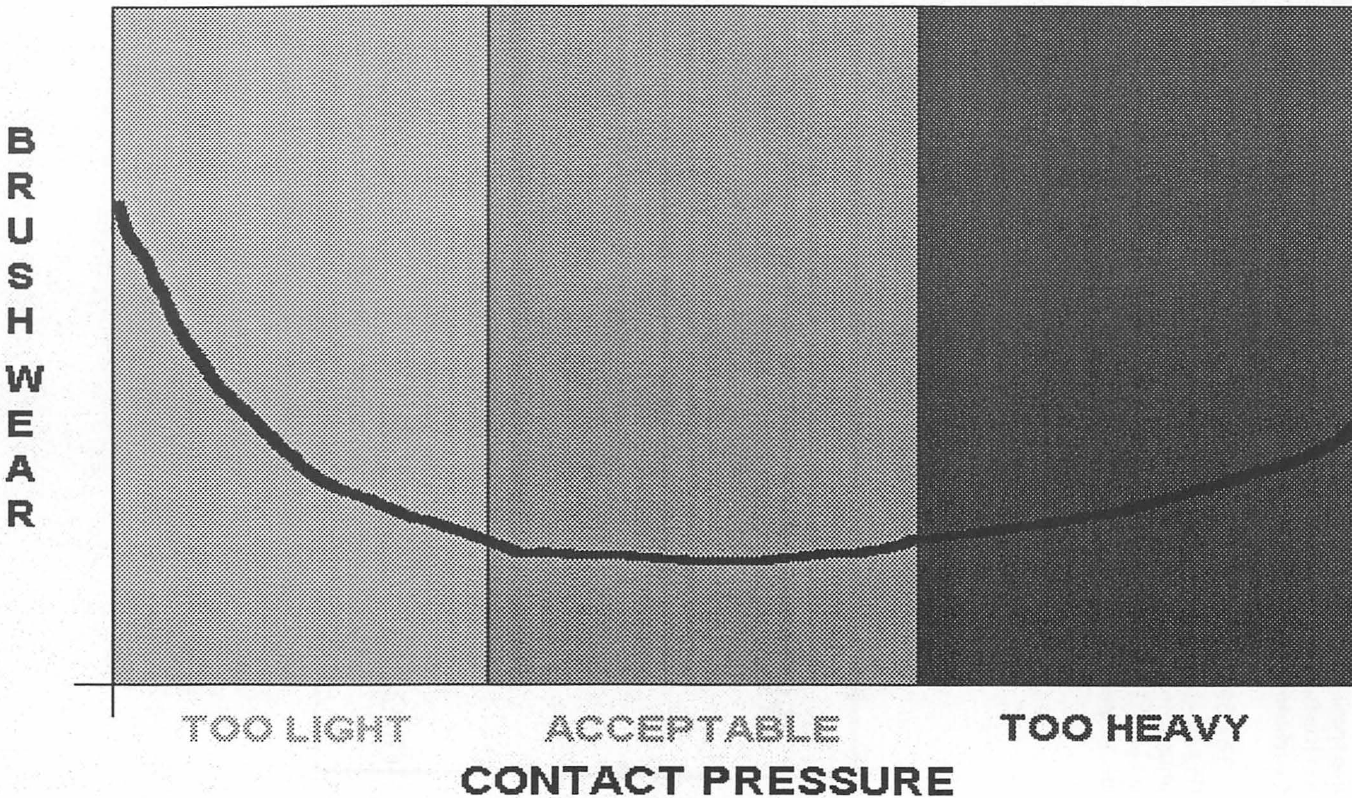

BRUSH WEAR
TOO LIGHT
ACCEPTABLE
TOO HEAVY
CONTACT PRESSURE

Figure 1

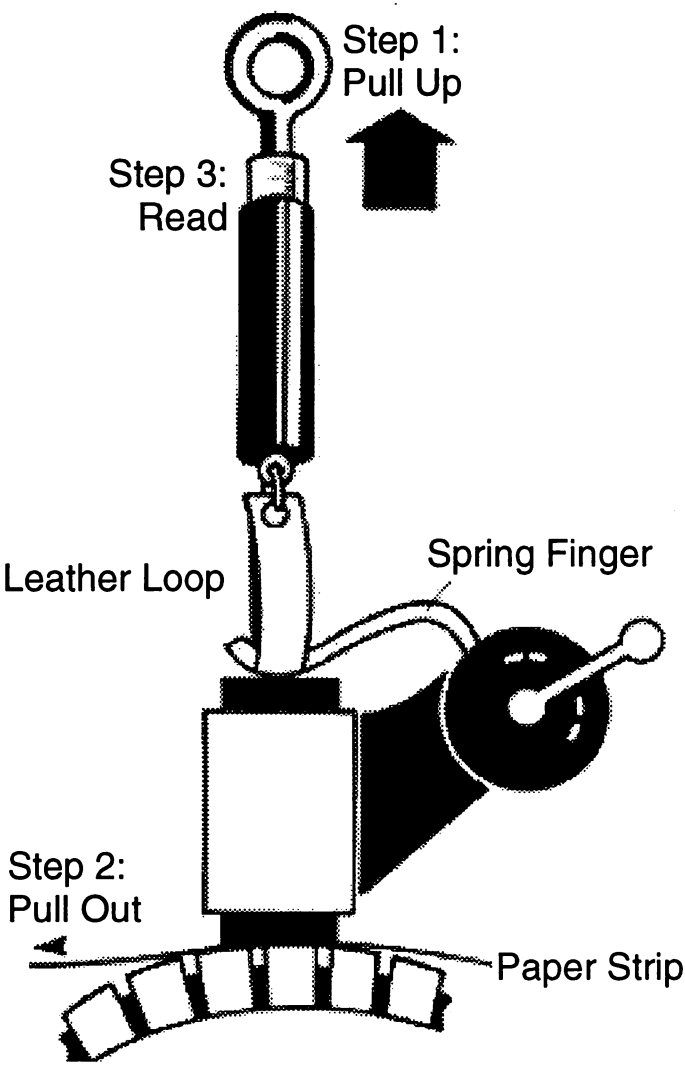

Step 1:
Pull Up
Step 3:
Read
Leather Loop
Spring Finger
Step 2:
Pull Out
Paper Strip

Figure 2

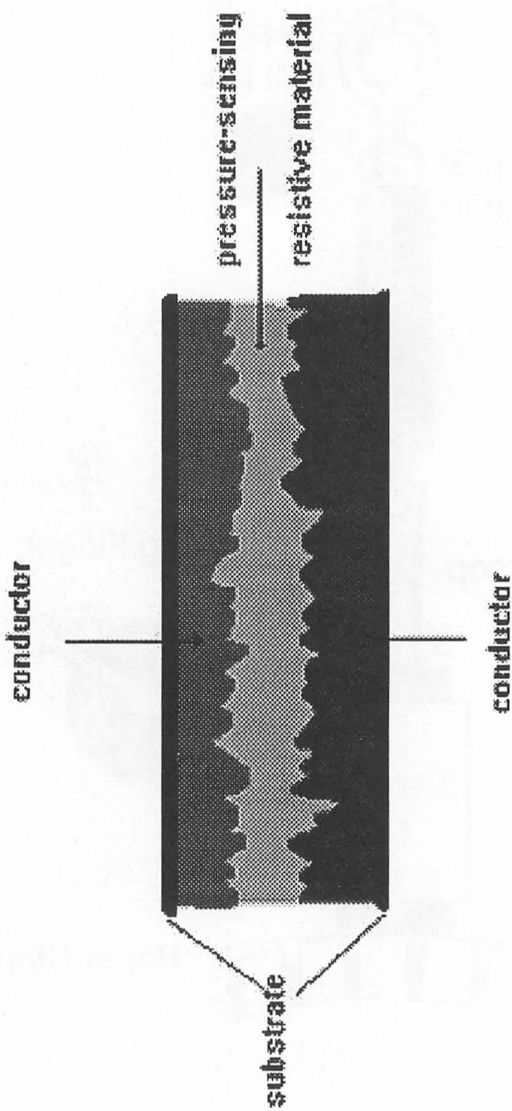

pressure-sensing
resistive material
conductor
conductor
substrate

Figure 3

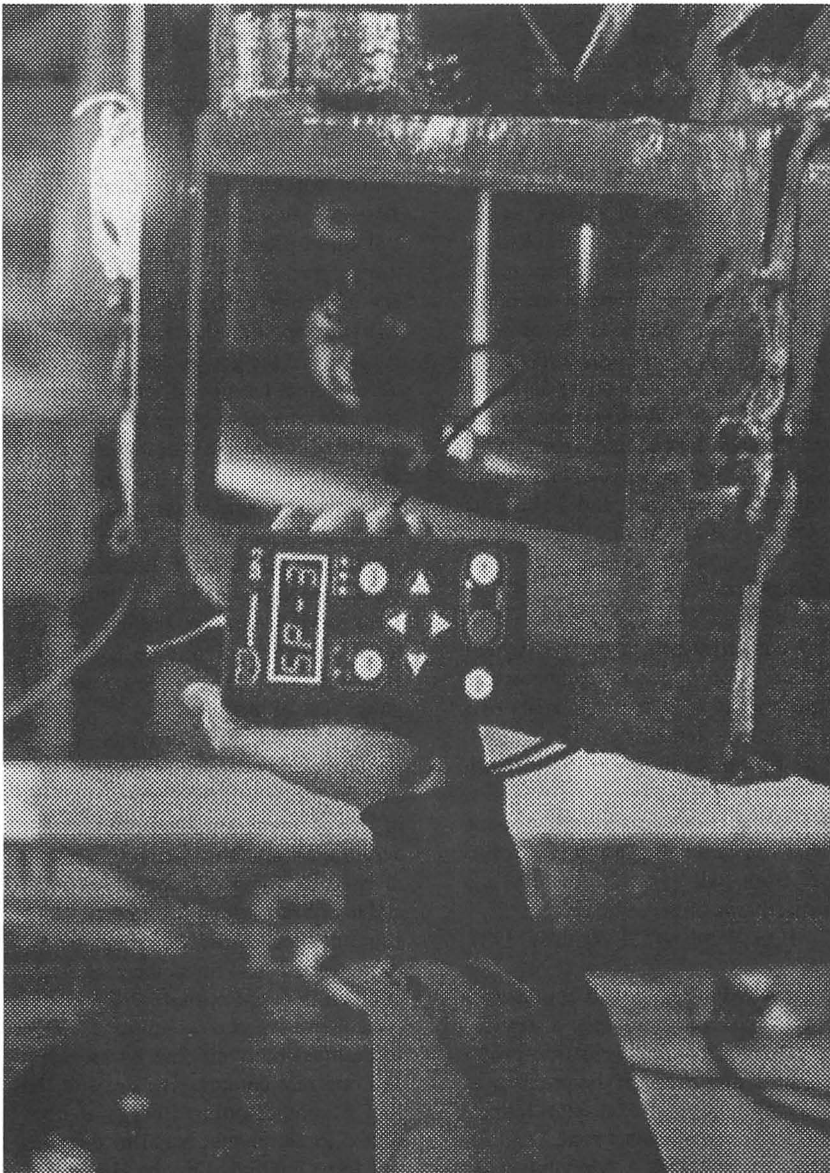


Figure 4

III. TOP-OF-RAIL LUBRICATION

Presented by:
Robert S. Runyon P.E.,
Norfolk Southern Corporation;
and
Dr. Sudhir Kumar
Tranergy Corporation

The rolling resistance of rail cars caused by friction has been the subject of numerous technical studies, as has the much larger field of track/train dynamics. Lubrication, in its many forms, has been perceived as one of the more promising methods for counteracting the effect of friction at the wheel/rail interface. A novel approach to the subject of rail lubrication, developed through the cooperative efforts of Tranergy Corporation, Norfolk Southern Corporation, and Texaco, is presented in the following discourse.

The problem

"Wear (friction) at the rail-wheel interface is an important technological nuisance, which in the U.S. costs two billion dollars annually..." (1)

Ernest Rabinowicz, M.I.T., 1981

"The maintenance and replacement of that rail is our biggest single dollar cost...Both fuel and rail are very big expense items on all railroads." (2)

H.G. Webb, ATSF Railway, 1987

"Current lubricants and application methods have only provided a superficial solution to rail lubrication problems....the root cause of the problem is the development of excessive lateral creep force in the contact zone." (3)

Mark A. Mulvihill et al,
Gulf Oil International, 1994

The above costs incurred by the railroads are largely due to undesirable wheel and rail damage and increased rolling resistance. The latter originates from wheel/rail friction, largely due to one or more of the following conditions:

1. Unequal tread diameters within a wheelset
2. Truck misalignment
3. Inter-axle misalignment.

The concept of wheel/rail friction is best introduced by considering a typical three-piece rail truck rolling on curved track as shown in Figure 1, with the curvature exaggerated for ease of illustration. For the moment, let us assume that the gauge clearance is near zero, so that the truck frame is parallel to a line tangent to either rail at a point halfway between the two axles. Because both axles are mounted between rigid side frames, each wheel is forced to roll in a direction slightly different from that of the rail alignment. The angle between the two directions is known as the angle of attack, and has the tendency to force one flange of each wheelset to contact the gauge face of the rail.

To negotiate the curve without derailment, the wheels must undergo a continuous change of direction by means of lateral creep, or sliding of the treads across the rails. This action is strongly resisted by friction between the tread and top of rail, with a force equal to the combined weight of the wheelset and its supported load times the coefficient of friction (approximately 0.3 under typical dry weather conditions). This force must be overcome by an equal and opposite compressive force at the flange contact point. Energy is consumed in an amount equal to the contact force multiplied by the lateral distance through which the wheelset slides. The flange, making contact at a larger diameter than the tread, will roll with a higher peripheral speed and rub against the rail gauge face, leading to additional friction losses.

In a realistic curve, each wheelset is permitted some free lateral movement between points of flange contact due to gauge clearance. This amount can vary from about 5/8 inch for new wheels and rails to more than 1-1/2 inches for worn wheels and rails. As illustrated in Figure 2, this condition permits the leading wheelset to assume a much larger angle of attack when compared with the simplified case, while reducing that of the trailing wheelset. However, given the customary tapered tread profile, the leading wheel on the high rail will roll on a larger diameter and pull ahead of the opposite wheel, thus partly mitigating the effect of gauge clearance and helping to steer the truck around the curve. Flange contact will likely become intermittent under this condition, especially at the trailing axle.

Lateral creep of a wheelset can occur only during flange contact. The lateral creep distance, expressed as a fraction of the rolling distance, is numerically equal to the angle of attack in radians. In the simplified example of Figure 1, with a typical axle spacing of 5-1/2 feet, this value is approximately 0.00048 times the track curvature in degrees.

Longitudinal creep, or sliding of the treads parallel to the rails, occurs when the tread diameters within a wheelset are not equal, or when the tread profile fails to compensate for the unequal rolling distances through a curve. The total creep distance at both wheels during one revolution is equal to the difference in circumference of the treads. As with lateral creep, energy is consumed in an amount equal to the creep distance at each tread multiplied by the friction force, which in this case is applied oppositely to both treads and need not be balanced by flange contact.

When rolling on tangent (straight) track, any residual misalignment tends to drive the leading wheelset into flange contact, while the trailing wheelset is pulled away from any similar contact with the opposite rail, causing it to follow the leading wheelset and reduce the angle of attack. For this reason, the trailing wheelset of a truck is likely to remain more or less centered between the rails, and experience flange contact less often and with less force than the leading wheelset, as will become evident from the test results presented in a later section. In practice, rail trucks on tangent track are observed to "hunt" or oscillate about the direction of track alignment, the exact behavior depending on the tread profile and equality of diameters within a wheelset, among other factors.

Performance will also be affected by misaligned (non-parallel) axles within a truck, bending its natural free-rolling path into a curve. Given the typical axle spacing as stipulated in the example above, a truck with misalignment of two milliradians could traverse a two-degree curve with zero angle of attack. Of course, this condition would have an adverse effect in curves of the opposite direction and on tangent track, causing preferential flange contact on one side. The effects of truck and inter-axle misalignment are illustrated in Figure 3.

The Association of American Railroads has measured angles of attack at all wheelsets of several trains while operating on tangent track, providing data from which the inter-axle misalignment was obtained by subtraction. The results of this work were presented by Som P. Singh in AAR Report No. R-800, to which the reader is referred for more detail. Distributions of the percentage of axles observed at various angles of attack and misalignment were obtained from this report for illustration in Figure 4.

Friction between wheels and rails contributes to the cost of train movement in two ways: added work must be done and fuel consumed to overcome the friction, which work serves only to accelerate wheel and rail wear, thereby shortening their useful life.

The solution

It is apparent that lateral creep and other sliding motions between wheels and rails are unavoidable with present-day rail vehicles and track geometry, but the lateral force and energy required to sustain such motion can be greatly reduced if the friction between sliding surfaces is controlled by lubrication. For many years, wayside rail lubricators have been placed at critical locations along the track to reduce friction at the flange contact points, with the primary goal of preventing derailments. While such devices are useful, they must be installed and maintained at numerous locations to properly lubricate the tracks of a large railroad.

More recently, attention has been focused on rail lubrication using equipment mounted on the train, more specifically on the locomotives to keep the logistics manageable. Several application methods have been tried with varying degrees of success, in which a lubricant is applied to the tread/flange interface of locomotive wheels, with the intent of secondary application to the rails through flange contact at the gauge face. Lubricants used for this purpose have included oil, grease, and graphite. Obviously, the tread surfaces cannot be lubricated in this manner without loss of adhesion.

At best, flange lubrication can only reduce friction at the flange contact points. It does not address the friction opposing lateral creep at the tread surfaces, nor does it affect the lateral forces exerted on the rails during flange contact. With consideration for these issues, a method was developed for application of a lubricant directly to the top of each rail at a point behind the trailing axle of the locomotive consist. This approach avoids contamination of the locomotive wheels while dealing directly with tread friction in the rest of the train. Although the amount of lateral creep is not affected, frictional losses and wear rates at the tread surfaces are both reduced considerably. It follows that the lateral forces will be diminished in proportion, with the secondary benefit of reduced energy loss and wear at the flange contact points.

Initial research

The lubricant must be selected to optimize the features most needed for the application. Aside from its primary function as a means to reduce friction, the substance must be characterized as:

1. Environmentally safe, to permit abundant use without danger of contaminating the soul or ground water;
2. Non-toxic to permit handling with normal safeguards;
3. Electrically conductive so as not to inhibit the operation of signals by track shunting;
4. Economical, providing provable benefits that exceed the cost of application;
5. Non-freezing in the coldest weather typically encountered;
6. Consumed and/or dispersed at a predictable rate by passage of the connected train, to insure sufficiency of lubrication without leaving slippery rails for the next train to follow; and
7. Non-lubricating at higher than

normal creep rates, to retain present stopping distance during a brake application.

No conventional lubricant has been found to possess all of the above characteristics. Therefore, the development of a successful top-of-rail lubrication system required the achievement of two distinct objectives: to develop a lubricant with the desired characteristics and determine its optimum application rate, and to design and build an application system capable of automatic and reliable operation on board a locomotive. The lubricant eventually developed is a water-based liquid of moderate viscosity, and bio-degradable.

Norfolk Southern first became involved in this project in December, 1993, by which time much of the theoretical and experimental work leading to the development of a suitable lubricant had already been completed through the combined efforts of Tranergy Corporation and Texaco. Our first task at this point was to conduct a feasibility test of the lubricant, using a train of 54 loaded coal hoppers with two six-axle locomotive units, and making several runs over a five-mile section of mainline track from Roanoke to Starkey, Virginia. A modified caboose (NS-51) was included between the locomotive and train to carry an assortment of test instrumentation. The lubricant was applied to both rails immediately behind the trailing wheelset of the locomotive from a pair of pressurized lawn sprayers.

Individual runs were made with various lubricant flow rates, plus a dry run and another run with water dispensed instead of lubricant. Measurements of locomotive electrical horsepower, drawbar force, and track speed were recorded at the rate of four per second throughout each run. At the maximum flow rate used, averaging 0.22 gallon per rail-mile, about five percent less work was needed to complete the trip than with the dry run. This is a significant benefit when one considers that 90 percent of the total work during the dry run was used to overcome gravity. The lower lubrication rates resulted in smaller but measurable reductions in the work needed.

Also during each test run, wayside measurements of lateral force and deflection of each rail were made at the exit spiral of a six-degree curve near the end of the test region. Lateral forces encountered at each rail during the dry run are illustrated in Figures 5 and 6. These were compared with corresponding forces measured during each lubricated run. Sample comparisons of the low rail measurements are shown in Figures 7 and 8, with force distributions of the same data compared in Figure 9.

System Development

Having demonstrated the possibility of significant benefits, it was decided that Tranergy Corporation would proceed with the design of a prototype system for more rigorous testing, which was christened as the "Sentraen 2000." From the hostile nature of the environment and the need for extreme reliability, it was decided that the following design criteria would apply:

1. The system must be controlled by a dedicated computer, which will permit flow rates to be controlled by software.
2. All external connections from the computer, either connected to or in close prosimity with locomotive circuits, must be electrically isolated.

3. The system must contain no unnecessary moving parts.
4. Lubricant will be dispensed through nozzles onto both rails behind the trailing wheelset of the locomotive, and as close thereto as possible to minimize lateral movement relative to the rails when curving.
5. Provision for application at both ends of the locomotive is mandatory to permit bidirectional operation.
6. Flow rate is controlled by pulse-width modulation (PWM) of two solenoid valves at each end of the locomotive.
7. Fully automatic means will be required to disable operation except at the trailing axle of the last unit in the consist, and altogether when the locomotive is operating as a pusher or without a train.
8. The complete system will include as few separate components as possible for ease of installation, using prefabricated cables for electrical connections.

Prerequisite to a successful design is a thorough understanding of the lubricant - especially those characteristics that affect its consumability, which in turn determines the application rate needed. Preliminary research has indicated that the rate of consumption is primarily dependent on the work dissipated due to friction at the wheel/rail contact points, which is proportional to track speed and somewhat proportional to curvature. Consumption at each wheel tread also increases directly with the supported weight, although no exact relationship is yet evident. Most of these initial conclusions are assumptions to a large extent, and will remain so until refined or perhaps disproved by extensive testing in the field.

The foregoing implies a need to adjust the lubricant flow rate in response to several external inputs. Track speed can be measured by an axle generator, already installed on many locomotives. Curvature requires the installation of a device to measure truck rotation. (A gyroscope was considered for this purpose, but none was available with the sensitivity required for lower track speeds and moderate curves.) After much discussion, a linear potentiometer was selected as the best available curve sensor, which visually resembles a shock absorber. With suitable placement, the potentiometer movement (and therefore its output voltage) can be made directly proportional to the trigonometric sine of the truck rotation angle. It can be shown that this value is exactly proportional to track curvature, with a given distance between truck centers.

To adjust for the effect of variable axle loads, a data terminal with keypad and LED display was included whereby the gross trailing tons can be entered, as there appears to be no way for this figure to be determined automatically. The data terminal can also be made to serve other purposes such as diagnostics and self-testing.

Figure 10 shows a functional block diagram of the system as designed from the criteria stated above. The onboard lubricant supply is maintained in a 55-gallon tank, pressurized through a regulator fed by main reservoir air pressure. The pressure tank is rated at 150 psi to protect it against regulator malfunction. The computer and most of the electronic components are housed in a weather-tight box referred to as the main controller. A pressure transducer for connection to the brake pipe was added after completing a series of tests for stopping distance, which indicated a need for lubrication to be shut off during automatic and/or emergency brake applications. The approximate physical location of components on the locomotive is shown in Figure 11.

Preliminary testing

Most of 1994 was spent on design and construction of the prototype unit, which was installed on an EMD SD60 locomotive in November of that year. Field testing was conducted at scattered intervals from this point through early December, 1995, involving several mainline trips with both empty and revenue trains, using the NS-32 research car for data collection. Much of the interspersed time was occupied with hardware modifications to correct defects revealed by testing, and with data analysis to better understand the lubricant.

The initial prototype unit included means to introduce low-pressure air immediately downstream from each solenoid valve, to purge liquid from the lines when not lubricating, and to prevent the nozzles from becoming plugged with dirt or ice. This idea was discovered to be impractical during the first test runs, as the volume of each line was sufficient to cause delays in response of up to 30 seconds. The next version included a pressure-relief check valve just ahead of each nozzle to keep the line filled with lubricant at all times, and a parallel air hose to purge each nozzle. Further observation has indicated that purging with air is unnecessary, the lubricant being sufficient to expel obstructions.

The nozzles were selected to produce a solid jet with no perceptible expansion. Considerable effort was applied toward refinement of the nozzle arrangement, using several combinations of orifice diameter and orientation. With increased flow rates, a small orifice leads to a high-velocity jet which can splatter from the rail upon impact. Conversely, with minimal flow rates, a large orifice will permit the lubricant to emerge as discrete droplets which are dispersed by the wind before reaching the rail. Either of these limiting conditions can be compensated to some extent by adjustment of tank pressure to keep the discharge velocity within acceptable limits.

Another compromise is necessary when defining nozzle orientation and position. The first tests were made with the nozzles directed at a moderate forward angle to minimize the effect of lateral movement, which caused the liquid to splatter onto the locomotive wheel treads and create adhesion problems. Later tests were run with the nozzles more nearly vertical without noticeable improvement. Reluctantly, we concluded that splattering could not be completely avoided with a forward-directed jet. The most recent (and apparently successful) design employs a low-profile bracket to place the nozzle closer to the wheel/rail contact, with the jet directed backward at 15 degrees from vertical.

As already stated, the lubricant must be applied at a variable rate which depends on several parameters. There is no convenient way to measure the flow rate in real time with the response needed to apply feedback control; the alternative is to use open-loop control which depends on a predictable flow rate resulting from a given modulation of the solenoid valves. To determine this relationship, the system components were put through a series of static calibration tests in which various track speeds and curvature values were simulated, and the percent modulation and flow accurately measured.

Figure 12 shows the results of one such test as a series of small circles. A simplified mathematical model of the system was used to derive the solid curve, which was visually fit to the measured data to determine two unknown constants that represent the geometry of the lubricant flow path. With these specified along with viscosity and tank pressure, the model can be used to calculate the modulation needed to produce a given flow rate.

Viscosity of the lubricant has been found to vary substantially with temperature, which is likely responsible for the observed scattering of the data points. For this reason, it became necessary to include one or more temperature sensors as inputs to the main controller. A final decision regarding their number and placement cannot be made until further testing has been completed.

Expanded testing

In October and December, 1995, an improved prototype unit was tested with loaded coal trains operating from Roanoke to Norfolk, Virginia, and with returning empty hopper trains, using a consist of two SD60 locomotives. Similar trains with identical locomotives but without lubrication were tested in early 1996 for comparison. The traction energy generated for each trip in kilowatt-hours was read from the locomotive trip monitors. This value is more closely related to the work performed in pulling the train than is the amount of fuel used, which is impossible to measure accurately in the field.

When the results of these tests were averaged, the lubricated runs showed an energy saving of 42 percent with loaded coal trains and 12 percent with returning empty trains, compared with corresponding dry runs. After correcting for the gain or loss of potential energy due to elevation difference, the saving became 25 percent with the loaded trains and 14 percent with the empty trains. The difference between loaded and empty trains is expected when one considers that lubrication can reduce only friction loss which, with loaded trains, is a larger fraction of the total work done.

It was realized from the beginning that any substantial increase in stopping distance caused by lubrication would undermine all benefits derived from its use. Although the lubricant was designed to become ineffective under the combined effects of wheel creep and brake shoe friction, only a test under operating conditions could verify this feature. Therefore, during one of the test runs, the movement was repeated several times through a short distance and a full service brake application was made each time at the same location. With the data normalized to a common initial track speed, stopping distance was unaffected provided that lubrication was disabled when the brake was applied.

Inspections of the locomotive underframe and running gear after each test revealed no accumulation of oily or greasy deposits which are commonly associated with flange and wayside rail lubricators. Being applied directly to the rails, the lubricant is prevented from being thrown from the wheels by centrifugal force, thus minimizing waste and contamination of the surrounding area.

From the latter part of April through most of May, 1996, the system was tested with a 90-car unit coal train in captive service between a mine near Albers, Illinois and a power plant near Carol, Indiana. Measurements of electrical horsepower, drawbar force, track speed, and various parameters within the lubrication system were recorded four times per second, using instrumentation on the NS-32 research car which was inserted between the locomotive and train. Six round trips were made weekly including those with and without lubrication, over 114 miles of mostly tangent track. Lateral forces on the rails were recorded as the train passed through a four-degree curve near Albion, Illinois.

The above test series was to be continued through the end of June, 1996, with a revised summer formulation of the lubricant. By the time of the conference in September, the test results are expected to be available and will be reported in the presentation.

Concluding remarks

Friction at the wheel/rail interface of the rail cars results in significant costs to the railroads. It is possible to contain these costs by a new computer-controlled top-of-rail lubrication method which applies a consumable, environmentally safe lubricant. The benefits measured to date include a 14 to 25 percent reduction in fuel consumption and over 60 percent reduction in peak lateral rail forces. Corresponding reductions in wheel and rail wear and reduced track maintenance cost would be expected. Further testing and use of this method should yield more specific numbers on these savings.

References.

1. "Rail and Wheel Lubrication" Proceedings, AAR Conference, published by Railway Systems & Management Association, 1981.

2. "Rail and Wheel Lubrication" Proceedings, AAR Symposium, published by Association of American Railroads, 1987.

3. "A New Approach to Wheel/Rail Lubrication", Mulvhill, Mark A. et al, NLGI Spokesman, Volume 58, No. 12, pp. 18-24, March 1995.

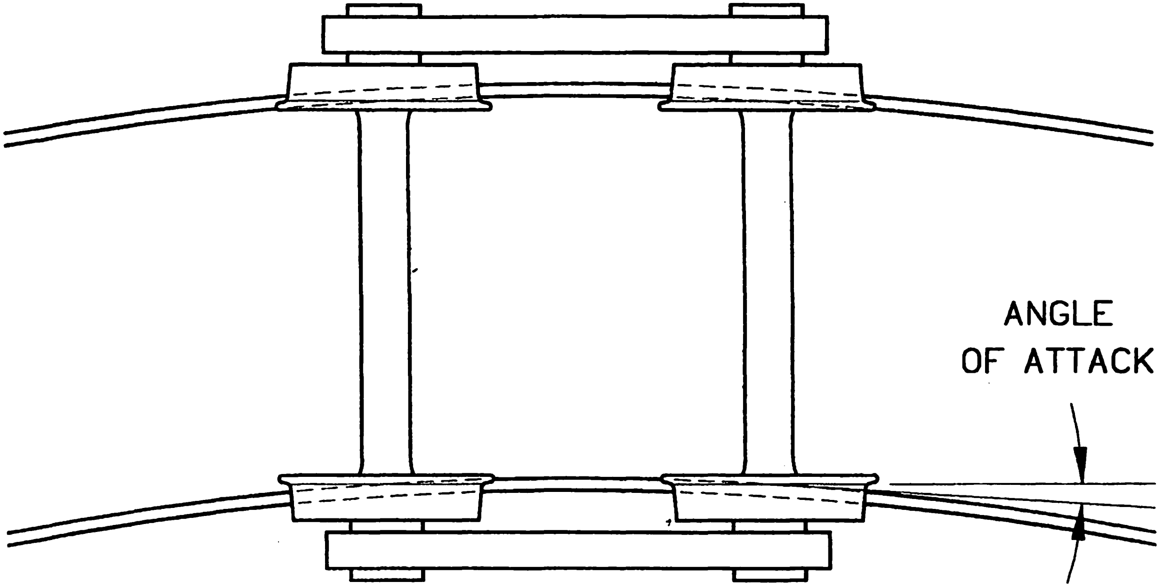


Figure 1. Three–Piece Truck on Curved Track

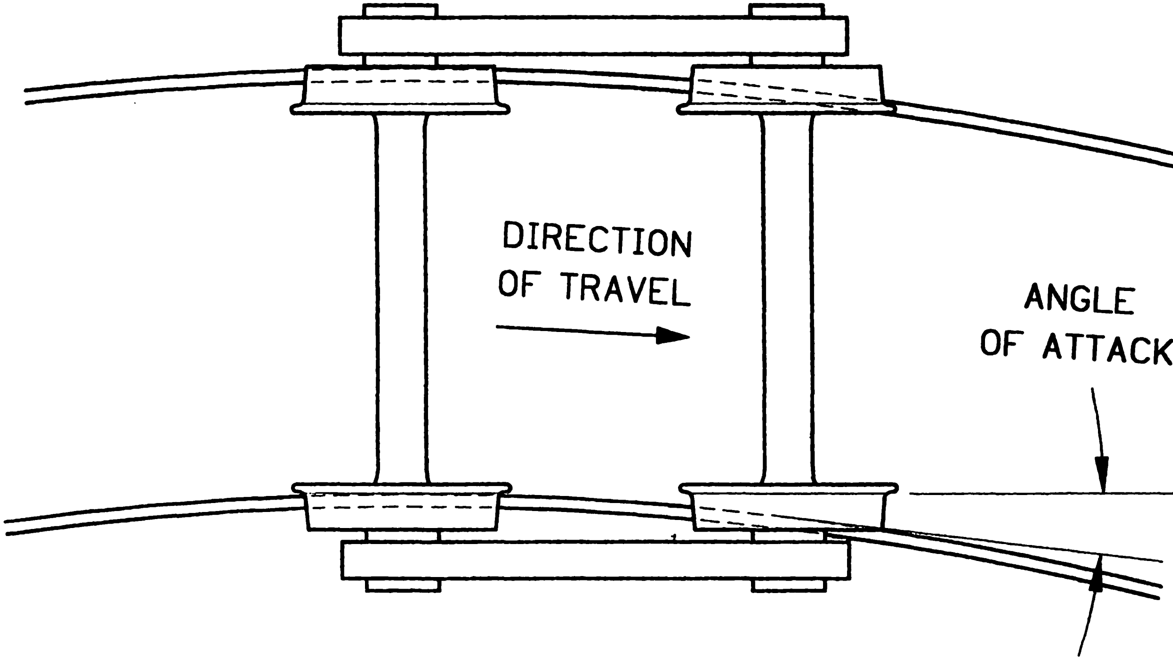


Figure 2. Angle of Attack as Affected by Gauge Clearance

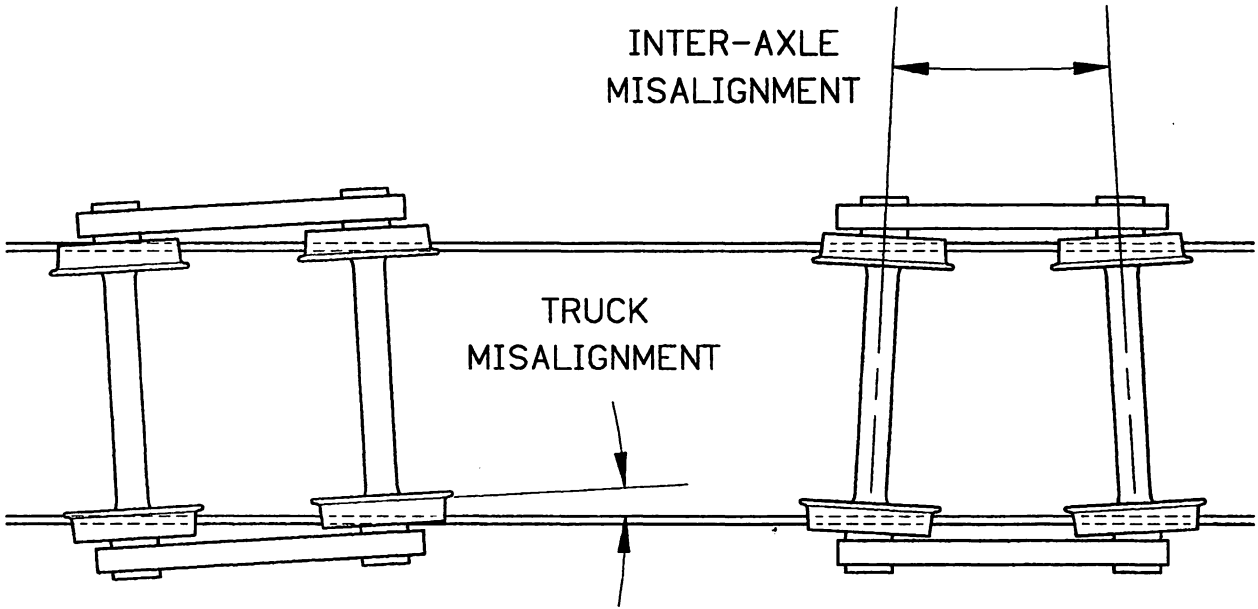


Figure 3. Illustration of Truck and Inter-Axle Misalignment

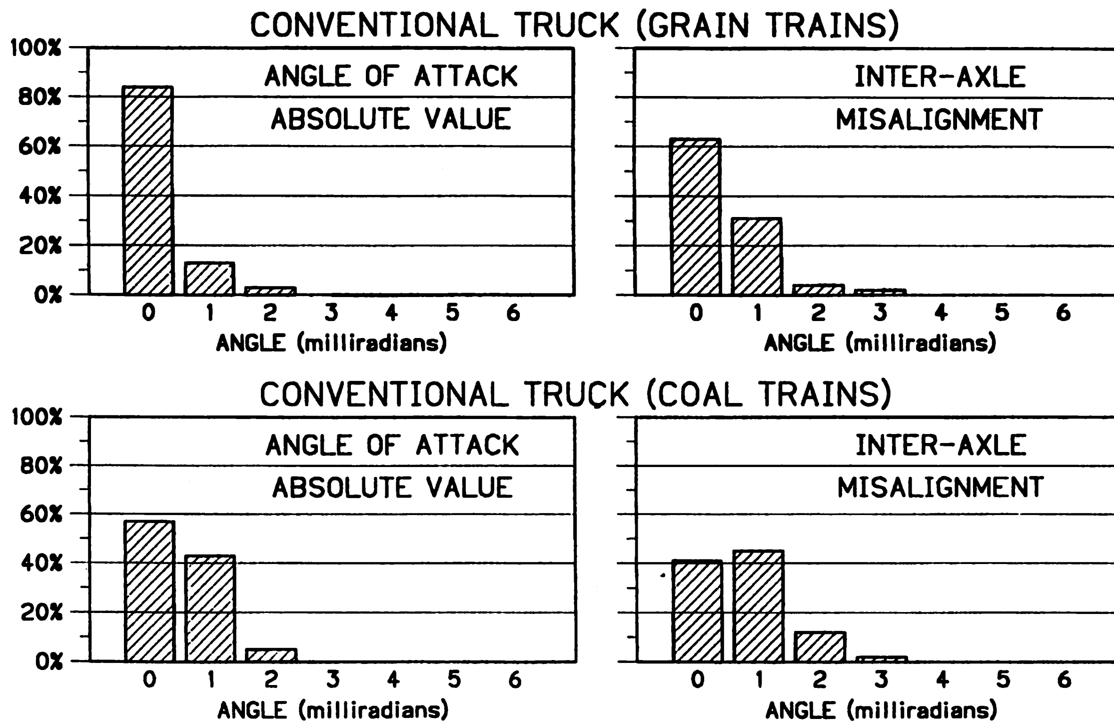


Figure 4. Distributions of Angle of Attack and Misalignment

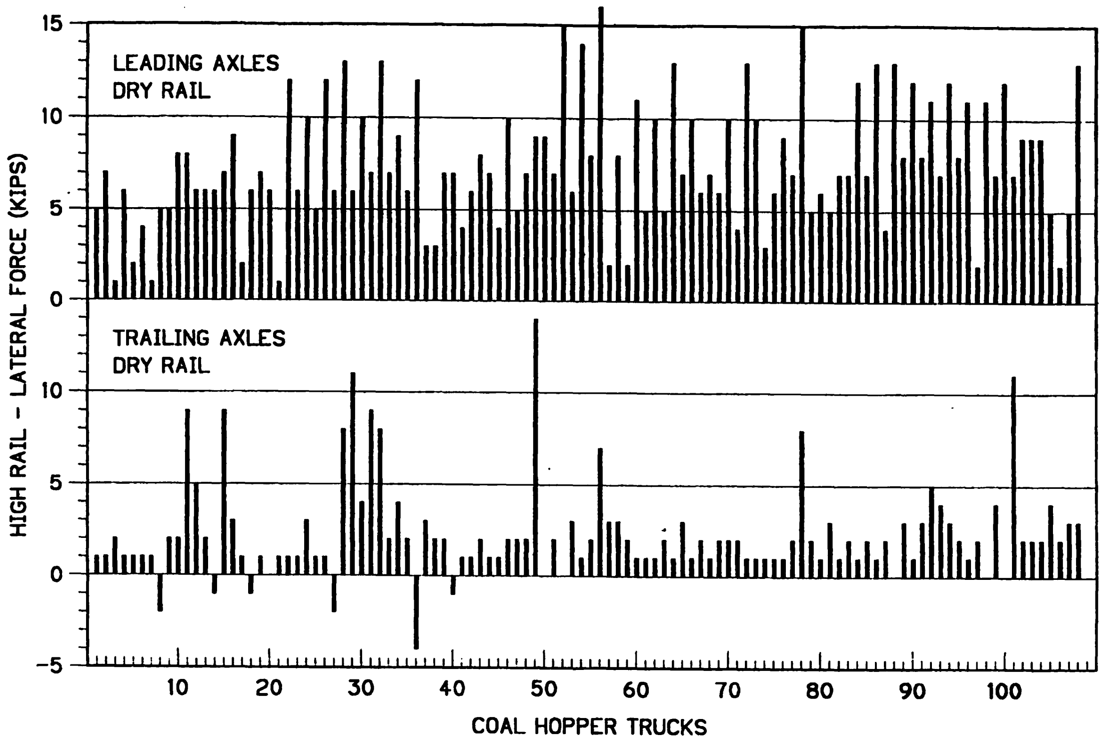


Figure 5. High Rail Lateral Forces Measured on Dry Rails

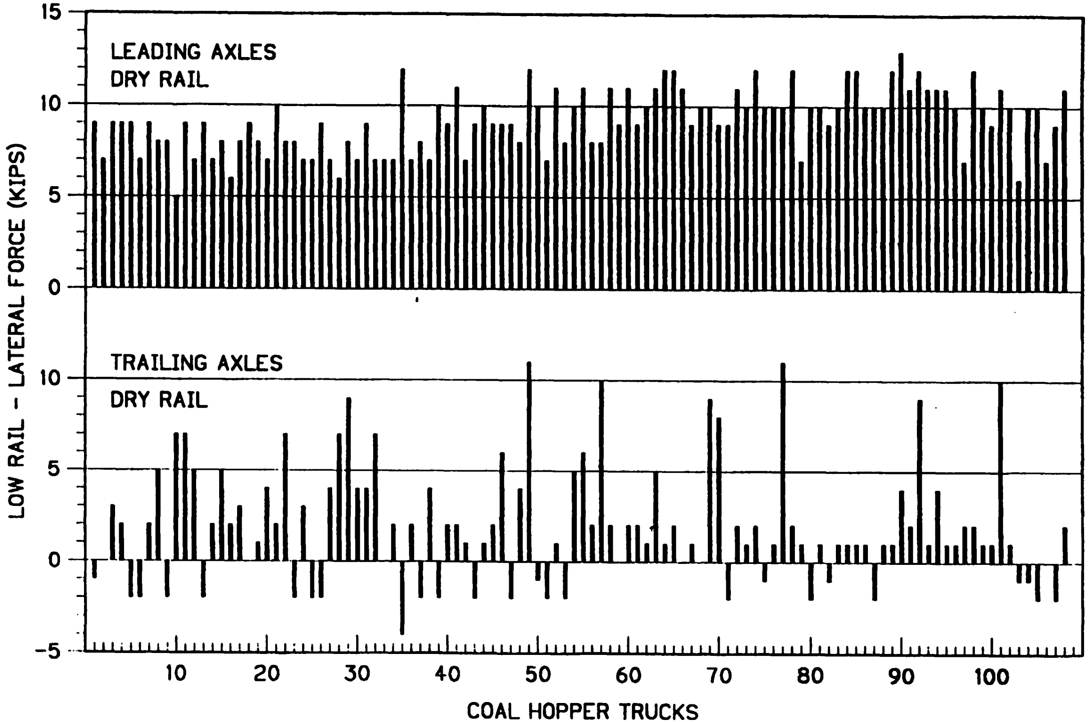


Figure 6. Low Rail Lateral Forces Measured on Dry Rails

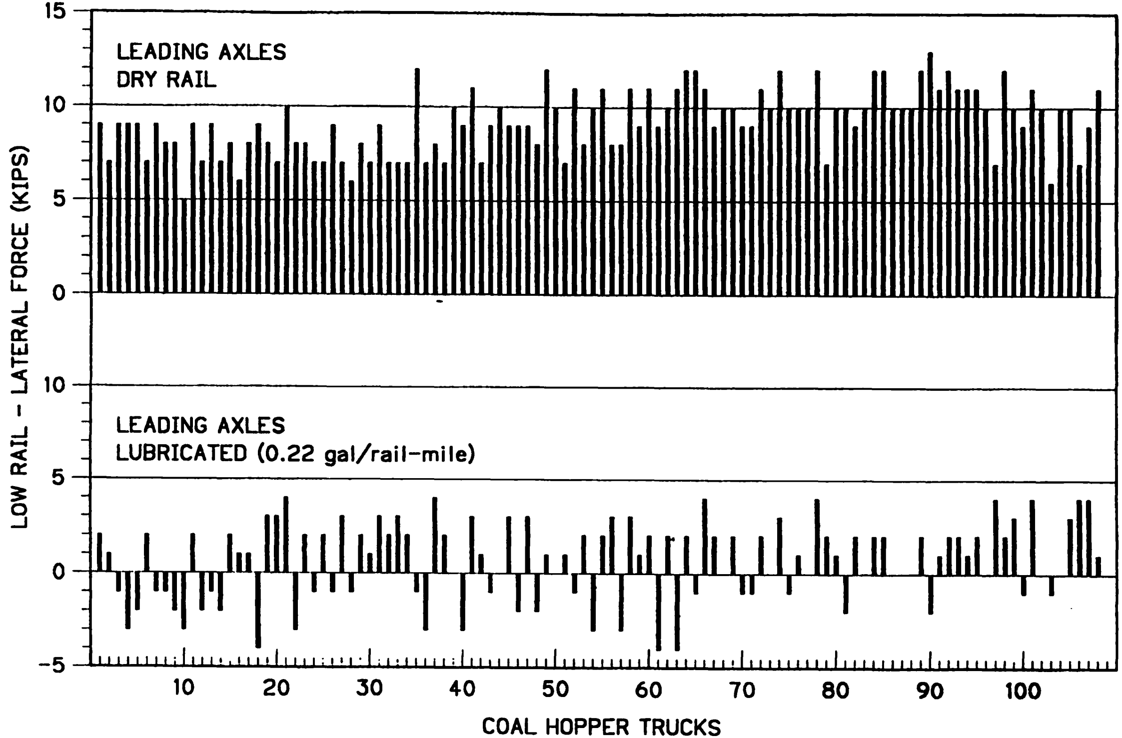


Figure 7. Effect of Lubrication on Leading Axle Lateral Forces

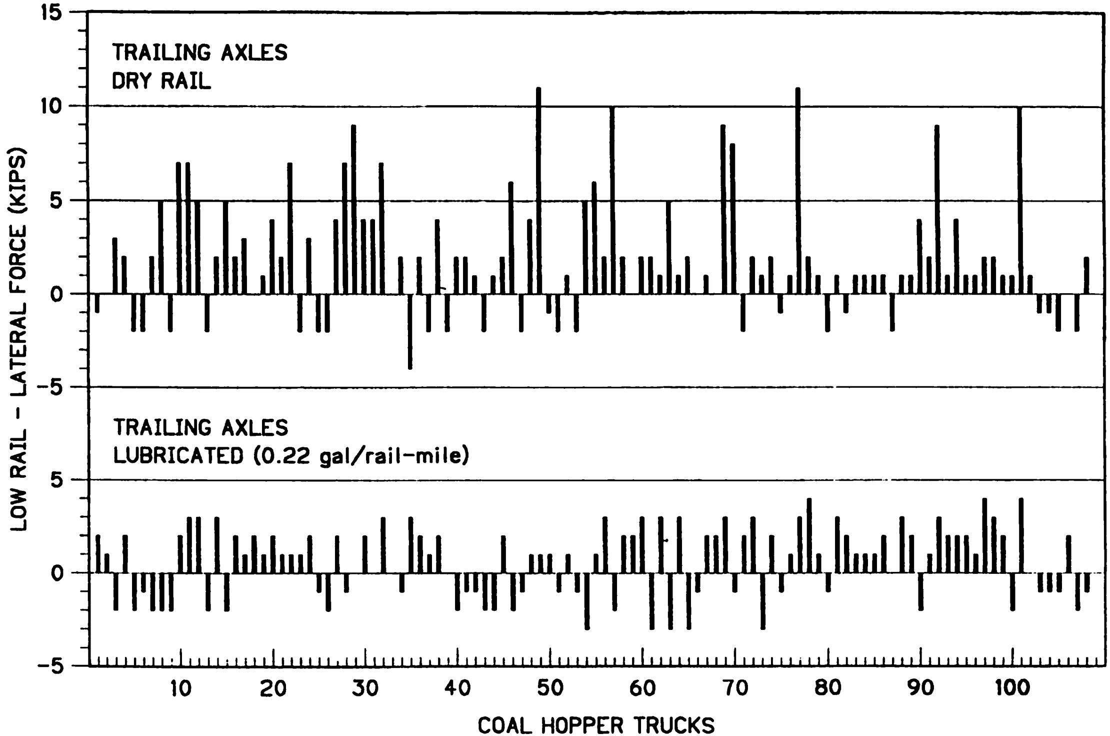


Figure 8. Effect of Lubrication on Trailing Axle Lateral Forces

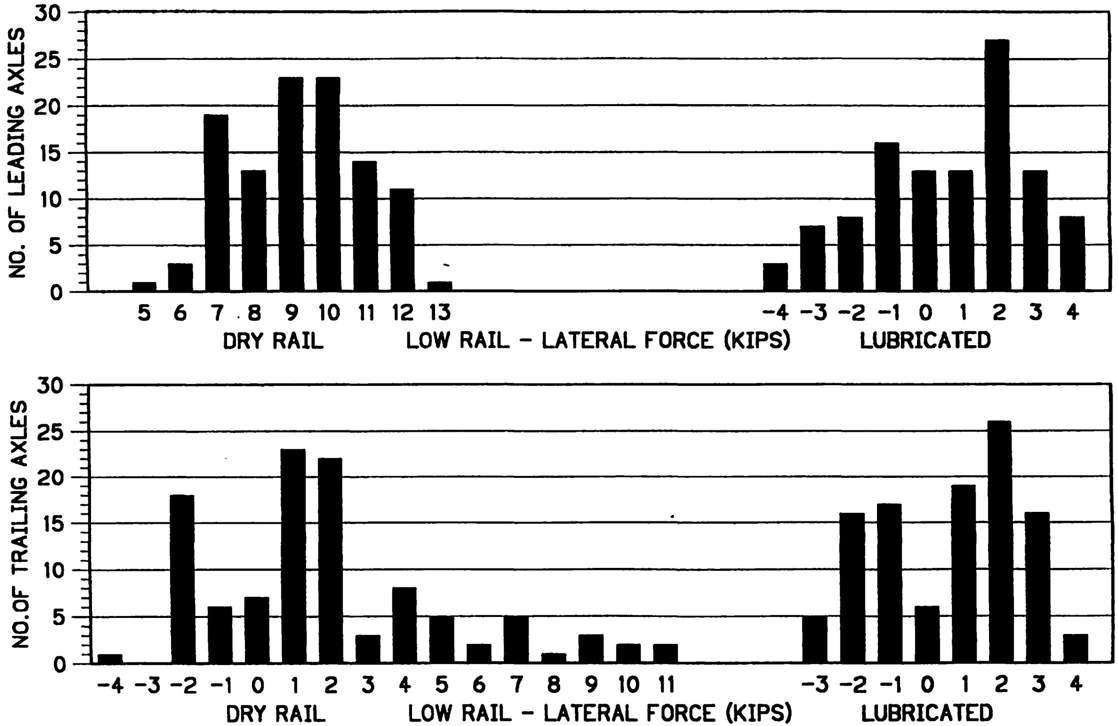


Figure 9. Lateral Force Distributions, Dry vs. Lubricated Rails

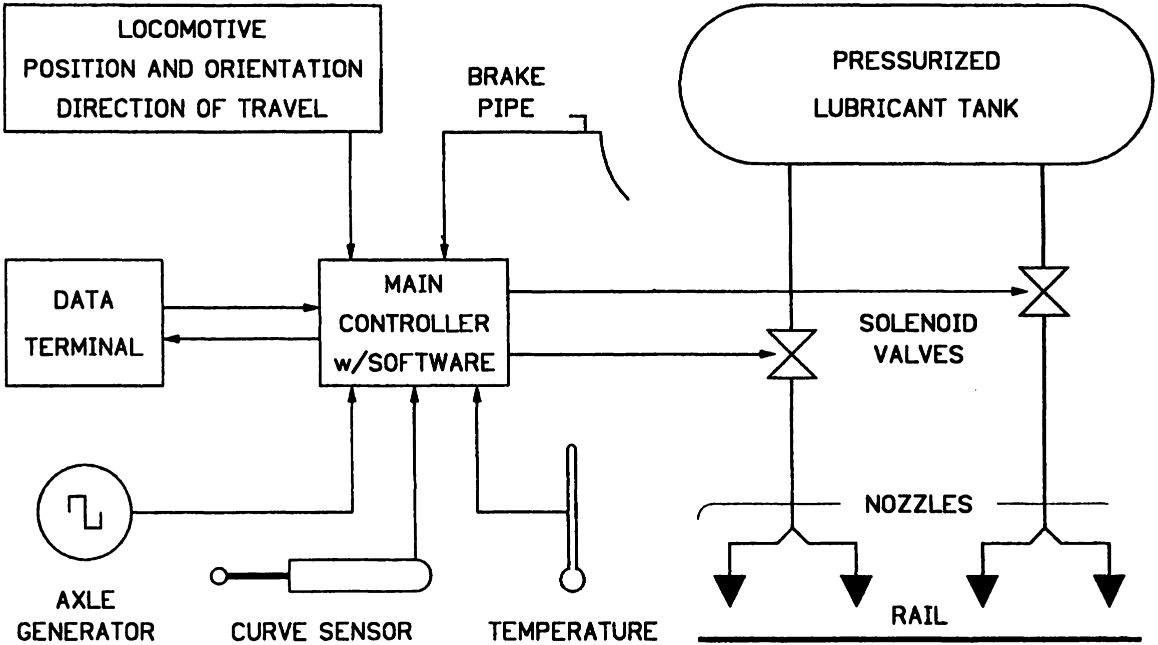


Figure 10. Functional Block Diagram of Lubrication System

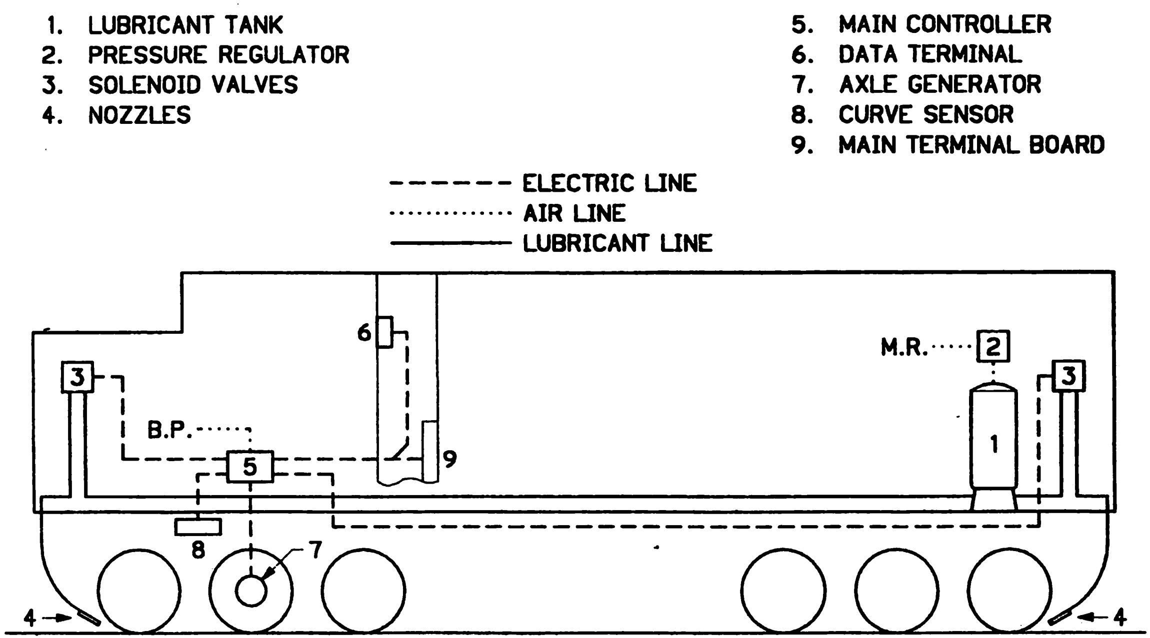


Figure 11. Physical Location of Lubrication System Components

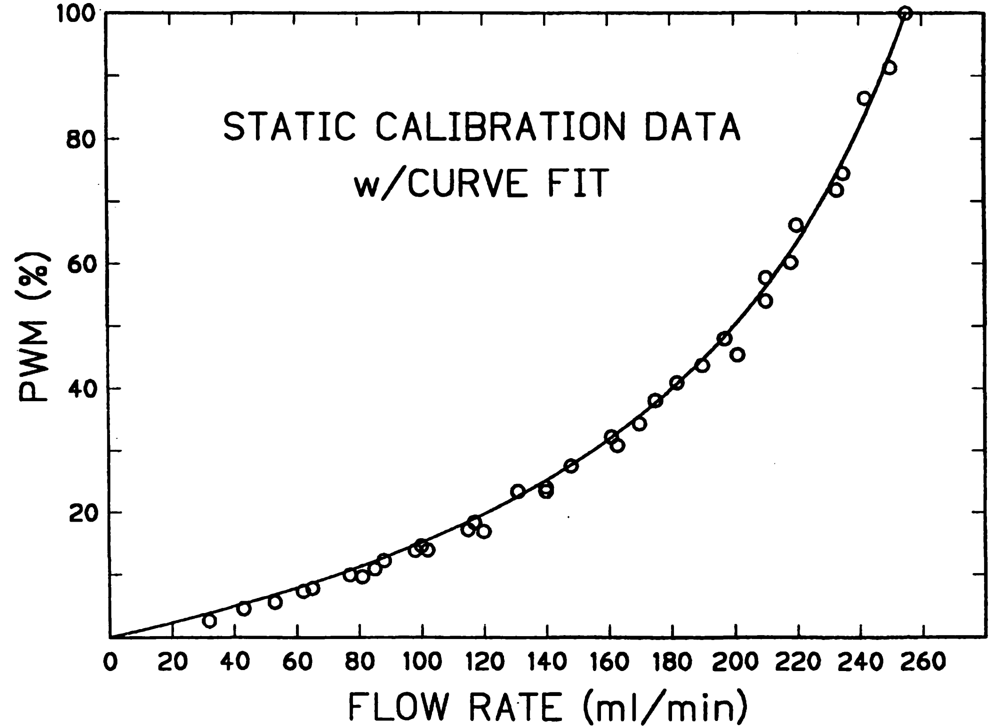


Figure 12. Relationship between PWM and Flow Rate

IV. TRACTION MOTOR VIBRATION AND ITS EFFECTS

Prepared by:
Timothy A. Frederick
Conrail

In August 1994, Consolidated Rail Corp. conducted a series of over-the-road vibration tests to determine the root cause of open exciter field failures on GE 752AG4 and 752AH3 DC traction motors. These traction motor failures were adversely affecting locomotive performance and customer service on some of Conrail's most heavily traveled routes.

The traction motors are subjected to shock and vibration loads induced via wheel to rail interfacing; for example crossovers, rail joints, tournouts, mud pockets, and rail profile deviations. The individual loads are further influenced by operational conditions and environmental extremes. The natural and induced loads combine to initiate the traction motor component failures. Of additional interest, were the effects, if any, resulting from traction motor involute profile gear wear.

A series of over-the -road vibration tests was performed to characterize the traction motor vibration environment and to examine what influence track conditions and roadbed have on traction motors and their components. Additionally, various degrees of worn gearing were tested to ascertain the vibration frequency and amplitude levels. Testing was also conducted to determine what influence, if any, clamping the connection straps would have on reducing the vibrational responses at the coil connection straps.

History

An examination of failed traction motors indicates that excessive vibration contributes to various types of failure modes: open fields, grounds, fatigue cracks, frame head fretting, and bearing failures. A statistical analysis of all Conrail traction motor failures from March 1993 thru March 1994 indicated the most prevalent defect to be open exciter fields on GE 752AG traction motors.

A failure analysis of three failed exciter coil connection straps removed from GE 752AG traction motors indicated the fractures are a result of high cycle bending fatigue. It is theorized that slight flexing of the traction motor frame provides higher stress levels in the connection strap, in particular between the bottom coil (6:00 position) and the axle bore coil (9:00 position) resulting in failure of the connection strap due to fatigue.

Testing

The testing was conducted by the Conrail Mechanical Dept. in cooperation with GE Transportation Systems Engineering, and was performed on a B40-8 locomotive, Unit # 5084, utilizing four AG traction motors. Unit # 5084 was chosen as the test locomotive due to its history of several open exciter fields or grounded traction motors.

The over-the-road testing was conducted on Mail 9H originating in Harrisburg, Pa. and terminating in Chicago, IL. This train was chosen due to its priority status enabling it to achieve maximum speed with minimal delays. The run time of Mail 9H was approximately 17-1/2 hrs. The runs were broken into three legs of the trip; Harrisburg, Pa. to Conway, Pa; Conway to Toledo, Ohio; and Toledo to Chicago.

The control motors were assembled utilizing new pinions and new bull gears at all four traction motor positions. Although motor positioning remained constant throughout the test, replacement wheel sets were applied. Wheel sets in various stages of gear wear permitted the effects of this variable to be examined. Gear tooth profile deviation was measured using a gear tooth profile gage and wire feeler gages. Table 1 describes the locomotive test configuration used for each over-the-road test run.

Table 1

Test Motor Configuration			
Run	Traction Motor	Gearing	Other
1	1	New	
	2	New	
	3	New	
	4	New	
2	1	Various worn	
	2	Various worn	
	3	Various worn	
	4	New	
3	1	Worn	Supported strap
	2	Worn	Supported strap
	3	Worn	Supported strap
	4	Worn	

The following parameters were fixed at the beginning of the test, minimizing system variables:

* New wheels with tape sizes ranging from 344-347.
* New axles with support bearing sizes at 9.000IN-9.002IN.
* The same support bearings were applied on all tests.
* New outboard bearings were applied to each wheel set.
* Sodium base gear lubricant was used on all tests.

The AG traction motors used were recently overhauled. The frames were welded and bored. New coils and interconnecting straps were applied eliminating the possibility of flawed components in the investigation. The locomotive trucks were reworked, and the following components replaced:

* New pedestal liners.
* New traction motor nose support pads.
* New lateral and vertical snubbers applied.

In addition, 92 Day PM inspection was performed on the locomotive.

Equipment

Seismic acceleromoters were used to measure the vertical, lateral, and longitudinal axes accelerations. A seismic accelerometer is a device which produces an electrical output signal proportional to acceleration. It is the transduction device used in many systems to measure the instantaneous or characteristic motion of a point on a structure. The accelerometer uses a piezo-electric crystal structure with an attached weight or mass coupled to a supporting base. The movement of the mass deforms the crystal, yielding a charge signal proportional to the acceleration of the structure.

Endevco Model 2272 crystal accelerometers were placed on the traction motor frames as follows: 1) Traction motor positions 1 and 4 had accelerometers applied in all three principle axes. 2) Traction motor positions 2 and 3 received only the vertical and lateral and vertical and longitudinal accelerometers respectively. The accelerometers were mounted via a triaxial block that was welded to the top of the traction motor frame. Columbia Model 606-3 miniature accelerometers were then applied to the coil connection straps of each traction motor in the vertical and lateral axes. The miniature accelerometers were applied to the connection straps by bonding a Textolite block to the strap using high temperature epoxy. The Textolite block isolated the accelerometers electrically from the strap. The acelerometers were mounted to the block using 4-48 installation studs. Pre-signal conditioning was accomplished by employing the appropriate line drivers. Line drivers convert accelerometer charge to amplified voltage for use with long coaxial signal lead cables.

Endevco Model 2775 and 2735 charge amplifiers were used to condition and amplify the accelerometer output signals to a Racal 24 channel tape recorder. The calibrated signals were recorded on the tape recorder configured for measuring frequencies from 5 Hz to 1250 Hz. Signal leads from the accelerometers to the charge amplifiers were routed on the locomotive platform opposite the motor leads, eliminating flux field interference possibilities. Instrumentation quality audio tapes were used for data recording. Locomotive speed was acquired from the speed signal of the #1 axle alternator. The Conrail test car was used as a rolling laboratory for data acquisition.

Analysis

A multi-channel high speed data acquisition/analysis system was used to analyze the field data. Twenty-one data channels were analyzed simultaneously using Fast Fourier Transformation or FFT in the frequency domain in a power spectral density mode. Upon completion of the analysis of all acquired field data, the data were then perused for worst case excitation and response levels to the strap. The composite profile was inputted to a computer aided vibration control and comprised of 1X field data at the motor. Using the developed composite profile, current design samples were evaluated on an exciter at exaggerated levels. This evaluation identified straps and terminals with a life expectancy fifteen times greater than the currently used models.

Evaluation

The first run was initiated to establish a baseline for the test and to determine if any motor position was more prone to failure. The analysis of the first run did not indicate that any failures were position relevant. It did however reveal that levels at each traction motor due to impact were random. This was attributed to truck and locomotive orientation and dynamic loading rather than traction motor positioning.

The second run evaluated the impact of traction motor accelerations as a function of bull gear profile deviation. The analysis indicated there is a direct correlation between profile deviation and motor frame excitation, that is, the greater the profile deviation the higher the level of excitation. Gear pass frequency is dependent on locomotive speed, however, the level is a function of speed, but more so, is dependent on power transmission levels of the gears. That is to say a locomotive coasting at 60 miles per hour has significantly lower frame excitation levels than a locomotive accelerating through 60 miles per hour in notch 8. It was also observed that impact levels are related to locomotive speed and track features. However the intent of this investigation was not to show this nor was the data analyzed to focus on this aspect. Further investigation and analyses would be required to further confirm this.

The third run attempted to evaluate the effects of clamping the coil connection straps. The results of clamping the connection straps were inconclusive. It is believed that since the clamps were applied after the traction motors were processed through vacuum impregnation, that the true effects, if any were not accurately reflected. It is believed that vacuum impregnation would tend to stiffen the clamp/strap combination but unfortunately this process was not performed. After two years of clamp applications on over seven hundred AG4 and AH3 traction motors, no failures have been observed. Statistically, this indicates some performance improvement.

The results of the over-the-road vibration test indicate that worn gearing is only one of the contributing sources of vibration. Other sources, such as the roadbed and track conditions cannot be altered and must be considered independently. In order to reduce the overall vibration levels in the motors, changes must be made to the condeming limits of worn traction gearing and other methods employed to reduce gear wear, i.e. utilizing oil filled gear cases and lubrication.

A note on data: observed acceleration levels at the top of the motors were in the range of 30gs vertical, 3gs lateral, and lg longitudinal in the time domain. The coil connection strap acceleration levels were in the range of 100gs vertical and 30gs lateral in the time domain. If the wave shape is complex, the danger with thinking in the time domain, is that the experimentor knows nothing about frequency. In almost all cases signals from spurious or random events are complex. In view of the fact that only amplitude is known, the displacement amplitudes (which are the damaging parameters) are also unknown and any estimate is erroneous. On the other hand in the frequency domain both frequency and amplitude are presented. From acceleration and frequency, displacements can accurately be determined. Hence failure criteria can be considered or examined with confidence. The recorded data was analyzed using Fast Fourier Transformation or FFT in the frequency domain in the power spectral density mode. It must be noted that the accelerations measured on the frame are excitation levels provided to the strap. The accelerations measured on the strap are responses as a function of excitation accelerations thru the motor. There are two prominent clusters of activity associated with strap response, one from 450Hz to 700Hz pertaining to gear pass frequency and one from 900Hz to 1150Hz related to track and roadbed (see figures). The gear pass amplitude and frequency changes with respect to speed and motor load.

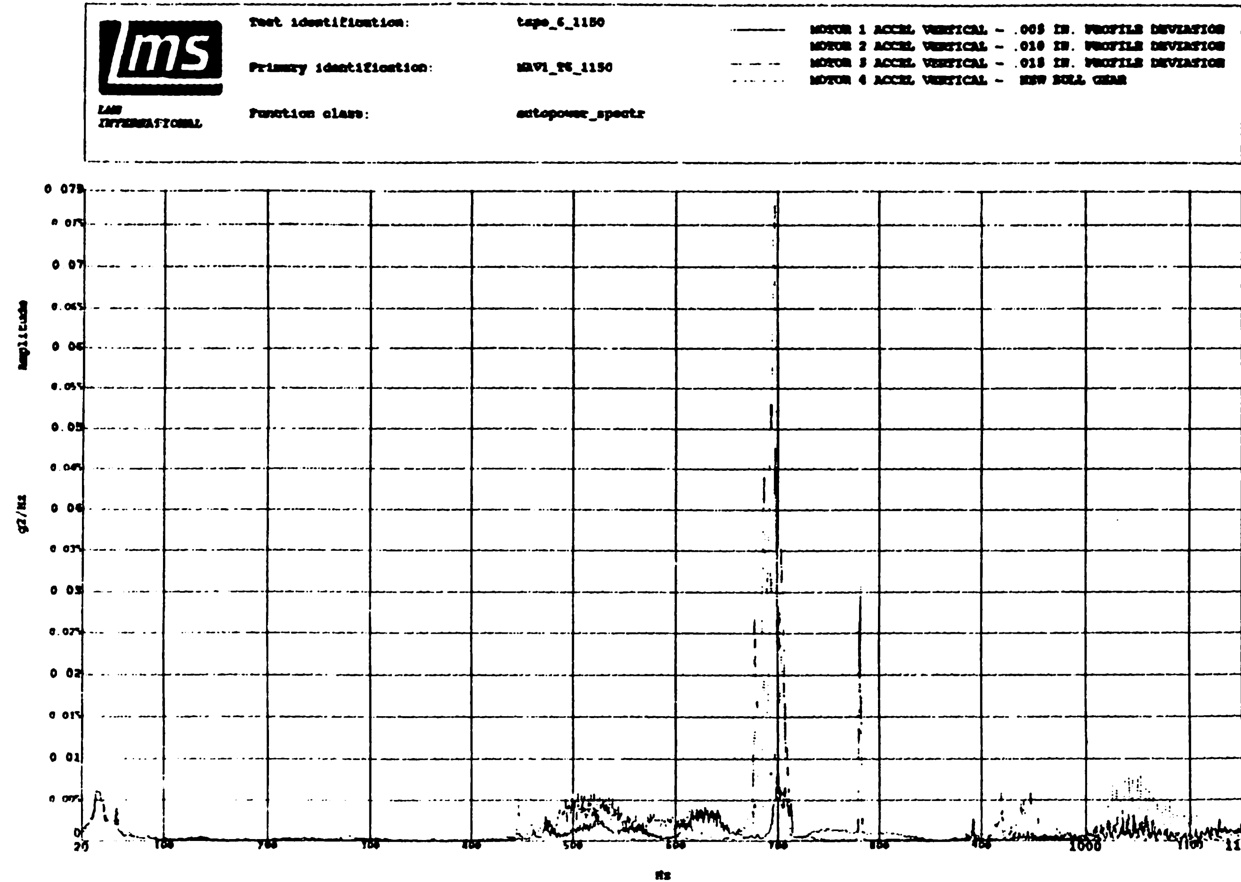
Depending on whether the motor is in power, braking, or coasting the energy under the frequency spectral curve varies. Power and braking provided the largest acceleration density and coasting provided the least acceleration density. This points out that gear pass frequency is the major contributor. Data indicate that high cycle fatique in the straps is a result of strap dynamic structural response.

Recommendations

1) Limit worn gearing to 0.005 in. profile deviation and arc tooth thickness to 0.030" from true form.

2) Use oil lubrication to prolong gear life. To date, Conrail has switched to the oil filled gear cases on all overhauled traction motors and 42" wheel conversions.

3) Failure of traction motors due to the high cycle fatique phenomena of the connection straps can be lessened through the employment of a more flexible and robust strap design or clamping the connection straps. The projection for strap life is estimated at thirty years using the new improved GE strap. The application of the improved strap will significantly improve traction motor reliability and reduce observed traction motor failures.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Primary identification:
Function class: autopower_spectr
MOTOR 1 ACCEL VERTICAL - .005 IN. PROFILE DEVIATION
MOTOR 2 ACCEL VERTICAL - .010 IN. PROFILE DEVIATION
MOTOR 3 ACCEL VERTICAL - .015 IN. PROFILE DEVIATION
MOTOR 4 ACCEL VERTICAL - NEW BULL GEAR
Amplitude
g2/Hz
Hz

Figure 1

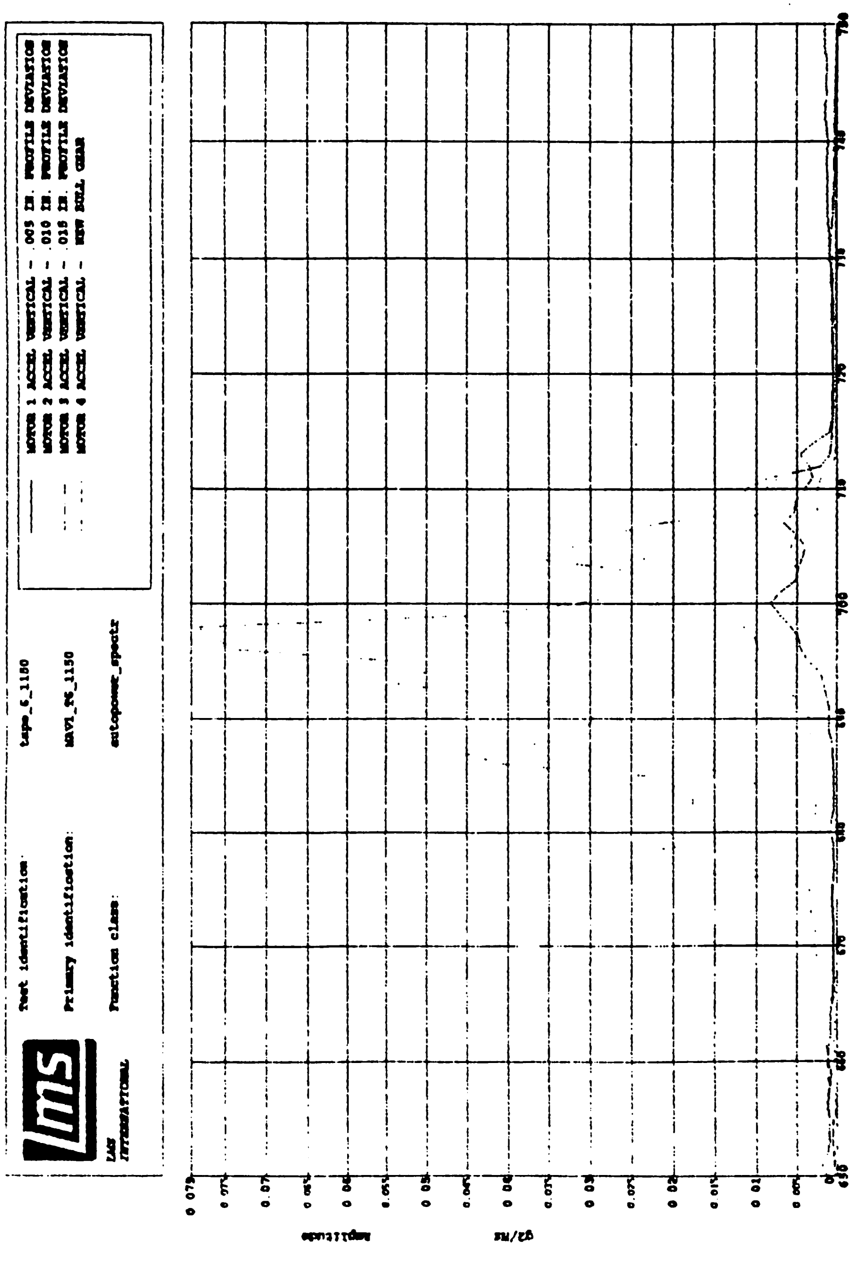

LMS INTERNATIONAL
Test identification: tape_6_1150
Primary identification: NAV1_F6_1150
Function class: autopower_spectr
MOTOR 1 ACCEL VERTICAL - .005 IN. PROFILE DEVIATION
MOTOR 2 ACCEL VERTICAL - .010 IN. PROFILE DEVIATION
MOTOR 3 ACCEL VERTICAL - .015 IN. PROFILE DEVIATION
MOTOR 4 ACCEL VERTICAL - NEW BULL GEAR
Hz
Amplitude
g2/Hz

Figure 2

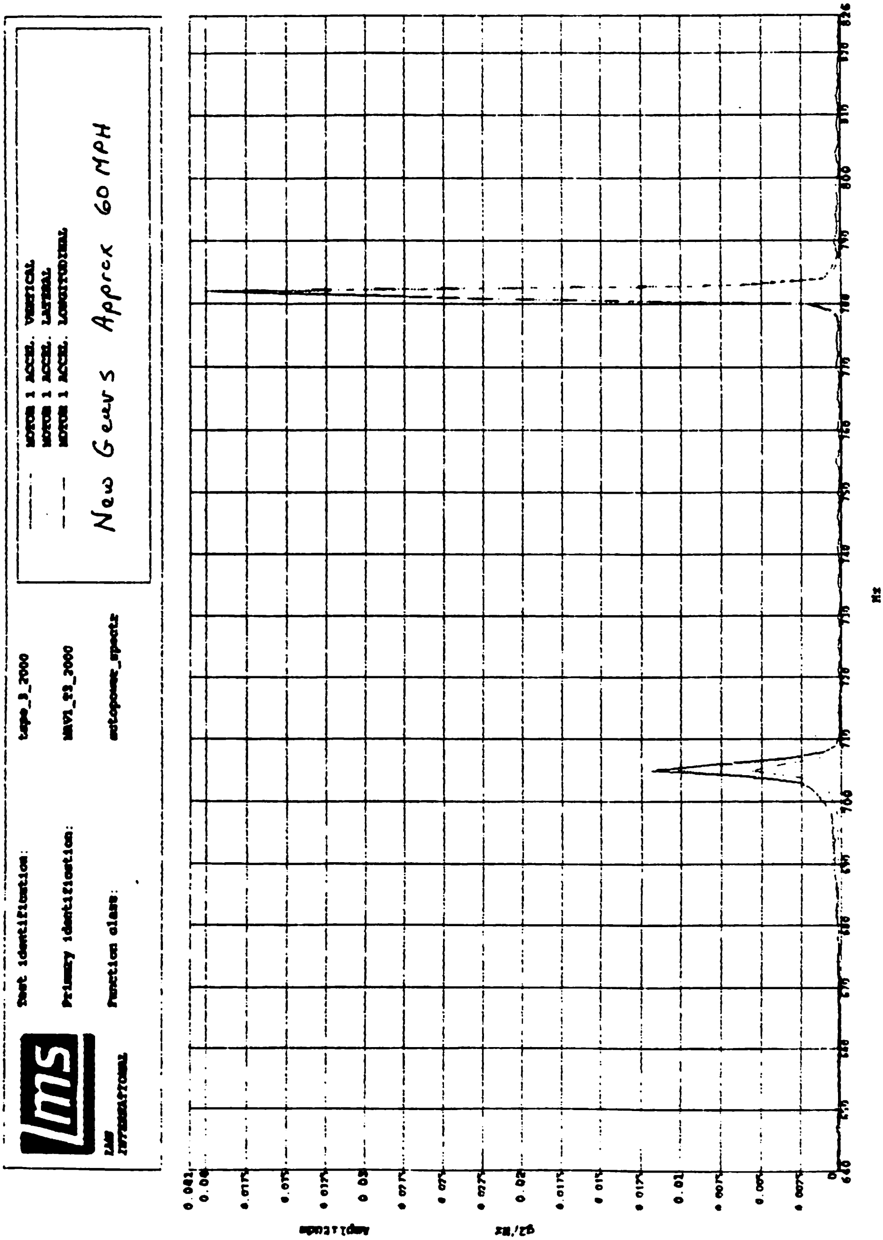

Test identification: tape_8_2000
Primary identification:
Function class: autopower_spectr
MOTOR 1 ACCEL. VERTICAL
MOTOR 1 ACCEL. LATERAL
MOTOR 1 ACCEL. LONGITUDINAL
New Gears Approx 60 MPH
Hz
g2/Hz

Figure 3

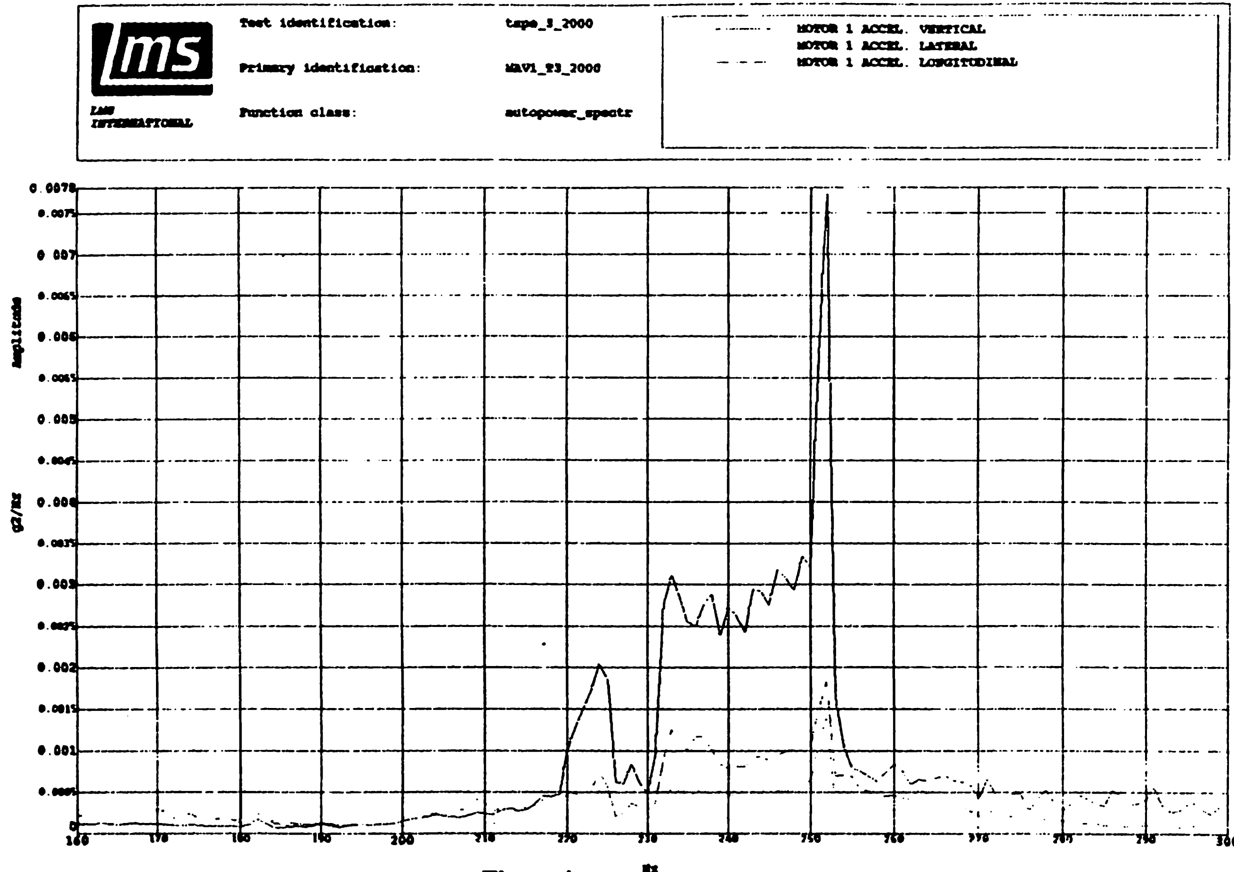
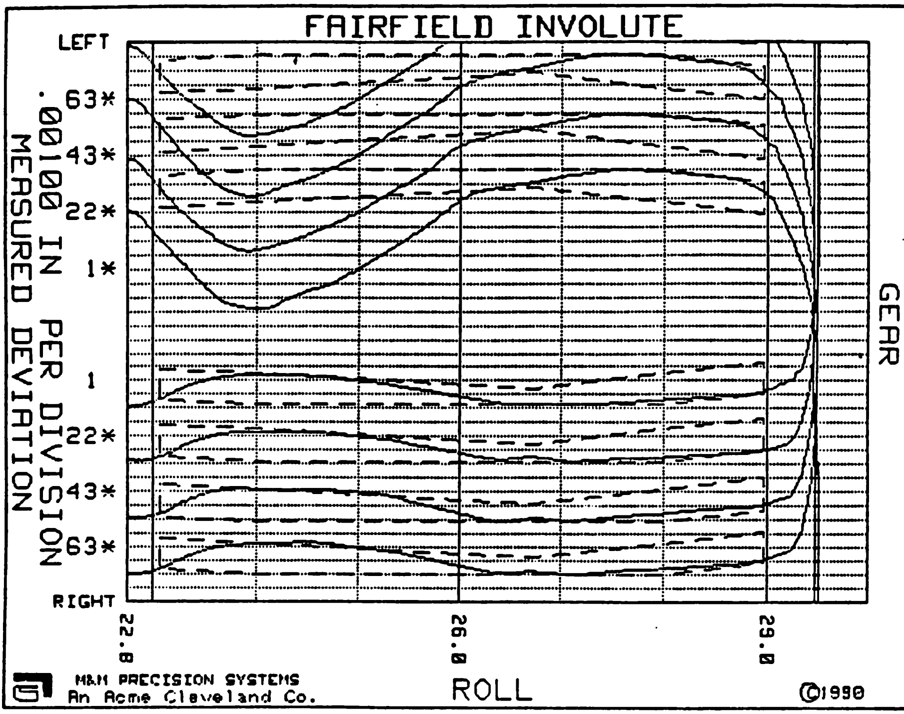

Test identification:
tape_3_2000
Primary identification:
MAV1_T3_2000
Function class:
autopower_spectr
LMS INTERNATIONAL
MOTOR 1 ACCEL. VERTICAL
MOTOR 1 ACCEL. LATERAL
MOTOR 1 ACCEL. LONGITUDINAL
Amplitude
g2/Hz
0.007
0.005
0.002
0.001
0
160
200
300
Hz

Figure 4

INSPECTOR : KENNEY FERGUSON　　DATE : 11/13/94　　PART # 41C635598P[illegible]

PART NAME : SPUR GEAR　　TIME : 14:27:53　　SERIAL # 598-1-57185



NOTE: "*" INDICATE OUT OF TOLERANCE

	LEFT FLANK				RIGHT FLANK		
TOOTH	SLOPE	HOLLOW	CROWN	TOOTH	SLOPE	HOLLOW	CROWN
1 *	.00318	.00547	.00240	1	-.00062	.00171	.00079
22 *	.00333	.00498	.00262	22 *	-.00050	.00175	.00063
43 *	.00295	.00539	.00285	43 *	-.00066	.00172	.00095
63 *	.00326	.00498	.00248	63 *	-.00073	.00182	.00084

CONSTRUCTION LINE TYPE ANALYSIS BETWEEN SPECIFIED SEGMENT: C1 AND C5

	LEFT FLANK	RIGHT FLANK
AVERAGE SLOPE	.00318	-.00063
TOLERANCE	.00000	.00000
TOLERANCE	.00000	.00000
AVERAGE CROWN	.00259	.00080
TOLERANCE	.00000	.00000
TOLERANCE	.00000	.00000
MAXIMUM HOLLOW	.00547	.00182
TOLERANCE	.00000	.00000
MAX SLOPE VAR	.00038	.00023
TOLERANCE	.00000	.00000

Scale .002 Per Line

Figure 5

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

MONDAY, SEPTEMBER 16,1996
3:45 P.M.

Pre-Convention Presentation Union Pacific

Salt Lake City, UT

T. H. VOLKMANN, Chairman
Sr. Mgr.-Loco. Maint.
Union Pacific
Salt Lake City, UT

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

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J. Sadler	Asst. Supt.-Diesel	Canadian National	Winnipeg, MB
B. Sweeley	Mgr.-Int. Locos	General Electric	Erie, PA

LMOA wishes to express its thanks to the Union Pacific Railroad for hosting the Pre-Convention Presentation in Salt Lake City, UT.

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

PERSONAL HISTORY

Tad H. Volkmann

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

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

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

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

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

I. AIR BRAKE TROUBLE SHOOTING: WHERE WE ARE NOW

Presented by:
Rick Gates, BN/SF

The techniques of trouble shooting locomotive air brake systems have evolved over the years and increasingly detailed and sophisticated manuals and other aids have been developed to help maintenance craftsmen more quickly and more accurately locate and correct brake system faults.

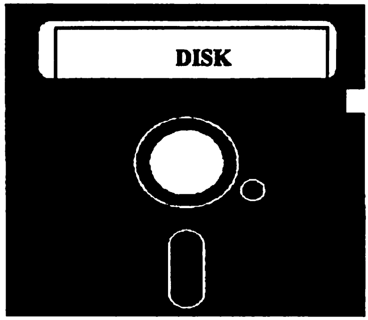
Early on we had the **Air Schematic,** a simple chart that showed a line connecting one component to another, with all components of the air system illustrated. There was little thought given to trouble shooting.

Flow Charting was quite an improvement, but still required a thorough knowledge of the air system. There was still no explanation of what was happening or WHY.

Booklets and pamphlets were quite useful but still required extensive knowledge of the air system, knowledge that only a few craftsmen possessed. It explained that if this happened to change this part or check that line. This method would require a craftsman to locate a description of the problem, refer him to another page or description, still within the flow charting concept requiring a quite thick booklet, another booklet of prints and still another booklet for the components. If the craftsman knew the air system well enough to use all this, he probably didn't need it.

Computers

With the advent of the laptop computer it has now been possible to commit all this information to a disk. This allows a craftsman to take the laptop to the locomotive, begin an air test and if a section of that air test fails to answer a YES or NO question, it will display a trouble shooting text that contains a description of what is happening and the prints and illustrations of the component.



This concept allows a craftsman having little or no experience with air to perform an air test to detect a problem if one exists, trouble shoot and repair the defect. The program is set up in a very user friendly way, in that it requires little knowledge of computer operation. Illustrations and schematics may be displayed by using the designated key to highlight the desired subject at any time during the test or in the text. If the detailed information is not needed there is not a lot of unnecessary text to read through.

Benefits

• New Form of Training.

Does not require a trainer to teach air system. It is a self-instructing program.

• Information Condensed and Available at Finger Tip.

Does not require prints and booklets to store and maintain.

• Requires Little Knowledge of Air System.

Directs the craftsman to the problem and its resolution without the necessity of knowing the system or its components.

• Reduces Time in Determining Defective Equipment.

It is not necessary to sift through a lot of unnecessary text to obtain the information needed.

• Improves Locomotive Reliability.

Does it right the first time and eliminates repeat failures.

• Improves Locomotive Availability.

Reduces locomotive detention time by allowing repairs to be performed more quickly.

• Cuts Budget Cost for Unnecessary Parts Change Out.

Eliminates the unnecessary changing of parts in attempts to fix the problem.

• Increases Utilization of Forces.

The less experienced craftsmen may be utilized to perform tasks with a higher degree of efficiency.

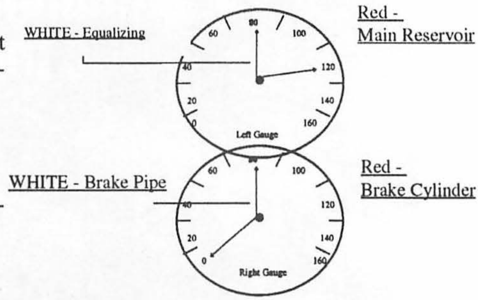
Following are examples showing the types of questions, answers and directions that appear on the laptop computer screen.

Does the automatic brake value fail to maintain equalizing reservoir pressure or brake pipe pressure?
EQUALIZING - Go to equalizing reservoir leakage trouble shooting.

BRAKE PIPE - Go to brake pipe leakage trouble shooting.

EQUALIZING RESERVOIR LEAKAGE

(" 0" psi leakage allowed)

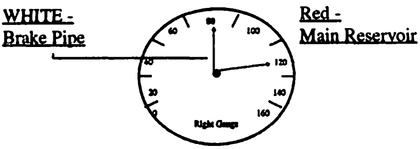


1. Check the equalizing reservoir gauge or change the gauge. (Gauge may be leaking internally.)
2. Change the gauge mounting "o" rings.
3. Change the gauge test probe plug "o" rings.
4. Check the equalizing reservoir gauge pipe from the gauge back to the automatic brake valve pipe bracket for leakage. (Use liquid leak detector on all fittings and pipes - leakage may be very small).
5. Check #15 pipe from the automatic brake valve to the P-2-A application valve for leakage.
6. Check #5 pipe from the P-2-A to the automatic brake valve, including the equalizing reservoir, for leakage.
7. Is the P-2-A exhausting air from the #24 exhaust port in the back of the P-2-A pipe bracket?

YES - Change the P-2-A.
NO - Is the automatic brake valve regulating valve exhausting air?
YES - **Replace the automatic brake valve.**
NO - Change the P-2-A and retest. If the problem persists change the automatic brake valve.

BRAKE PIPE LEAKAGE

(5 lbs. per minute maximum allowed)



1. The auxiliary reservoir system must be fully charged before checking for leakage.
2. Make sure the train line angle cocks are closed and check them for internal and external leaks.
3. Check brake pipe unions behind angle cocks for leakage.
4. Check the #8 vent valve and its fittings for leakage.
5. Check the auxiliary emergency brake valve.
6. Check the brake pipe volume reservoir and #11 pipe to the A-1 charging. Also check #1 pipe, which runs from the front #8 vent to the A-1 charging.
7. Check the dead engine feature and its piping.
8. Check the 26F control valve for air leaking from any of its exhaust openings or from #10 exhaust port. If the #10 exhaust port is leaking change out the control valve.
9. Check the control valve pipes and fittings.
10. If air is exhausting from the A-1 charging valve change it out.
11. Check the brake pipe cut-out valve and its flanges.
12. Check the alerter air manifold for brake pipe leakage.
13. If you can hear air exhausting in the automatic brake valve, change it.

J-RELAY VALVE BLOWS

If the blow occurs only in when the automatic is in the suppression or trail position, replace the 26-30 double check valve, otherwise change the J-Relay valve.

INDEPENDENT BRAKE VALVE BLOWS

Is the automatic brake valve in the applied position?

YES - Cut out the MU-2A. **Is the independent still blowing?**

> **YES** - Replace the **independent brake valve.**
>
> **NO** - **Open** the independent application and release line. Is there pressure in this line with the independent in release?

If your answer is **YES** - Replace the **16-20 double check valve.**

If your answer is **NO** - Replace the **control valve quick release portion.**

NO - What part of the independent brake valve is blowing?

Is the Quick Release Spool Valve? - Replace the independent brake valve.

Is the Quick Release Exhaust? - Cut out MU-2A. Is it still blowing?

> **YES** - Replace independent brake valve.
>
> **NO** - Replace control valve quick release portion and it's mounting gasket.

Independent Spring Chamber - Cut out MU-2A. Is it still blowing?

YES - Replace independent brake valve.

NO - Check the J-1 Relay, valve mounting gasket. If the locomotive has a J-1.6 Relay valve, replace the J-1.6 and both mounting gaskets.

CONTROL VALVE BLOWS

Is the independent brake applied?

NO - Close the control valve cut-out cock. Is the valve still blowing?

NO - Check for equalizing reservoir and brake pipe leakage.

YES - Cut out the MU-2A, is the valve still blowing?

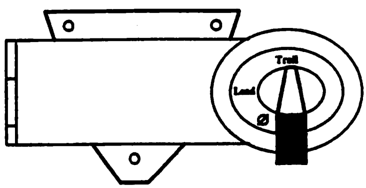
NO - Replace the 16-20 double check and retest.

YES - Replace the control valve service portion and retest.

YES - Cut out the MU-2A. Is the valve still blowing?

NO - Replace the 16-20 double check valve, and retest.

YES - Replace the control valve service portion and retest.



AUTOMATIC BRAKE VALVE BLOWS

Equalizing Reservoir Regulating Valve - Change the P-2-A. If the blow persists then change the automatic brake valve.

Brake Pipe Exhaust - Cut out the brake pipe cut-off pilot valve. **Is the valve still blowing?**

YES - Replace the **automatic brake valve.**

NO -

1. Make sure the dead engine fixture is cut out.
2. Change A-1 mounting gasket.
3. Replace the automatic brake valve.

Large Cavity Exhaust - 1. If the air system is not in emergency and the blow will stop when the cut-off pilot valve is cut out, **change the A-1 charging valve.**

2. If the blow only occurs when either the automatic or the independent is applied and the gauge shows brake cylinder pressure, **change the 26-30 double check valve.**

3. If the blow stops when the automatic brake valve is put in suppression and there is no brake cylinder pressure. **Change the P-2A.**

4. If the blow is not effected by brake valve handle positions or by the cut-off pilot valve. **Change the automatic brake valve.**

UNDESIRED EMERGENCY

If in consist, you need to isolate each locomotive and test until you find which one is causing the emergency, then troubleshoot as single unit.

If you were performing a normal 212 air test, when you made the reduction did the equalizing reservoir pressure drop faster than normal or about the same as usual?

1. If faster than normal check for bad equalizing reservoir leakage and if none is found check the 24a choke in the P-2-A pipe bracket. If no leakage is found **change the P-2-A and retest.** Finally **change the automatic brake valve and retest.**
2. If the drop was about the same as usual, **check for a defective #8 vent valve.**
3. If the unit gets PCS light, without an emergency rate of brake pipe reduction, **change the A-1 charging valve.**

If you were testing the alerter or overspeed for proper **penalty application** and an emergency application occurred. **Did the reduction in equalizing reservoir pressure seem to go much faster than normal or about**

the same as usual?

1. If it was much faster than usual - check the #24a choke in the P-2-A pipe bracket. (No. 56 drill)
2. If it was about the same - check for a defective #8 vent valve.

SYSTEM WON'T RESET FROM AN EMERGENCY

1. Make sure the safety devices and overspeed circuit breakers are **"ON"**.
2. Place the automatic brake handle in **EMERGENCY** at least one minute before moving the handle to the **OFF** position.
3. Did air blow from the A-1 timing choke immediately after the emergency?

If the answer is **NO** - Replace the **A-1 charging valve.**

If the answer said **YES** - Crack the fitting on the pipe from the **PC switch and check for pressure.**

A. if there isn't any pressure the PC switch is broken.

B. If there is pressure put the automatic brake valve into emergency and check for pressure in #12 at the A-1 charging pipe bracket.

1. If there is no or little pressure and #12 pipe is not obstructed, **change the automatic brake valve.**
2. If there is sufficient pressure (M.R.) **replace the A-1 charging valve.**

SYSTEM WON'T ACTUATE

Does the Quick Release portion have an exhaust of air when the Independent Brake valve is depressed?

NO - Loosen the fitting at #13 port to the Quick Release portion and check for air pressure.

1. If air is present change the Quick Release.
2. If no or little pressure is present, check the actuating line for broken pipes or open cut-out cocks. If the lines are OK change the Independent Brake Valve.

YES - Loosen the fitting at the 16-20 double check valve on the control valve side and check for pressure.

1. If there is pressure **change the control valve.**
2. If there is no pressure, crack the double check fitting on the J-Relay side of the check valve. **Does air escape?**

NO - Change the J-Relay.

YES - Check for pressure in the I.A.R. line. If there is pressure with the independent released, **change the independent.**

INDEPENDENT BRAKES WON'T APPLY

Make sure the main reservoir is charged and that all the independent application and release (I.A.R.) train line cocks are closed.

Crack the fitting on the SA-26 independent brake valve side of the 16-20 double check. Is air pressure present?

NO - Replace the SA-26 independent brake valve.

YES - Crack the fitting on the J-Relay side of the 16-20 double check. Does air escape?

NO - Replace the 16-20 doublecheck valve.

YES - Replace the J-Relay valve.

INDEPENDENT BRAKES WON'T RELEASE

Make sure the independent is in the release position then crack the pipe on the J-Relay side of the 16-20 double check. Does air escape at the fitting?

NO - Is brake cylinder pressure dropping to "0"?

NO - Replace the J-Relay valve.

YES - Check the truck cut-out cocks if they have been cut-out and plugged. If not check brake cylinders and brake rigging for binding.

YES - Loosen #20 pipe from the independent on the inlet side of the 16-20 double check valve. Does air escape?

YES - Replace the independent brake valve.

NO - Pressure must be coming through #16 pipe from the control valve. Go to **"AUTOMATIC BRAKES WON'T RELEASE"** trouble shooting section.

AUTOMATIC BRAKES WON'T RELEASE

When the automatic brake handle is placed in release, does brake cylinder pressure reduce to "0"?

YES - Check brake cylinders and brake rigging for binding.

NO - Does brake pipe pressure increase with equalizing reservoir pressure to 90lbs.?

NO - If there is sufficient main reservoir pressure and the automatic brake valve is in release, go to **"SYSTEM WON'T CHARGE"** trouble shooting.

YES - Check #16 pipe on the control valve side of the 16-20 double checkvalve. If air escapes **replace the control valve.** If there is no pressure,check for air pressure in #16 pipe on the J-Relay side of the check valve. **Replace the J-Relay if there is no pressure.** <u>Replace the 16-20 double check valve if there is pressure.</u>

SYSTEM WON'T CHARGE

Check the safety devices circuit breakers. **Is the P.C.S. light on?**

NO - Is there any equalizing reservoir pressure?

NO - Is there any pressure in #15 pipe at the automatic brake valve pipe bracket?

NO - The regulating valve portion of the automatic brake valve is bad. Change the automatic brake valve.

Yes - Is there any pressure in #5 pipe at the automatic brake valve pipe bracket?

NO - Change the P-2-A.

YES - Relay valve portion of the automatic brake valve is bad. Change the automatic brake valve, check the pipe bracket, and **replace the mounting gasket.**

YES - Is brake pipe pressure the same as equalizing reservoir?

YES - The system must be charged, to retest.

NO -

1. Check the auxiliary emergency brake valve for exhaust air.
2. Check both #8 vent valves that they are closed.
3. Check the brake pipe train line for air pressure. If there is pressure the gauge is bad. If there is no pressure, is there a constant blow in the exhaust cavity of the automatic brake valve?

YES - Change the A-1 valve.

NO - The relay valve portion of the automatic brake valve is bad. **Change the automatic brake valve.**

YES - **Is there any equalizing reservoir pressure?**

NO - Make sure the automatic brake valve is in release and that there is sufficient main reservoir pressure. **Is there any pressure in pipe #15 at the P-2-A?**

NO - Change the automatic brakevalve.

YES - Change the P-2-A valve.

YES - Put the automatic brake valve in emergency, wait one minute, and then put the handle back in release position. **Did the P.C. light go out?**

NO - Put the handle back in emergency. Is there pressure in #12 pipe at the A-1 charging valve?

NO - Check #12 pipe and theutomatic brake valve pipe bracket or obstructions and if there are none change the automatic brake valve.

YES - Change the A-1.

YES - If the brake pipe recovered go ahead and retest. If not, make sure the cut-off pilot valve is cut in and then loosen the #53 pipe at the A-1 valve. Does air escape?

NO - Change the automatic brake valve. The relay valve portion is bad.

YES - Change the A-1.

AUTOMATIC BRAKES APPLY THEN RELEASE

Once the brakes started to release was the release slow or fast?

SLOW - THESE CHECKS MUST BE MADE WHILE THE BRAKES ARE STILL APPLIED.

1. Check the independent for a slight blow out of the spring housing exhaust. If there is a blow replace the 16-20 check valve.
2. Check #16 pipe from J-Relay to check valve for leaks.
3. Check #16 pipe from check valve to the control valve pipe bracket for leaks.
4. Check the 26F control valve quick release and service portions mounting gaskets for leaks.
5. Check #7 and #9 control valve pipes and their reservoirs for leaks.
6. Change the quick release.
7. Change the control valve.
8. Replace the J-Relay.

FAST - 1. If brake pipe and equalizing reservoir increased: Is the automatic brake valve cut-out pilot valve in passenger position?

NO - The automatic brake valve or the P-2-A are defective. Replace the P-2-A first then retest.

YES - If the **A.B.V handle** was moved toward release prior to the brakes releasing, then the brakes being released is normal. Place the pilot cut-out valve in the **"In or FRT"** position and retest.

2. If only brake pipe increased, **did the increase occur before or after the A.B.V. was cut out?**

BEFORE - Change the automatic brake valve.

AFTER -

1. Change the dead engine check valve and retest.
2. Check the A.B.V. brake pipe check valve (brass nut located at the right, front, and bottom of the A.B.V.), then retest.
3. Change the automatic brake valve.

3. If there was neither an increase in brake or equalizing reservoir; Check the actuating train line. Is air pressure present?

YES - Make sure the independent is not in the actuate position or that it's exhaust hose has not been kinked. If not replace the independent brake valve.

NO - Check control valve selector volume reservoir and #9 pipe for leaks. Check control valve control volume reservoir and #7 pipe for leaks. Check for leaks around the control valve service portion and quick release portion. If no leaks are found change the quick release, retest, then replace the service portion if necessary.

SYSTEM WON'T RESET FROM A PENALTY

Can you hear air blowing in the automatic brake valve exhaust cavity?

NO - Check the P-2-A #3, #10 and #8 pipes for air leakage (**If air is exhausting from any of these pipes, the P-2-A valve will not reset). If no leakage is found replace the P-2-A valve.**

YES - The automatic brake handle must be in suppression before penalty will reset. If it is in suppression and still won't reset, check #8 pipe for leakage, if none is found **change the automatic brake valve.**

SYSTEM WON'T GO INTO A PENALTY

ALERTER - The automatic brake valve must not be in suppression and brake cylinder pressure must be under 25lbs before the alerter will function. Is there air pressure in #3 pipe of the P-2-A valve?

NO - Change the P-2-A valve.

YES - Check the alerter magnet valve for proper operation and #3 pipe for obstructions. If they are **OKAY**, is there pressure in the lines from either the horn or bell to the alerter manifold?

NO - Replace the alerter manifold.

YES - There should be no pressure when the horn or bell are not in operation. Fix source of the air pressure in these lines.

DEADMAN - Is there pressure in the pipe at foot pedal?

YES - did the whistle sound when the pedal was released?

YES - Replace the P-2-A valve.

NO - Is there air pressure in the pipe between the whistle and the foot pedal?

YES - Replace whistle.

NO - Replace foot valve.

NO - Make sure there is no brake cylinder pressure and that automatic brake valve is not in suppression. Check to see that there is no pressure in #26 pipe to the P-2-A valve. If not replace the P-2-A valve.

OVERSPEED - Did the warning whistle sound when in overspeed condition?

NO - Make sure the cut out to the whistle is open. Is there pressure in the line from the cut out to the magnet valve?

NO - Is there pressure between the P-2-A valve and the cut out?

NO - Change the P-2-A valve.

YES - Change the cut out.

YES - Is there current flow to the magnet valve?

YES - Problem is with the speed-recorder switch.

NO - If there is pressure in the line on the whistle side of the magnet valve, replace the whistle and/or the choke beneath it. If there is no pressure, replace the magnet valve.

YES - check the timing choke under the whistle for being the proper size

(whistle should blow for 6 to 12 seconds before going into penalty). If the system will not go into a penalty with the choke removed change the P-2-A valve.

II. LMOA BEST PRACTICES: INTERNAL WATER LEAKS ON EMD LOCOMOTIVES

Prepared by: Frank Cowan, NS & Keith Mahalik, EMD

While most water leaks are external and can be easily detected and corrected, this paper was written to deal with the more complex problem of internal water leaks.

The following is a recommended procedure for detecting, correcting and analyzing internal water leaks on EMD locomotives.

Detection:

1) The first step that should be taken when the locomotive arrives (running or dead), is to take a lube oil sample and test for free water, then forward to test lab for analysis.
2) Check engineman's reports for water usage and locomotive history for most recent failures.
3) If locomotive is dead on arrival, fill cooling system with water. Open cylinder relief valves, remove crankcase and air box doors. Perform bar over inspection looking for obvious leaks (water on top of pistons, etc.) and to ensure no mechanical damage exists. Inspect top deck, looking for any obvious leaks. Check for broken crab or liner studs. This can be accomplished with a slight hammer test.
4) If no leaks are found, close relief valves, top deck covers and apply air box and crankcase doors and perform the following:

a) After all fluid levels have been checked, crank engine and allow to warm up. Do a thorough inspection of external components, piping and couplings to insure no external leaks exist.
b) Slowly advance throttle to No. 8 position.
c) After engine has reached operating temperature and coolant level stabilizes, mark cooling water sight glass on expansion tank.
d) Load test engine for at least one hour, while frequently checking water level in sight glass for droppage.

5. Reduce throttle to idle, open generator field switch and move isolation switch to isolate position and perform the following:

a) Perform a thorough top deck inspection, looking for water running down and around cylinder head pots and cylinder head flanges. Water in these areas are indications of defective seals on cylinder head water discharge elbows or a cracked cylinder head at the water discharge port. It may be necessary to shut engine down and remove crab plate to verify a crack at the water discharge port.
CAUTION: water in these areas can also be an indication of a leak at one of the "y" pipes in the engine vee, allowing water to leak through the top deck rail gaskets.
b) Inspect top of each cylinder head, looking for evidence of water around core plugs and inner stud nuts. Water around liner stud nuts usually indicate that a head to liner gasket failure has occurred.

6) If no leaks are found during top deck inspection, shut engine down and do the following:

a) Again, open all cylinder relief valves. Remove air box and crankcase covers.
b) Remove expansion tank filler cap. Apply an approved cooling system pressurizing device, and pressurize cooling system to 30-40 P.S.I. using shop or locomotive main

reservoir air.

CAUTION: Pressurizing cooling system above 50 P.S.I. can damage radiators and aftercoolers.

c) Inspect water jumper lines and turbocharger aftercoolers (on turbocharged engines) for leaking.

d) While barring engine over, inspect interior and exterior of cylinder liners for signs of water. Also inspect the top of each piston crown for water droplets.

e) If no leaks are found, remove lube oil strainer housing cover. Inspect oil cooler inlet pipe inside of strainer box for water. If water is found entering strainer housing through oil cooler pipe, oil cooler is leaking and must be replaced.

f) It may also be necessary to check water pumps for leaking water into the crankcase because of defective seals. To do this, drain crankcase oil below the bottom of accessory housing. While looking through No. 1 and No. 9 oil pan cover openings, look for water running down accessory housing directly into crankcase.

g) On turbocharged locomotives, remove turbocharger inlet screen, inspect screen for grayish deposit build-up. Grayish deposit on turbo screen is an indication that water is being blown out the stack as a result of a leaking power assembly not discovered with aforementioned tests, or a cracked block.

h) While turbocharger screen is removed, inspect interior of each exhaust manifold for discoloration or deposit build-up. If discoloration or deposits are found in any one manifold, remove that manifold and inspect for a leaking power assembly or cracked block. Cracks in the block are usually found in the exhaust scroll area where exhaust port is welded to the top plate of the engine.

7. If first pressure test is not successful, it will be necessary to apply an 80lb hydro test to the engine block. To apply hydro test to the engine block, do the following:

a) Remove both water pump inlet pipes and apply blanking plates to each water pump inlet. One blanking plate should be equipped with a water connection to pressurize block.

b) Disconnect cross-over pipe at each water pump discharge elbows and apply blanks.

c) Disconnect "y" pipe discharge flanges and apply blanks to "y" pipe. One blank must be equipped with a pet cock to discharge air.

d) On turbocharged engines, remove aftercooler pipes and apply blanks to small "y" in engine vee and both ends of water manifolds under aftercooler housings.

e) Open pet cock on "y" pipe blanking plate. Connect water line to blanking plate on water pump inlet and fill engine with water until water is discharged through pet cock on "y" pipe blanking plate, then close pet cock.

8. Repeat inspection procedure for 6c and d.

Note: most internal water leaks will be found and corrected before you get to this point. The important thing is that on locomotives with known internal water leaks, you should not stop looking until leak is found.

Corrective action:

Since most internal water leaks are power assembly related, the following are recommended procedures to improve power assembly reliability.

Head to liner gasket failure:

Life of the head to liner gasket and water seals is primarily dependent on four criteria:

1. Head to liner gasket and water seal integrity.
2. Surface roughness on cylinder head and liner gasket surfaces.
3. Proper convex on cylinder liner gasket surface.
4. Proper clamp load on head to liner gasket.

While the first three criteria can be monitored by periodic inspection and spot checks, torque is a poor method of measuring clamp loan. Clamp load can best be measured by measuring stud stretch. This can be accomplished with the use of an ultrasonic measuring device.

Broken liner studs:

In instances where there is a regular occurrence of broken liner studs, it is recommended that studs be replaced with rolled thread studs any time studs are removed for liner re-conditioning.

Cracked cylinder heads:

Cylinder heads usually crack in the fire face between exhaust valve seats or between exhaust valve seat and injector hole, or at the water discharge port on top of the head.

Cracks in the cylinder head fire face can usually be attributed to any one or combination of the following:

1. Poor cooling water flow through the cylinder head.
2. Defective injector nozzle causing hot spots on fire face of cylinder head.
3. Over torquing of injectors during installation.
4. Improper scavenging air allowing cylinder heads to overheat.
5. Plugged air box drains (particularly on normally aspirated engines), allowing lube oil to be mixed with scavenging air while engine is operating.

Cracks on top of the cylinder head at the water discharge port are usually the result of improper torquing of crab plates. Crab plates should be properly torqued, using two pass method, torquing outboard crabs first as described in the EMD engine maintenance manual.

Liner water jumper failures:

Water leaks at liner water jumpers usually occur at the jumper saddle gasket, jumper to liner "o" ring or cracks at the braze joints on the jumper line itself. In most cases these failures can be attributed to improper installation. When applying jumper lines, all gasket surfaces should be thoroughly cleaned, properly torqued, and jumper positioned so there is no stress to cause cracking. Refer to EMD pointers dated April 16, 1974 for proper installation of liner water jumpers. To further reduce strain on water jumper lines it is recommended that water manifold support brackets be applied especially on 16-cylinder turbocharged engines. See EMD pointers no. 3L-78 for proper installation.

Analyzing internal water leaks:

Analyzing internal water leaks (or any failure) can be as easy as collecting data and analyzing it. This can best be accomplished through statistical process control (SPC).

Initially, knowledge of failure modes will be broad in nature. However, there are several charts that are helpful when evaluating data collected during problem solving activity. Some of the most effective charts are pareto, histograms, run charts, and cause and effect diagrams.

Decisions based on data and meaningful statistics are more likely to be sound decisions. Many of the aforementioned failure modes have been analyzed and corrective actions put in place based on data collected through SPC.

If statistical process control is not a part of your maintenance process, consider it. SPC can be a powerful tool in identifying problems and finding ways to improve reliability.

III. LMOA BEST PRACTICES: OIL OUT STACK

Prepared by: John Baranko, Conrail & Jay Holley, CSX

O.O.S., as it is referred to by many railroads, is a condition whereby engine lubricating oil is being emmited out of the exhaust stack.

Although oil out of the exhaust stack can occur on both EMD and GE locomotives, the condition of oil out the stack is more predominant on EMD locomotives.

For many valid and logical reasons, this is a condition that has to be corrected immediately. Unfortunately, the correct solution to this phenomenon may not be readily discernible. In many cases they are varied, and can become time consuming, not only in actual labor hours, but also in out-of-service time for the locomotive.

This report will attempt to list a set of guidelines based on the "best practices" that are followed by several railroads. It is divided into two sections, the first on turbocharged engines, and the second on normally aspirated (blower type) engines.

One important assumption that will be made in regard to these practices is that the locomotive in question is one that has been in service and not just out of overhaul or rebuild.

Other assumptions are:

- that the air box drains are open and functioning properly;
- that the locomotive in question has already been qualified to the extent that it is the source of the oil out the stack condition, and not a locomotive that may have been in consist and become covered in oil.
- that an oil sample was taken and analysis for fuel dilution was done, with the results available to the mechanics performing the inspection.
- that review of the locomotive maintenance history has been done, looking for repeat shoppings, major component renewals that may have a bearing on the oil out the stack condition.
- that last, but certainly not the least important, the locomotive has been thoroughly cleaned prior to starting the inspection and repair processes.

Turbocharged

If oil analysis indicates fuel dilution, a thorough check of all fuel lines and injectors is required. Besides diluting the lube oil, under certain conditions, defective injectors can contribute and cause oil out the stack.

Visually inspect exhaust stack. Determine if oil is still present in exhaust area of turbocharger.

Visually inspect exhaust area of turbo for foreign object damage or diffuser warpage.

If no apparent damage is present but there is oil in the stack, you must now determine if the source of the oil is the engine or turbocharger.

It is recommended that you remove the turbo screen completely (not just the inspection cover). Once the screen assembly is removed, a determination can be made as to where the oil is coming from. Let's first assume that the inspection reveals no oil is coming from the engine, but rather is isolated in the turbocharger. To further qualify the turbocharger, inspect the eductor tube in the turbocharger to verify or eliminate (them) as the primary cause of the oil condition. You should also inspect and qualify the oil separator and its components. This alone can cause an oil out the stack condition. If this system is OK, prior to condemning the turbocharger itself as the cause of the oil out the stack condition, you should inspect the primary and sec-

ondary air intake filter systems for a plugged condition, and if necessary, assemble the turbo screen and take manometer readings with the engine running to verify these systems are clean. Plugged filters can cause the labyrinth seals to allow oil out the stack. If these inspections and tests verify that the air system is "in spec", then the turbocharger should be renewed. After renewal, load box the unit to verify that the problem has been corrected.

Now, let's make a different assumption, and that is that the oil is present in the exhaust manifold of the engine (while the turbo screen is removed). If it can be determined that the oil is coming from a particular cylinder or cylinders, make note of that, and a thorough inspection of these cylinders should be done. Let's assume the oil cannot be isolated to any one particular cylinder or cylinders.

Inspect the "vee" of the engine to see if there are signs of oil leaking from top deck lid and frame gaskets (Figure 1) Correct the condition if found and thoroughly clean the "vee".

Perform a top deck inspection, paying particular attention to valve guides (broken or worn), loose or broken crab studs, broken head seat rings, cracks in and round head pot area.

Any one or combination of these defects can cause oil out the stack, and should be corrected.

Continue the engine inspection by performing an air box inspection. Check the general condition of the air box for abnormal amount of oil. If it is isolated to any particular area determine the source. If the entire air box is generally the same, continue by inspecting each power assembly. Look for scored liners, broken rings, wet pistons or scored pistons. Any defective power assembly should be renewed.

If after the entire engine inspection is performed and no defects are found as described, it is recommended that all crab nuts be retorqued per appropriate spec. Close up the engine and perform a load test to verify that the oil out the stack condition has been corrected. During the load test, engine temperature control devices should be qualified for proper operation and settings, as a cold engine can cause oil out the stack. If the condition has not been corrected, it is recommended that you pull a power assembly out of the engine, thoroughly inspect the head pot area for excessive wear. Also check the head seat ring for wear and tolerance. The power assembly should be taken apart, inspecting the piston oil rings, liner assembly and cylinder head for excessive wear (in the valve guide areas). Based on this inspection, you will have to determine if the general condition is good, or whether the engine needs a major rebuild to correct the defect.

Generally speaking, if the crab nuts were not properly torqued and are loose, the head seat rings can wear out prior to the power assembly changeout period. It may be required to renew all the head seat rings in order to correct the oil out the stack condition. In most cases, if you followed these guidelines, oil out the stack can be corrected on turbocharged engines.

Normally Aspirated (Blower Type)

All of the assumptions stated previously would also apply to normally aspirated engines.

If oil analysis indicates fuel dilution, a thorough check of all fuel lines and injectors is required. Besides diluting the lube oil, under certain conditions defective injectors can contribute to and cause oil out the stack.

Inspect the exhaust stacks and verify if one or both stacks have oil in them. If only one stack has oil present then

the engine inspection should be concentrated in that area. Let's assume both stacks have signs of oil present.

The primary and secondary filter systems should be checked to insure that they are not plugged. A manometer should be used to verify condition. Correct if found "out of spec". Inspect and qualify the oil separator system.

After the filter systems are qualified and resolved, a thorough engine inspection should follow.

Inspect the "vee" of the engine for oil accumulation. Determine if there is oil present. You must also determine if the oil that is present came from the stack or the top deck lid and frame gaskets. Oil leaks from the top deck can cause an oil out the stack condition.

If the oil present in the "vee" is runoff from the stacks, it should be thoroughly cleaned along with the spark traps (if equipped) in the exhaust manifolds. (Figure 2)

The next portion of the inspection should be a thorough top deck evaluation. Look at and verify condition of valve guides and look for loose or broken crab studs, broken heat seat rings, and cracks in and around head pot areas.

Any one or combination of these defects can cause oil out the stack and should be corrected.

After the top deck inspection is performed, you should do an air box inspection. (Figure 3). Check the general condition of the air box for any concentration of oil. If oil is found in one area more than another, concentrate your inspection in that area. Inspect the roots blower, paying particular attention to the air ducts. Excessive oil in this area indicates blower rotor end seal failure, and the seal should be renewed.

Next, inspect each power assembly. Look for scored liners, broken rings, wet pistons and scored pistons. Pay particular attention to the condition of the liners. Look for a varnishing condition. Varnishing can be characterized by light brown or tan deposits on the liner walls.

One one or combination of these defects can cause oil out the stack. All defective power assemblies should be renewed.

If the liners appear to have a varnishing condition, it is recommended that the unit be load boxed for several hours in order to break down the coating and allow the rings to reseat properly. There are some additives available on the market that can be added to the fuel which can expedite the removal of the varnish by increasing the firing temperature. You must follow manufacturer's directions on quantity per gallon of fuel.

As with the turbocharged engine, it is also recommended that all cylinder crab nuts be retorqued. The unit should be load boxed to verity that the oil out the stack condition has been corrected.

During load test, engine temperature control devices should be qualified for proper operation and settings, as a cold engine can cause oil out of the stack. It is also recommended that after a unit has been load boxed and the stacks are dry, let it idle for several hours to insure that the condition has been corrected.

If the condition has not be corrected, then it is recommended that a power assembly be removed. (Figure 4) Thoroughly inspect the head pot area for excessive wear. Check the head seat ring for wear and tolerance. The power assembly should be taken apart, inspecting the piston, oil rings, liner assembly and cylinder head for excessive wear (in the valve guide area.) Based on this inspection, you will have to determine if the general condition is good, or if the engine needs a major rebuild to correct the defect.

Generally speaking, if the crab nuts were not properly torqued and were loose, the head seat rings can wear out prior to the power assembly changeout period. All the head seat rings may have to be renewed to correct the oil out the stack condition.

With many normally aspirated engines which get only light loading, oil out the stack can be a common problem. Load boxing on a regular basis or change in type of service is a good preventative maintenance practice.

Though not a primary cause, injector and valve timing should also be checked if oil out stack troubleshooting does not reveal the cause.

Malfunctioning or leaking injectors can lead to piston and liner washdown and premature scoring. Washdown can also lead to lubricating oil bypassing the rings and causing smoke or oil out stack. Valve and injector timing should be checked to insure maximum engine performance even after the oil out stack cause has been determined, since prior troubleshooting of the engine may have resulted in improper fuel injector or valve adjustment while repairs were being attempted.

In most cases, if you follow these guidelines, you can correct an oil out the stack condition on normally aspirated engines.

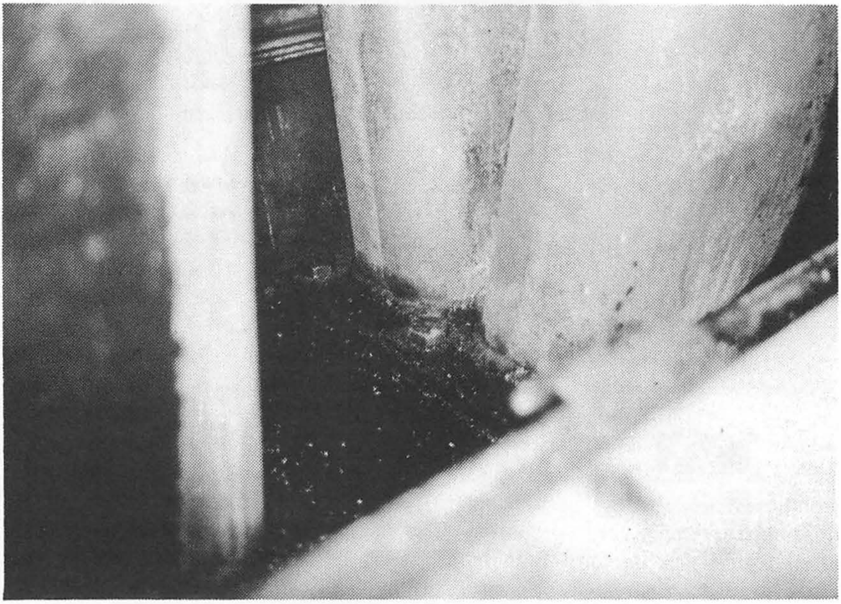


Figure 1.
Vee of turbocharged engine with top deck, gaskets and seals leaking oil.

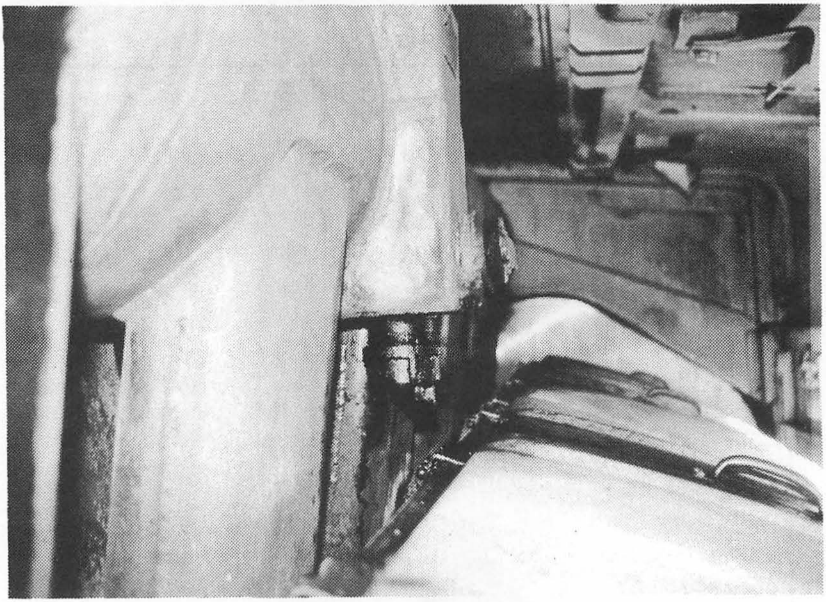


Figure 2.
Normally aspirated engine equipped with spark traps with obvious oil out stack problem.

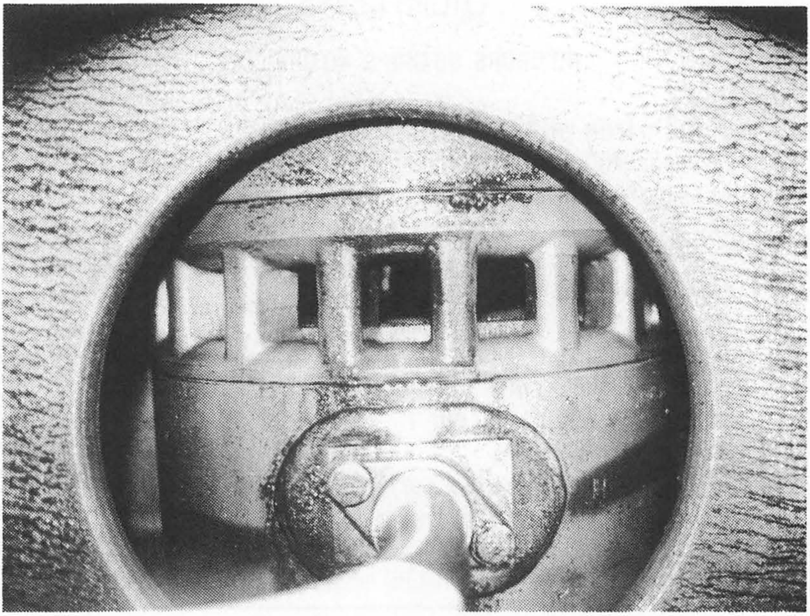


Figure 3.
View of power assembly through air box prior to ring liner piston inspection.

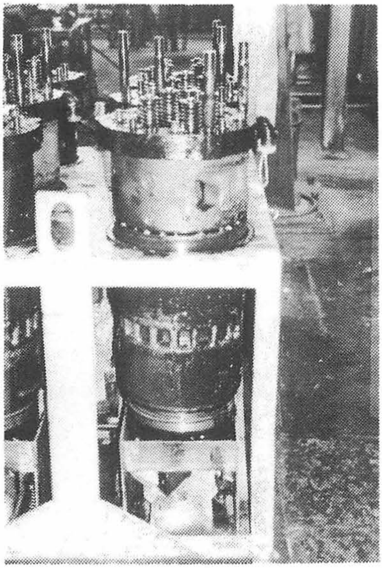


Figure 4.
Power assemblies removed for thorough inspection from an oil out stack engine.

Figure 5.
Locomotive repaired for oil out stack after following best practices guidelines outlined in this paper.

REPORT OF THE COMMITTEE ON FUEL, LUBRICANTS & ENVIRONMENTAL

TUESDAY, SEPTEMBER 17, 1996
9:00 A.M.

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

Vice Chairman
BRUCE A. KEHE
Manager Mech. Svcs.
EJ & E
Gary, IN

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M. Logan	Staff Engr.	Chevron Oronite	Richmond, VA
D. McAndrew	Fuels & Lub. Spec.	General Electric Co.	Erie, PA
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G. Schafer	Senior Technologist	Texaco, Incorporated	Beacon, NY
E. Shamah	Sr. Staff Engr.	Chevron Research	Richmond, CA
C. Tincher	Product Manager	Lyondell Lubricants	Houston, TX
M. Wierucki	Engineer of Test	CP Rail System	Winnipeg, MB

PERSONAL HISTORY

Chuck Kunkel

Mr. Kunkel has been with the Union Pacific for 24 years. He has held various positions in the locomotive engineering and maintenance environment. He currently is the Senior Mgr. - Research and Development. His responsibilities include lubricant, fuel and water treatment. Chuck is married with two children and his hobbies are fishing and auto mechanics.

I. STANDARDIZED TEST PROCEDURES: THE ANNUAL SUBCOMMITTEE UPDATE

Presented by:
Ron Lodowski, Conrail

Introduction

"Do more with less." The vital buzz words of today's world economy. To illustrate this fact, a locomotive fleet analysis of a major Eastern railroad was conducted. In 1989, locomotive fleet size was approximately 2,350 units; by 1996 that total had dropped to less than 2,000 units. This equates to a 15.8% decrease. One very interesting fact was uncovered. While the number of low horsepower locomotives (that is, less than 3000 horsepower) had decreased by 44.5% during this period; the number of high horsepower locomotives increased by 37.4% (Figure 1).

Due to obvious economic benefits; the industry trend is toward higher horsepower locomotives. What must be remembered is that while fleet size has decreased and locomotive horsepower has increased, gross freight ton mileage has increased and lubricating oil consumption has decreased. This means and that more stress than ever before is being placed on locomotive lubricants and more then ever, careful analysis of lubricating oil and quality diesel engine lubricants are necessary. Numerous industry surveys that have been conducted have indicated that the measurement of insolubles levels and acid neutralization testing were in need of improvement in both accuracy and repeatability. As a consequence the LMOA Fuel, Lubricants, and Environmental (F, L & E) subcommittee on standardized test procedures was formed.

The 1995 F, L & E Committee paper, *Standardized Test Procedures: Past, Present & Future Developments* dealt with the past, current, and future activities of its internal multi-industrial subcommittee. This subcommittee was created to address the questions of finding a swift and economical pentane insolubles screener test and to determine its correlation to the 1993 LMOA Insolubles Test Procedure (ITP). In addition; a study of current alkalinity measurements and their correlation to metal corrosion is being sought. This is the yearly summary highlighting the activities of the subcommittee.

Capacitance Measurement versus 1993 LMOA Insolubles Test Procedure

To reiterate what has been stated in earlier F, L & E committee papers, pentane insolubles are largely carbon based particulate (e.g. soot) which are produced during diesel engine operation. The particulate is formed during the normal combustion of diesel fuel oil but an elevated soot level can be an indication of a mechanical abnormality (e.g. broken or worn rings, worn liners, or improper diesel engine timing). Left unchecked, high insoluble levels can result in plugged filters; engine sludging; and premature component replacement.

The 1993 LMOA Insolubles Test Procedure (ITP) was developed and provides a proven repeatable, standardized pentane insoluble test for the railroad industry. However, the LMOA ITP was found to be too time consuming to run on a routine basis. Therefore, what was required by the railroad industry was a quick, inexpensive, and uncomplicated screener test that would correspond to the 1993 LMOA ITP with acceptable correlation.

The criteria for the development of an approved LMOA laboratory test procedure or screening test are ease of running samples, quickness of running samples, repeatability and reproducibility of test results, and minimal equipment expense. When these criteria are met, the greater will be the procedures' acceptance and ultimately the improvement in all railroad maintenance practices on both Class I and short line railroads. The current laboratory device that apparently meets these criteria is a capacitance meter. This device was perfected based on the principle that the dielectric constant changes in dirty or sooty fluid as compared to a neat fluid. The device currently can be bought for approximately $500 US and, once properly standardized, an oil sample can easily be run every minute. What was needed was the current correlation between the capacitance meter's readings and the concentration of soot present in the oil, as determined by the 1993 LMOA ITP.

The original correlation collected from an Eastern railroad appeared to be a shotgun blast point scattering of information (Figure 2). What would be revealed later is that the data were acceptable when appropriately examined. Preliminary analysis of the capacitance meter procedure by a major Western railroad derived the conclusion that this procedure would be accurate in predicting the 1993 LMOA ITP to within 1.5% by weight (Figure 3). Additional data were obtained from the another major Western railroad based upon over 600 samples (Figure 4). At this time the data obtained by the Eastern railroad reevaluated (Figure 5). The correlation that will be suggested is based upon the running of almost 1000 samples using the 1993 LMOA ITP, plotting the correlating capacitance meter data points, and determining the linear regression trend line of the maximum pentane insoluble value at each reading. The present 4% pentane insoluble limit that is listed in the General Electric Transportation Services Group Maintenance Instruction; MI-00128; mathematically corresponds to a capacitance meter reading of 30.88. The coefficient of determination (r^2) for the trend line equated to a value of 0.82. The coefficient of determination ranges from 1.0 for a perfect correlation to 0 for no correlation. This value correlates reasonably well with the r^2 value of 0.88 reported for the same procedure in the 1993 LMOA F, L & E Committee paper; *Insolubles Determination With The Advent of Multigrade Diesel Engine Oils.*

Considering this, the LMOA, F, L & E Committee is suggesting that a capacitance meter screening test reading **Less Than or Equal to** 30 need not have the 1993 LMOA ITP performed to determine the soot loading. If a reading **Greater Than** 30 is registered the LMOA ITP should be run to ensure maximum oil drain interval. It should be further mentioned at this time that, if water is present in the lubricating oil, an erroneous capacitance meter reading can be obtained based upon the natural electrical conductivity of diesel engine cooling water. The 1993 LMOA ITP should be performed whenever the presence of water has been determined. Considering these guidelines, the major Western railroad that was mentioned in the 1995 LMOA paper has seen a 50% reduction in the number of 1993 LMOA ITP performed with no adverse effects on locomotive fleet performance.

New additive systems promise to decrease sludging on locomotive components while tolerating higher insolubles levels in lubricating oils. Consequently, it may be possible in the

future to increase soot loading in lubricating oils beyond current diesel engine maximum limits with no adverse effects on component performance. If higher soot loading limits become acceptable to diesel engine manufacturers, a new capacitance meter 1993 LMOA ITP correlation will need to be derived.

Current Accepted Test Methods versus Soft Metal Corrosion

Over exposure to an engine oil with minimal acid neutralizing capabilities will result in the accelerated corrosion of soft metal surfaces, primarily copper and lead. When this occurs, bearing surfaces can be adversely affected and lubricating oils exposed to accelerated oxidation processes. To prevent this situation, railroads and diesel engine manufacturers have established minimal limits for pH, TBN, and TAN levels in used engine oils. The total base number (TBN) is an expression of the quantity of acid that is required to neutralize all alkaline constituents of the diesel engine oil additives, while total acid number (TAN) is an expression of the quantity of base that is required to neutralize all acidic constitutents of the diesel engine oil additives. What is now necessary as an industry is to determine to the best of our ability the relationship between bearing corrosion or control of corrosive wear in the engine and base or acid numbers.

The LMOA subcommittee has initiated an analysis of all current, accepted neutralization measurement techniques. Measurement by pH was not considered at this time by the subcommittee since pH measurement is the measurement of acidic characteristics in aqueous solutions. TBN measurement by ANSI/ASTM D664-75 was likewise not considered, since the test method has been replaced by ANSI/ASTM D4739-87. Methods that are being considered are being measured using actual used lubricating oil samples and how they relate to metal weight loss from main bearing coupons provided by the major North American main bearing manufacturer. Considering these guidelines it was determined that TBN determination by ANSI/ASTM D664-75 does not provide useful indication that the used lubricating oil has turned corrosive to lead. TAN determination by ANSI/ASTM D664 initially appears to provide useful indication that the oil has turned corrosive to lead. Differential infrared analysis (DIR) in the 1725-1670 abs/cm-1 absorbency band also appears to provide useful indication that the oil has turned corrosive to lead. Infrared analysis reveals similar oxidation DIR numbers regardless of currently tested oil additive technologies (Figures 6a & 6b). The major drawback of infrared technology is the initial cost of laboratory equipment.

A test procedure is being developed to remove oxides that might accumulate on coupon samples before corrosion testing. If this step is not accomplished the subcommittee fears that the much erroneous weight loss data might be accumulated The corrosion testing must always begin with uniformly conditioned bearing coupons. Likewise, if infrared is determined to be the procedure of choice, a uniform IR procedure must be developed.

While the subcommittee is still addressing the situation, there are still several practices that could be followed to provide increased diesel engine protection.

1. Initiate a routine bearing inspection policy whenever the diesel engine has been exposed to emulsified oil or severe water contamination (greater than 0.2%).

2. If initial main bearing examination reveals no unusual situations, and routine lubricating oil analysis reveals wear metals that continue to rise, perform an examination of additional bearing locations (i.e. connecting rod bearings).
3. A lubricating oil sample should be taken and analyzed as often is economically and logistically possible to ensure proper trending of wear metals.

As always, the LMOA recommends that such practices be reviewed with responsible parties on your railroad before they are initiated and if your current practices are more stringent than those proposed to follow the more strigent.

Conclusion

Several promising aspects have been examined by the subcommittee. However; as with all committee work sometimes progress is hindered by forces and individuals outside the committee's. The work will progress mainly through the persistent labor of the subcommittee's members. With the diligent efforts of the subcommittee it's initial objectives will be realized.

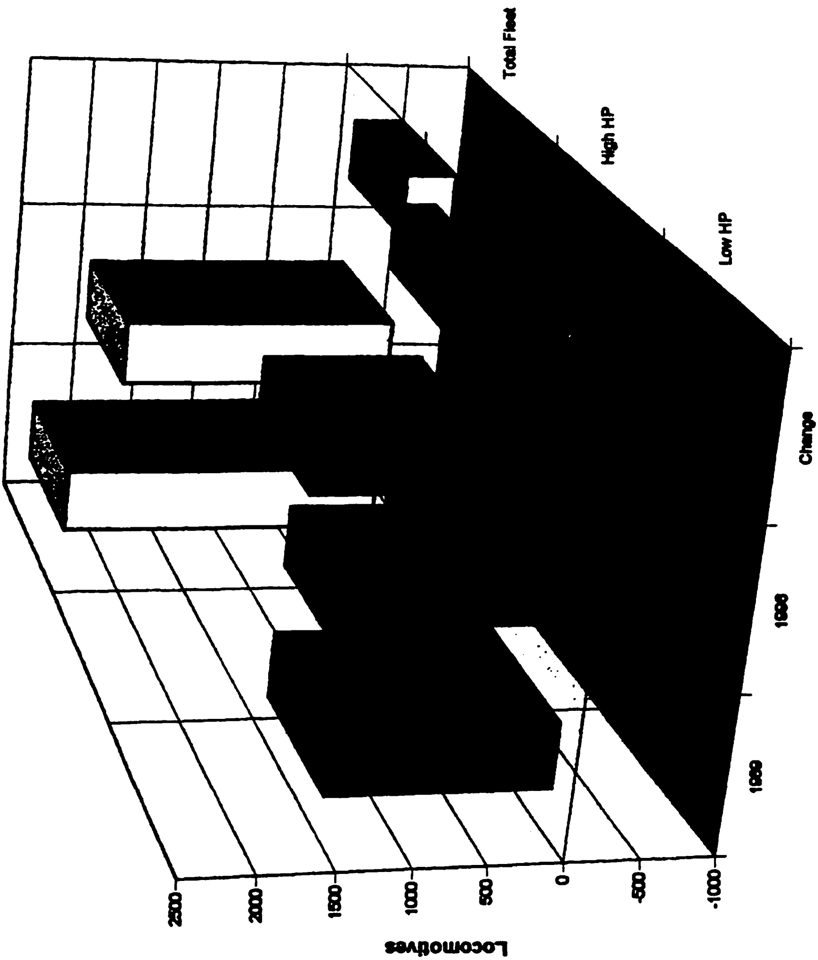
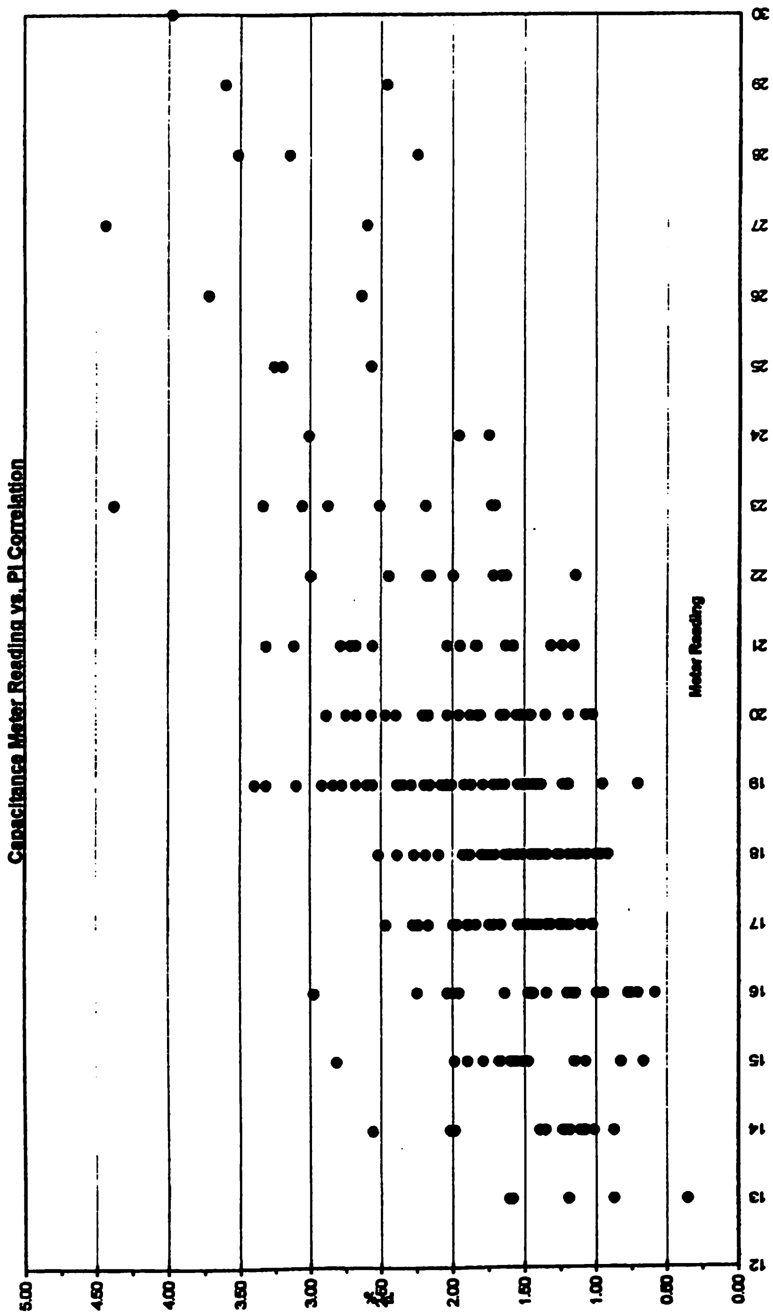

Total Fleet
High HP
Low HP
Change
2500
2000
1500
1000
500
0
-500
-1000
Locomotives

Figure 1


Capacitance Meter Reading vs. PI Correlation
Meter Reading
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
12
13
14
15
16
17
18
19
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21
22
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27
28
29
30

Figure 2

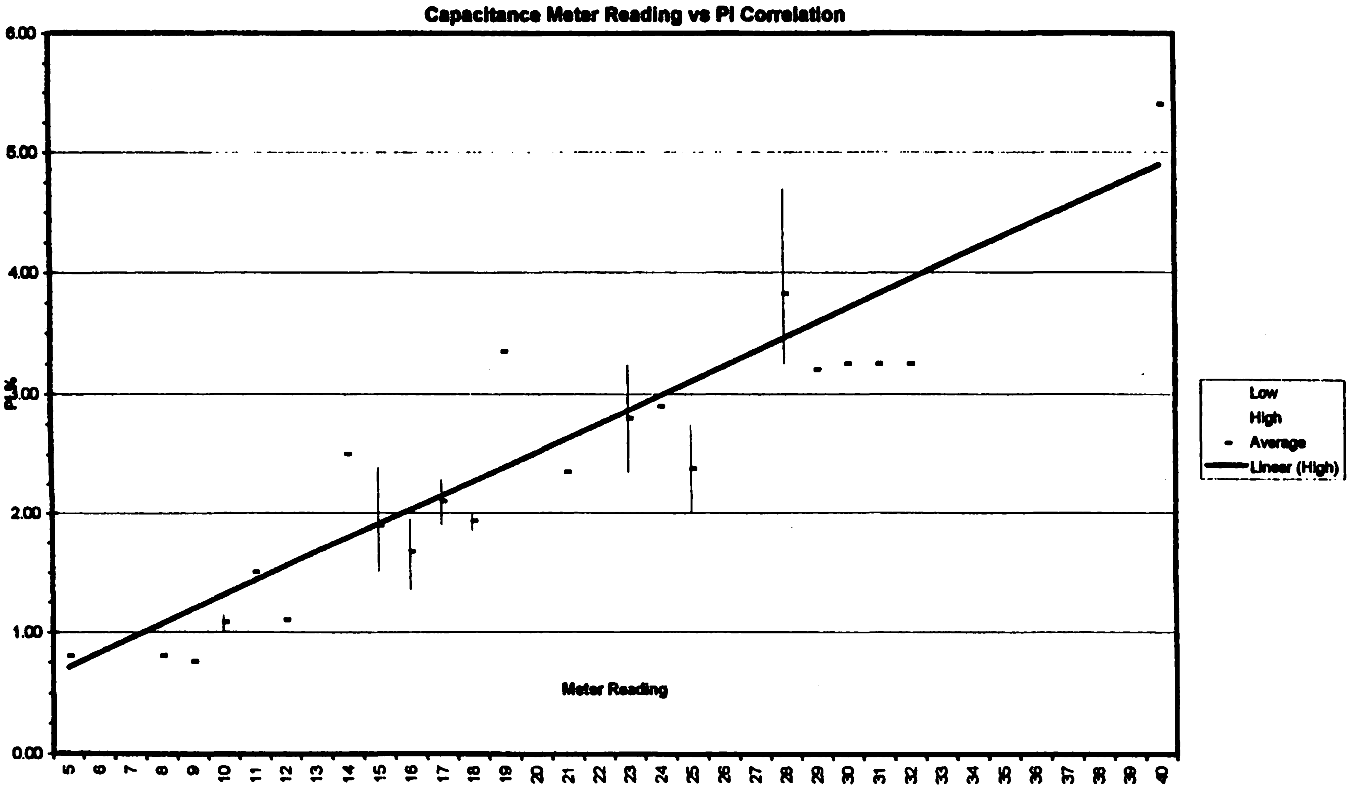
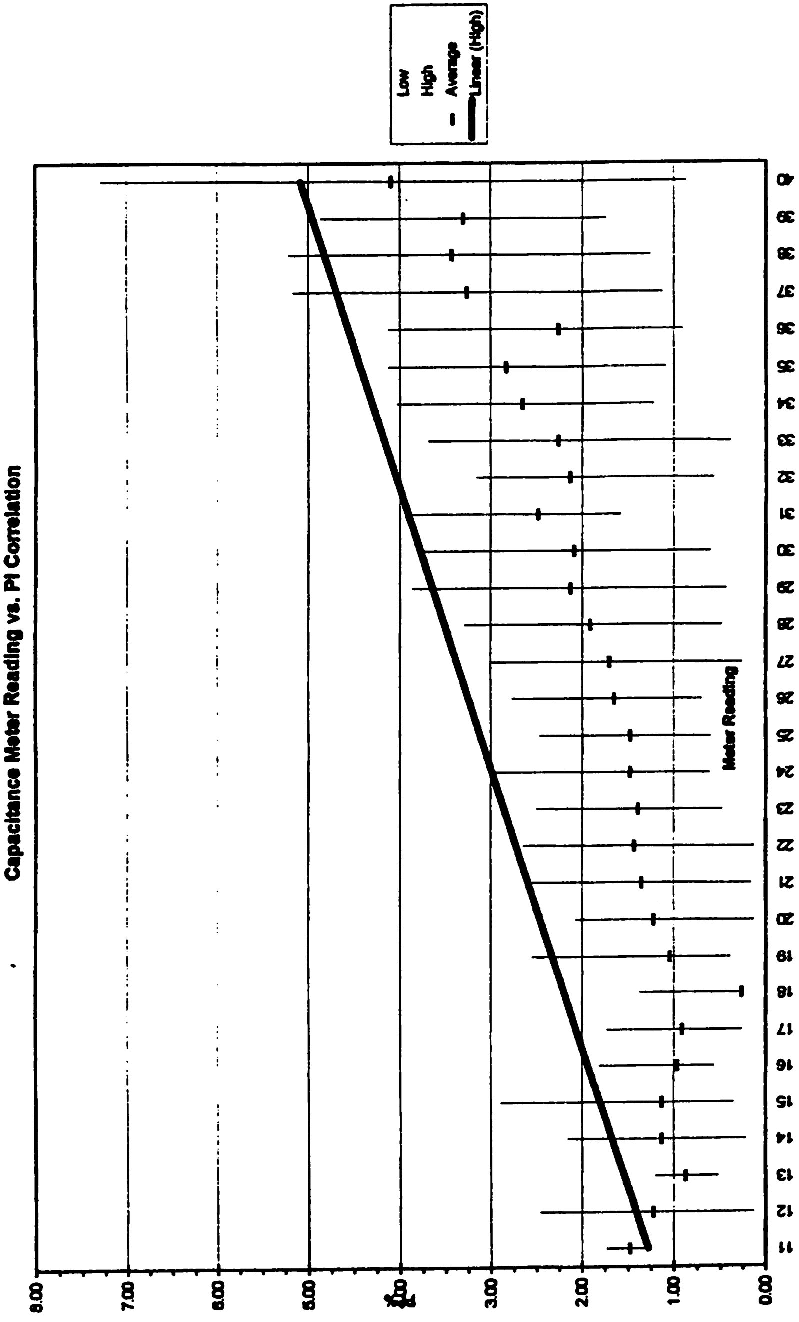

Capacitance Meter Reading vs PI Correlation
6.00
5.00
4.00
3.00
2.00
1.00
0.00
PI.%
Meter Reading
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Low
High
Average
Linear (High)

Figure 3



Capacitance Meter Reading vs. PI Correlation
Low
High
Average
Linear (High)
Meter Reading
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
11
12
13
14
15
16
17
18
19
20
21
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37
38
39
40

Figure 4

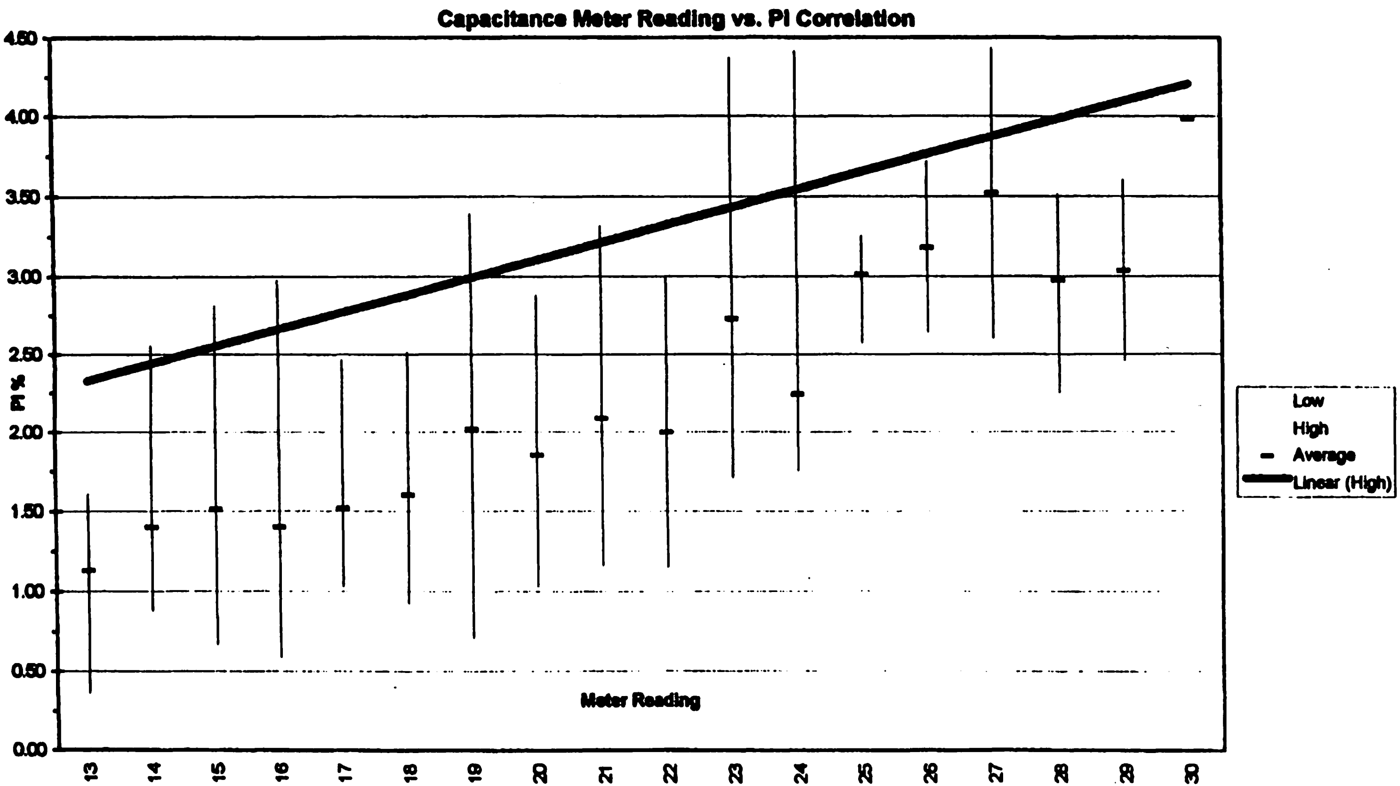

Capacitance Meter Reading vs. PI Correlation
PI %
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Meter Reading
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
Low
High
Average
Linear (High)

Figure 5

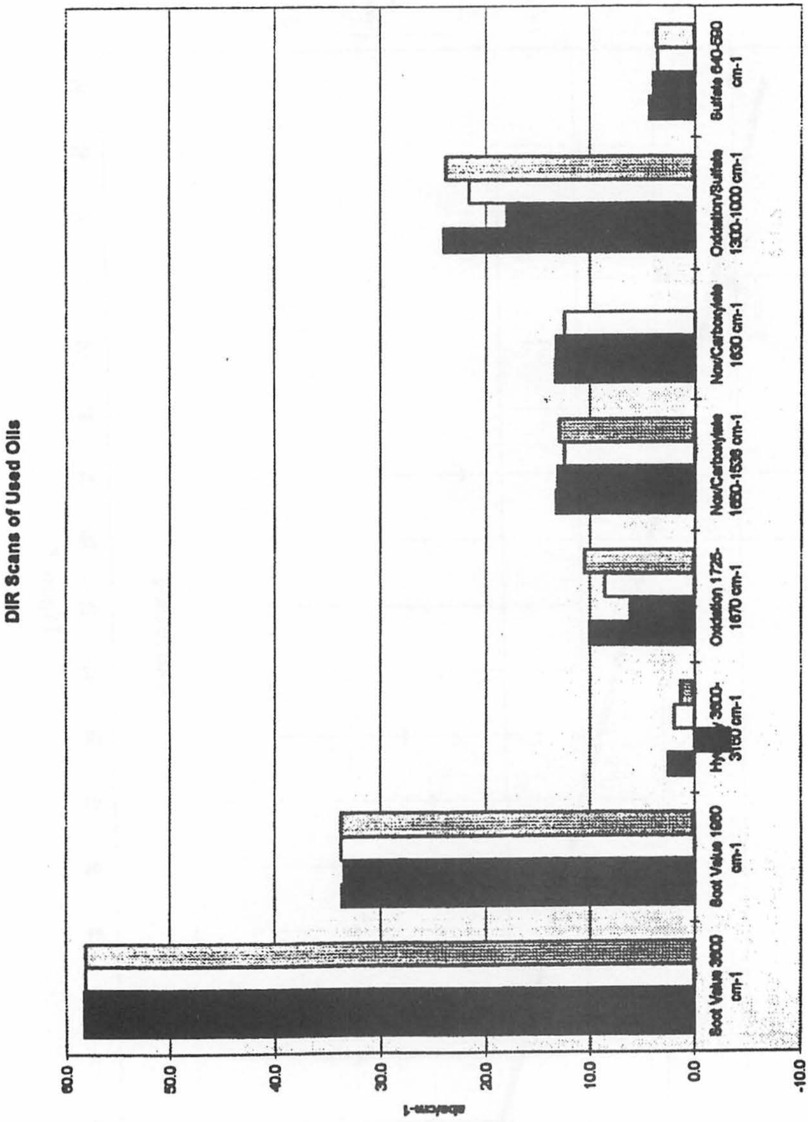

DIR Scans of Used Oils
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
Soot Value 3800 cm-1
Soot Value 1980 cm-1
Oxidation 1725-1670 cm-1
Nox/Carboxylate 1650-1536 cm-1
Nox/Carboxylate 1630 cm-1
Oxidation/Sulfate 1300-1000 cm-1
Sulfate 640-580 cm-1

Figure 6a

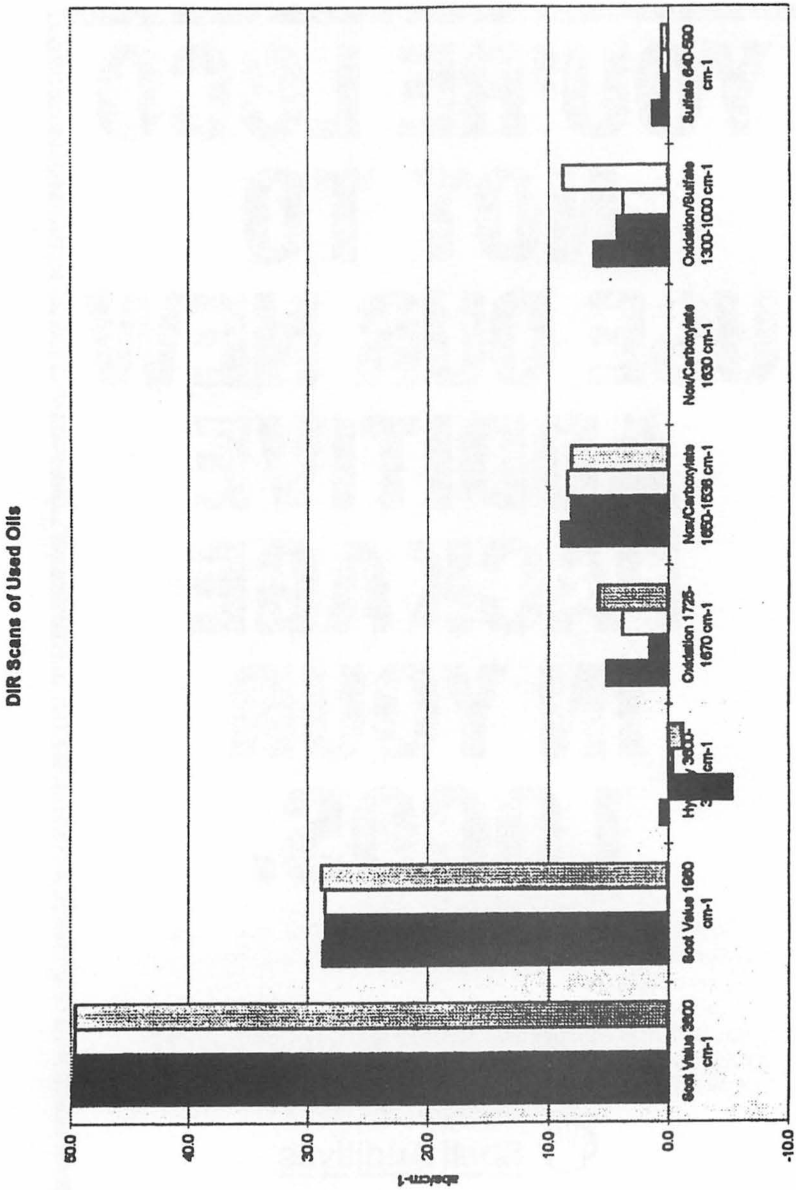

DIR Scans of Used Oils
abs/cm-1
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
Soot Value 3800 cm-1
Soot Value 1980 cm-1
Oxidation 1725-1670 cm-1
Nox/Carboxylate 1650-1636 cm-1
Nox/Carboxylate 1630 cm-1
Oxidation/Sulfate 1300-1000 cm-1
Sulfate 640-590 cm-1

Figure 6b

II DIESEL FUEL STANDARDS AND THEIR APPLICATION TO RAILROAD FUEL QUALITY ISSUES

Presented by:
Bruce Kehe, EJ & E

The railroad industry annually consumes over 4 billion gallons of diesel fuel at a cost of approximately 2.6 billion dollars. With this enormous expense, it is not surprising that railroads spend considerable time and effort in the quality control of their diesel fuel. The goals of this effort are the prevention of locomotive fuel filter plugging and the subsequent locomotive failures and train delays. With today's emphasis on locomotive "reliability," "availability" and "on time performance," premature plugging of locomotive fuel filters is unacceptable.

Despite considerable efforts in the area of fuel quality control, several major railroads had significant fuel problems in 1995. One class I railroad which routinely achieved a 92 day locomotive fuel filter life, was forced to go to a 23 day fuel filter change because of premature plugging. A second major railroad saw wayside fuel filter life at one fuel facility reduced from an average of 30 days to less then seven days. A third major railroad reported in one month over 70 locomotives with plugged fuel filters.

Some major causes of fuel filter plugging problems have been identified as (1) excessive particulate, (2) excessive water and (3) poor fuel stability. Stability is a measure of the amount of insoluble residue formed in fuel in storage and upon heating. Each of these three contaminants can contribute to premature filter plugging.

Solid insoluble matter, present as excessive particulate or resulting from poor stability, coats the filters and inhibits the passage of fuel. Excessive water causes the paper filter media to swell and the pores to close. Water also promotes corrosion and is essential for microbiological growth. Both corrosion and microbiological debris are additional sources of insoluble matter which deposit on fuel filters.

The purpose of this paper is to report on efforts within the ASTM (American Society for Testing and Materials) Committee D-2 to eliminate these problems.

ASTM Committee D-2

ASTM is a not-for-profit organization which provides a forum for producers, users, ultimate consumers, and those having a general interest (representatives of government and academia) to meet on common ground and to write standards for materials, products, systems and services. From the work of 132 standards-writing committees, ASTM has developed more than 8,800 standards. The standards and other related technical information are sold throughout the world.

The ASTM Committee D-2 is responsible for writing specifications for petroleum products and lubricants. Among the specifications is ASTM D 975, the "Standard Specification for Diesel Fuel Oils." This standard sets minimum requirements for low and high sulfur No. 1-D and No. 2-D fuels. No 1-D fuels, which are more volatile (and similar to jet fuels), are typically used in cases where abnormally low fuel temperatures are encountered.

Appearance and Workmanship

One recent effort of the ASTM Committee D-2 at improving fuel quality is the addition of appearance and workmanship requirements to the ASTM D 975 specification. These additions were balloted and approved at the December 1995 meeting of ASTM Committee D-2. The new requirements are aimed at reducing the amount of free water and particulate in the diesel fuel.

The appearance requirement will consist of inserting the following items in ASTM D 975 Table 1 for all grades of No. 1-D and No. 2-D:

> Property - Free water and particulate contamination, maximum
> ASTM Test Method - D 4176
> Requirement - 2

In the D 4176 test procedure, fuel clarity is rated by placing a standard bar chart behind a fuel sample in a clean glass jar and comparing it's visual appearance with a standard haze rating photograph. The fuel must have a chart rating of 2 or better. The sample is then swirled and examined for visual sediment or water droplets below the vortex.

The former ASTM D 975 specification allowed up to 0.5% BS&W (bottom sediment and water) in the fuel. This is equivalent to approximately 500 ppm water or particulate. In contrast many railroads have diesel fuel specifications with particulate limits one tenth of that value.

The workmanship requirement will consist of an additional section in the D 975 specification which states:

"The diesel fuel shall be visually free of undissolved water, sediment and suspended matter."

The new appearance and workmanship requirements significantly reduce the free water and particulate in diesel fuel. One railroad's experience indicates a fuel will not pass these new requirements if it has over 0.03% water and over 25 ppm particulate.

Railroads cannot rely on the wayside fuel filters to prevent locomotive fuel filter problems. At the high volume and high pressures seen in wayside applications, the filters pass a significant portion of the particulate matter and water that they see. The inspection of fuel at receipt for water and particulate is a major tool in preventing locomotive fuel filter problems. The LMOA committee encourages railroads to include the new appearance and requirements as part of their fuel specification and to use the new procedures in their inspection of incoming fuel.

Particulate Contamination In Middle Distillate Fuels By Laboratory Filtration

A second effort of the ASTM Committee D-2 aimed at improving fuel quality is the development of a new particulate test procedure specific for diesel fuel. This procedure is entitled "Particulate Contamination in Middle Distillate Fuels by Laboratory Filtration". In essence, it is a modified version of ASTM D 5452, "Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration." A key modification is the replacement of the flushing fluid (petroleum ether) specified in D 5452 with a heavier, more effective fluid (heptane or iso-octane). The diesel fuel specific procedure will not be assigned an ASTM number until it is finally approved by voting membership.

Currently, suppliers and railroads use a wide variety of test procedures for determining the amount of particulate in their fuel (Figure 7). The establishment of a standard test procedure will allow easier comparisons of fuel quality between different railroads and suppliers.

Railroads are encouraged to keep track of the status of this new standard and to adjust their laboratory procedures and fuel specifications accordingly. Once the procedure is fully established, the addition of a limit on particulate contaminate can be developed as part of the ASTM D 975 specification.

Oxidation Stability

At the December 1995 meeting, the ASTM Committee D-2 also attempted to ballot the addition of a stability specification to the ASTM D 975 standard. The proposed diesel fuel thermal stability requirement was to be added to Table 1 of the D 975 specification for all grades of No. 1-D and No. 2-D diesel fuel. The specification would allow a maximum of 2.5 mg/100 mL (25 ppm) total insoluble residue to be formed when the fuel was tested to ASTM D 2274.

The D 2274 procedure consists of heating a portion of fuel for 16 hours at 203 F. At the end of the time period, the fuel is filtered and the filterable residues weighed. The glassware is then washed with solvent, the solvent evaporated and the adherent residues weighed. The combined filterable and adherent residues make up the total insoluble residue.

Understandably, objections to the stability ballot were raised by representatives of the committee. The ASTM D 2274 test is a cumbersome and time consuming procedure. The refineries are simply incapable and unwilling to wait the 16 plus hour time period required to complete ASTM D 2274 before release of a fuel.

This does not negate the need for a fuel stability requirement. The 1995 fuel problems seen in the railroad industry were, in a large part, due to poor fuel stability. One Class I railroad ran the ASTM D 2274 stability test on fuels from several locations (Figure 8). The results showed a wide difference in the fuels. A majority of fuels were within the proposed specification. It is the few that were far out of specification that highlight the need for a stability requirement in railroad fuels.

The ballot for the stability specification now goes back to the ASTM subcommittee for reconsideration. One option the ASTM subcommittee has is to resubmit an earlier version of the ballot which contained the same oxidation stability requirement (maximum 2.5 mg/100 mL when tested to D 2274), but had a note which allowed alternate test methods to be used upon agreement between the fuel supplier (seller) and purchaser. In case of a dispute, the D 2274 test would be the referee method.

This change would allow railroads and suppliers to agree to use the Dupont F 21 Fuel Stability test procedure as a routine quality control measure for the fuel. The Dupont F 21 test method is the standard procedure used by the railway industry to evaluate fuel stability and is mentioned in most specifications. It is a much shorter procedure than ASTM D 2274 and would not restrain the refineries from releasing their fuel in a reasonable time period.

The Dupont F 21 procedure consists of filtering a 50 ml sample of the fuel, heating it for 90 minutes at 300 F and refiltering it through a standard filter paper (pad). The darkness of the pad is measured either with a reflectometer, or is visually compared with a standard chart to rate the fuel. Most railroads consider a pad rating of 7 or less as having acceptable stability (Figure 9).

The LMOA Fuel, Lubricants and Environmental Committee supports the ASTM effort to establish a diesel fuel stability standard and has written a letter in support of that need. The LMOA committee encourages the railroads and engine manufacturers to adopt the proposed standard and to follow and support the effort in establishing an ASTM fuel stability requirement.

Particulate Contamination Testing

Railroad	Test Method	Specification
A	ASTM D-96	.05%
B	EMD ASH Test M.I. 1750	1.3 mg/L
C	Modified ASTM D-5452	15.0 mg/L
D	In House Filtration Procedure	35.0 mg/L
E	ASTM D-2276	5.0 mg/Gallon
F	In House Filtration Procedure	12.0 ppm
G	In House Filtration Procedure	No Visible Matter
H	In House Filtration Procedure	0.75 mg/100 mL

Figure 7

Oxidation Stability of Diesel Fuel (ASTM D2274)

Location	Date Sampled	Filterable Insolubles mg/100 mL	Adherent Insolubles mg/100 mL	Total Insolubles mg/100 mL
1	05/19/95	0.00	0.08	0.08
2	05/24/95	0.08	0.20	0.28
3	05/25/95	0.04	0.12	0.16
4	06/13/95	0.48	0.52	1.00
5	05/17/95	0.40	0.56	0.96
6	07/13/95	0.44	0.28	0.72
7	07/13/95	0.48	0.36	0.84
8	08/03/95	0.52	0.20	0.72
9	06/30 - 08/01/95	1.04	3.00	4.04
10	07/01 - 07/27/95	1.04	0.48	1.52
11	06/28 - 08/01/95	6.56	1.12	7.68
12	06/30 - 07/13/95	3.80	0.84	4.68

Figure 8

Thermal Stability Testing

Railroad	Test Method	Specification
A	Dupont F-21	Pad Rating $\leq$ 5
B	Dupont F-21	Pad Rating $\leq$ 7
C	Dupont F-21	Pad Rating $\leq$ 7
D	Dupont F-21	Pad Rating $\leq$ 7
E	Dupont F-21	Pad Rating $\leq$ 7
F, G, H	No Testing Performed	N/A

Figure 9

III. A LOOK AT GENERATION 5 OIL PERFORMANCE AND FUTURE OIL NEEDS

Presented by:
Glen Bowen, BN/SF

As the title indicates, the purpose of this paper is to review the performance of Generation 5 oils, the current generation of locomotive lubricating oil in service through most of North America today, and to define future oil trends and needs.

You may recall that the Generation 5 oils came into existence in large part due to changes in the General Electric locomotive. In 1984 General Electric developed a three ring piston design which significantly reduced oil consumption in its new locomotives. In many services these drier General Electric locomotives, operating with most Generation 4 oils, were not capable of going 92 days without viscosity increase and low total base number (TBN) problems.

The railroad industry demanded oils that were capable of at least 92 day oil change intervals in these newer locomotives. This resulted in the development of additional oils with longer life. These oils were first classified by General Electric as Generation 4 Long Life oils. Those railroads operating with the newer General Electric locomotives were quick to make these oils their standard.

In 1989 this LMOA committee officially adopted the term Generation 5 oils to describe the long life oils and set standards to meet that definition:

Generation 5 Oil Definition

Oil be field tested per LMOA guidelines and be OEM approved

10,000 miles/month or 20,000 gallons of fuel/month

Meet or exceed a 180 day drain in new low oil consuming engines:

- Oil would retain a minimum of 1.0 TBN (ASTM D664)
- Oil would see less than a 30% viscosity increase max (100C)
- Less than 5% pentane insolubles (ASTM D-893-B)

Criteria were based on MVI SAE 40 products.

The Generation 5 oils have now been in use for over 9 years and it is of interest to see how the oils are being used today and how that compares with the original intent: the development of an oil that would achieve a minimum 180 day service life in a low oil consumption engine.

This LMOA committee conducted a survey asking each of the Class I railroads how they were using the Generation 5 oils today. More specifically we asked "does your railroad use a single grade or multigrade oil? What Generation additive package do you use? What are your oil and filter change intervals?"

Without going into a lot of detail, there are three items that stand out in the table (Figure 10):

1. There are several railroads not achieving a 180 day oil change
2. There are several railroads not using Generation 5 product
3. There are differences in oil TBN levels used

Looking at the survey results, you might question whether the Generation 5 oils were successful. That they didn't achieve their goal of 180 day life and are not in universal use. However, this is not very fair considering the changes that have occurred over the last 7-10 years which have dramatically affected oil performance.

The first major factor has been the increase in oil stress brought about by the combination of operation and locomotive changes. These are reflected in information available through the

Association of American Railroads and the National Petroleum Refiners Association.

Over the last 10 years there has been a 23% decrease in the number of locomotives in service. This is a result of the retirement of older lower horsepower locomotives and the introduction of new higher horsepower units.

At the same time there has been an increase in business level. Total fleet work performed by those locomotives has increased by 29% (Figure 12). Looking at the average work per locomotive (Figure 13), there has been an 68% increase over the time period. The definition of a Generation 5 oil was written around 10,000 miles per month-service, but it is not uncommon to see railroads with locomotives averaging over 15,000 miles per month.

The average load hauled per train (Figure 14) has increased by 8% in the last ten years. This corresponds with an increase in the severity of the locomotive duty cycle.

With regard to oil stress, the total engine oil sales figures over the last 10 years (Figure 15) present an interesting picture. Engine oil sales have dropped by about 58% over the last ten years. This is the result of fewer locomotives in service, the addition of more locomotives with lower oil consumption, the introduction of longer life Generation 5 oils and the use of multigrade oil.

Combining the oil sale and net ton mile graphs you can generate a measure of oil stress (Figure 16). Over the last ten years there has been a 204% increase in oil stress. In just the last 7 years illustrated, the period of time that the Generation 5 oils have been in use, oil stress has increased by 135%.

The second major factor affecting oil life and oil stress has been the introduction of multigrade oil. Multigrade oil was adopted by most Class I railroads between 1990 and 1992. Multigrade oil has demonstrated a 20% lower oil consumption when compared with single grade oil. That means that the oil is staying in the crankcase longer and seeing additional stress.

The multigrade oils have changed the oil characteristics so dramatically that viscosity increase is no longer the major concern. Where Generation 4 and Generation 5 MVI SAE 40 oils were changed primarily for viscosity increase in the low oil consumption engines, the Generation 5 multigrade oils are rarely changed for that criterion.

This does not mean that the Generation 5 multigrade oils have been found to last forever; only that a new hurdle has been reached. Soot loading and total base number depletion have become the new criteria for removal. Some railroads using multigrade oils have experienced engine cleanliness and oil filter plugging problems. Laboratories of these railroads have switched emphasis from viscosity to insolubles and total base number (TBN) retention.

Because of its concerns that crankcase oils were not being drained frequently enough, General Electric has developed oil change criteria based on locomotive utilization. These were introduced to the industry in 1994 as MI 00128 (Figure 17).

General Electric's 3 month drain interval for severe-duty locomotives is one of the reasons that railroads are not achieving drain intervals of 180 days with Generation 5 oils.

A third and final factor affecting the Generation of oil additive in use and oil change interval, is the "fine tuning" of railroad oil programs to reduce cost. This includes but is not limited to:

- Railroads without General Electric locomotives using less expensive lower TBN and earlier Generation oil additives

- Railroads with mixed fleets using one Generation oil additive in one part of their railway and a second in another
- Railroads with mixed fleets using less expensive lower TBN and earlier Generation oil additives.

It is apparent from this discussion that oil performance is an ever changing issue. It is further apparent that it will continue to change in the future. As part of this paper the LMOA committee asked the Class I railroads and locomotive manufacturers to comment on future engine designs expected to affect lubrication.

The two engine changes most frequently mentioned (Figure 18) were increase in horsepower and tighter engines. The increase in horsepower will continue the trend toward a reduction in the locomotive fleet and an increase in oil stress. The affect of tighter engines, aimed at exhaust emission reduction, will further stress the oil in all manufacturers' engines. Scheduled oil changes in all manufacturers' engines are inevitable.

Finally, the LMOA committee asked the railroads and engine manufacturers what they would like to see in a new oil, a "Generation 6" product (Figure 19).

Improved insoluble control and improved engine cleanliness were mentioned first as desirable improvements. The railroads would like to see oils that control insolubles by keeping them in suspension throughout the engine, but allow removal at oil change.

Longer drain intervals are still mentioned as a desirable improvement. Railroads recognize the costs of oil and disposal of used oil and filters. The 180 day oil life in today's most severe service is a target goal.

Improved viscosity control in multigrade oil is identified as the third most desirable improvement. Viscometric properties relate to both bearing protection and fuel economy benefits, making viscosity stability a desirable characteristic.

Additional improvements desired in a new oil are: lower engine wear rates, more chlorine free oils, lower lube oil consumption, more options in total base number (TBN), and more single grade SAE 40 oils formulated for fuel economy.

How Generation 5 Oils Are Being Applied Today

Oil Additive Railroad	Crankcase Oil Used Single Grade	Crankcase Oil Used Multigrade	Oil Additive Pkg Generation in Use	TBN	Oil Change Interval (Days) GE	Oil Change Interval (Days) EMD	Filter Change Interval (Days) GE	Filter Change Interval (Days) EMD
A	X		5	13,17	LA & 92	LA	92	92
B	X	X	5	13,17,18	LA & 92 & 180	LA	92	92
C	X		5	17	LA & 92	LA	92	180*
D		X	5	17	LA**	LA	60	92
E	X	X	3 & 5	10,13,17	LA & 180	LA	N/A	92
F		X	5	18	LA	LA	92	92
G		X	5	17	N/A	LA	92	92
H		X	5	17	LA & 180	LA	92	92
I		X	5	17	LA & 180	LA	92	92
J	X***	X	4 & 5	13	LA & 92	LA	92	92
	5	8						

LA = Laboratory Analysis

** Railroad D averages a 163 day oil life in GE locomotives

* Railroad C uses a "depth" type EMD oil filter

*** Railroad J uses single grade oil in engine break-in only

Figure 10

Total Number of Locomotives in Service

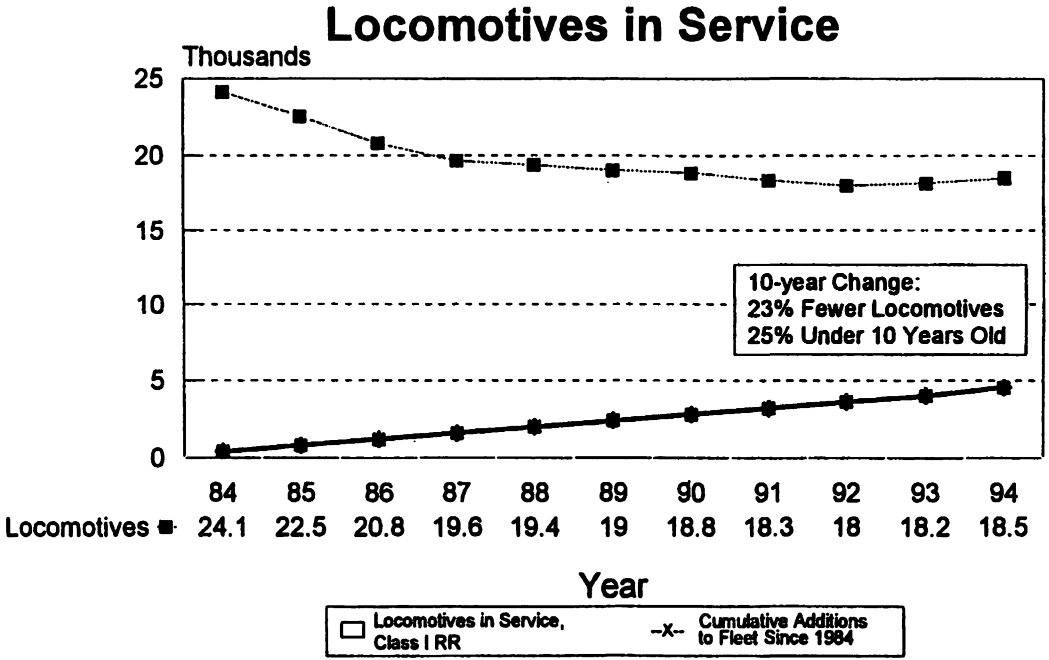


Figure 11

Total Number of Locomotives in Service

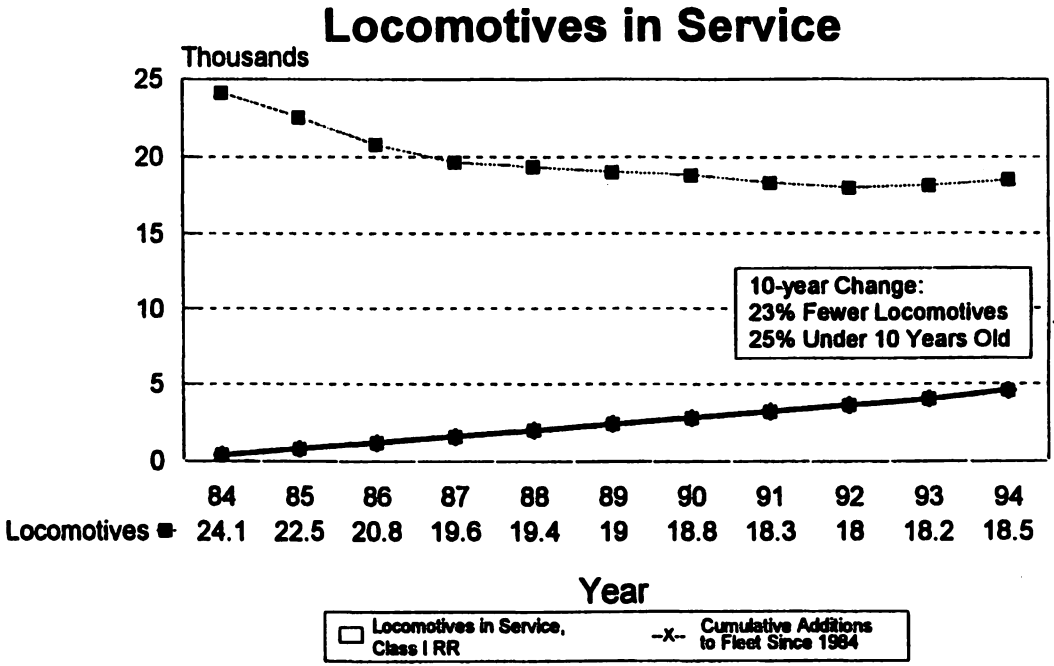
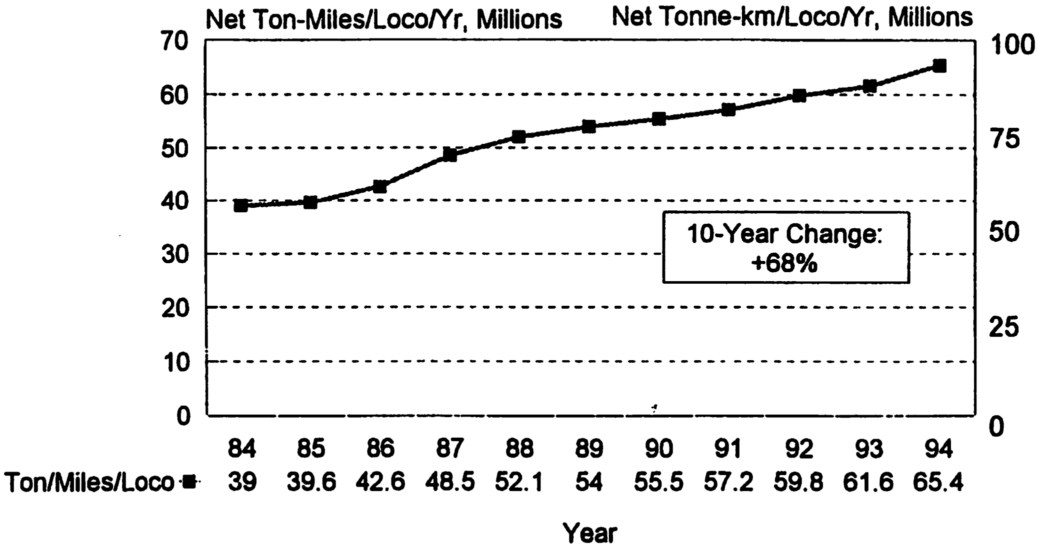


Figure 12

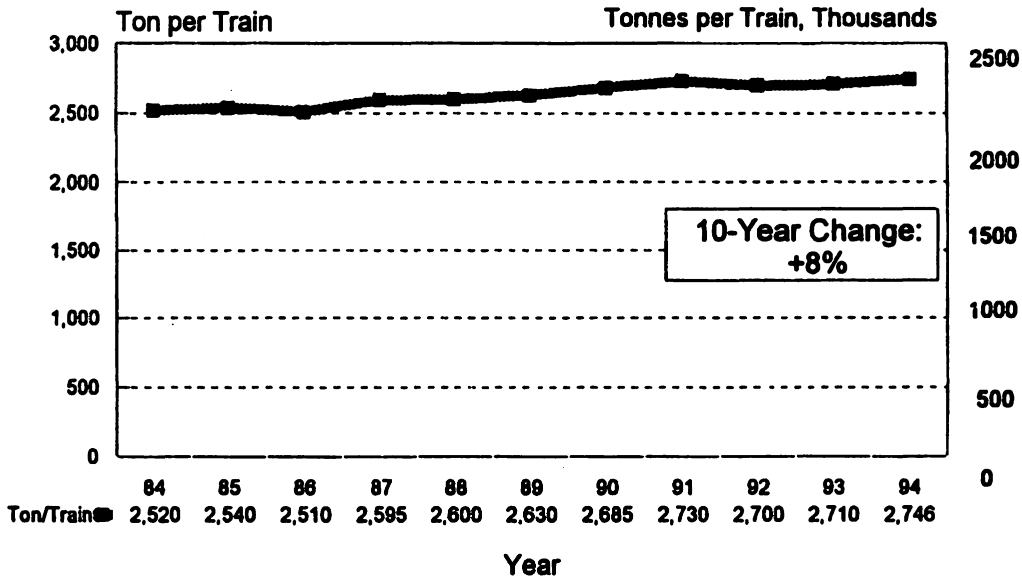
Average Work per Locomotive



Source: Association of American Railroads, "Railroad Facts", 1995 Ed.

Figure 13

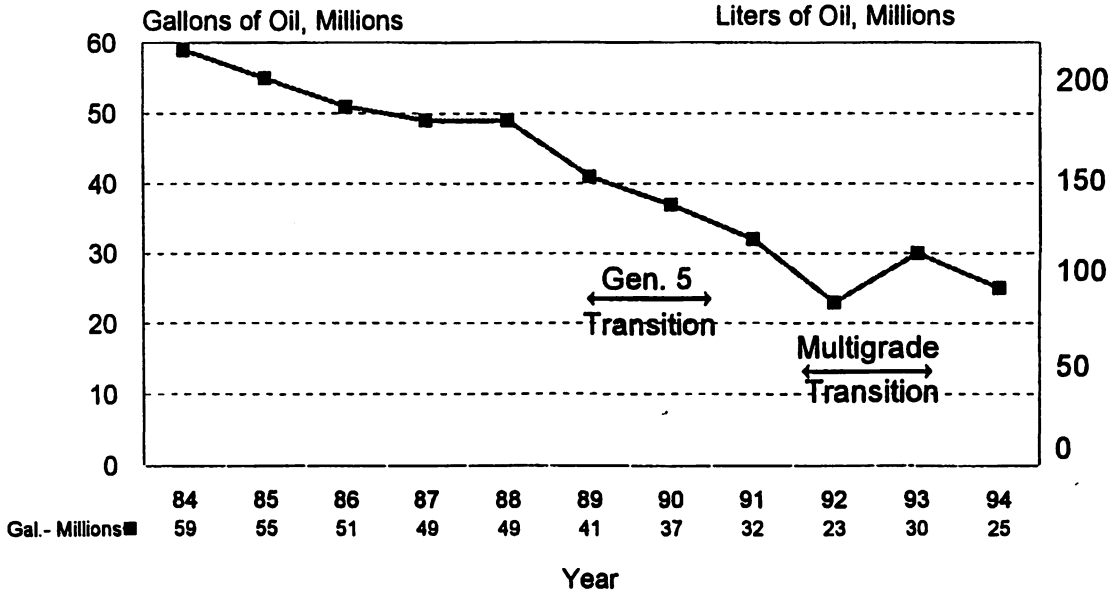
Average Load Hauled



Source: Association of American Railroads, "Railroad Facts", 1995 Ed.

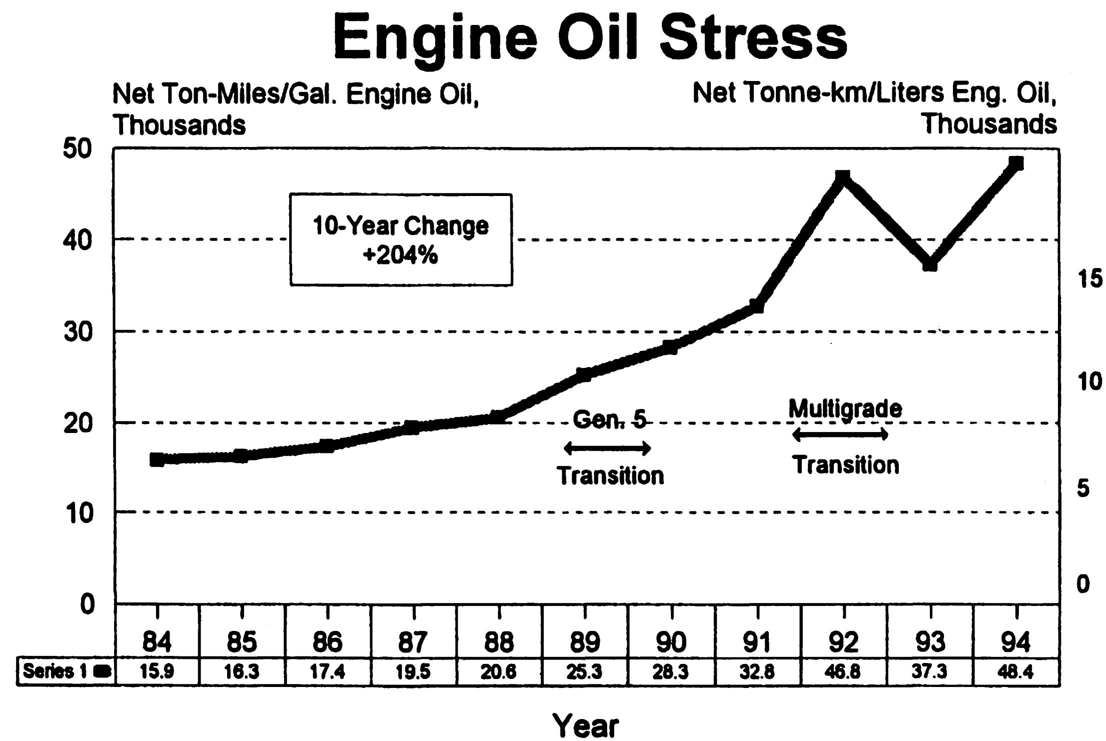
Figure 14

Total Engine Oil Sales



Source: National Petroleum Refiners Association

Figure 15



Source: National Petroleum Refiners Association

Figure 16

1994 General Electric Introduced a New Specification (MI 00128) Limiting Oil Life

- 12 Cylinder Engines:
  - 3 Months for MW*HR/Month > 300
  - 3-6 Months for MW*HR/Month 225-300
  - 9 Months maximum for MW*HR/Month <225

- 16 Cylinder Engines:
  - 3 Month for MW*HR/Month > 400
  - 3-6 Months for MW*HR/Month 300-400
  - 6 MOnths maximum for MW*HR/Month < 300

Figure 17

Survey Results

UPCOMING ENGINE DESIGN CHANGES EXPECTED TO EFFECT LUBRICATION

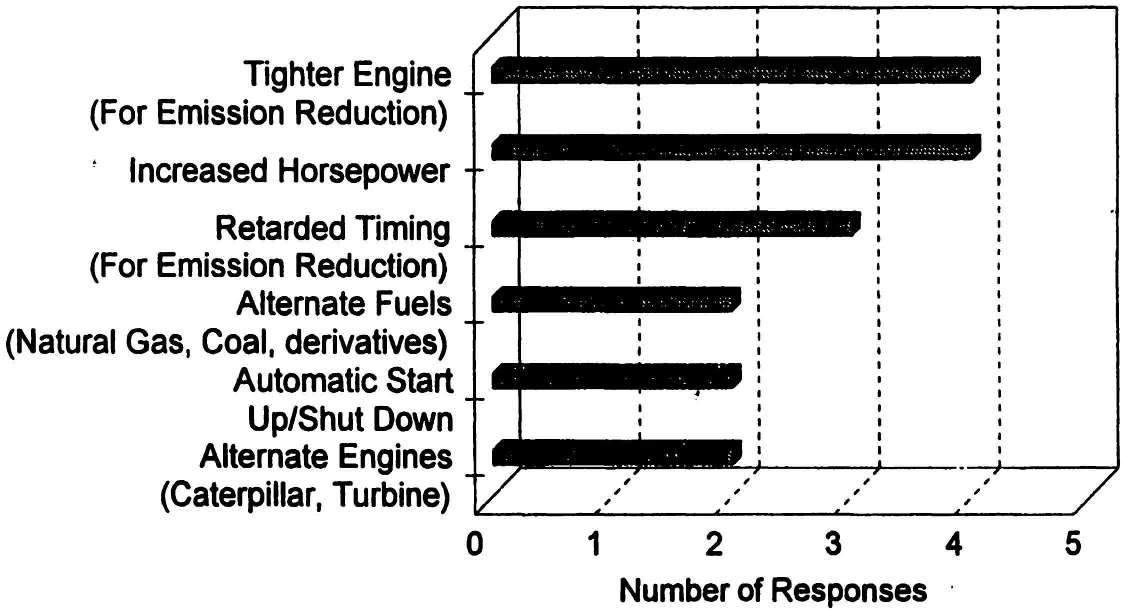


Figure 18

Survey Results

WHAT RAILROADS WOULD LIKE TO SEE IN A "NEW ENGINE OIL"

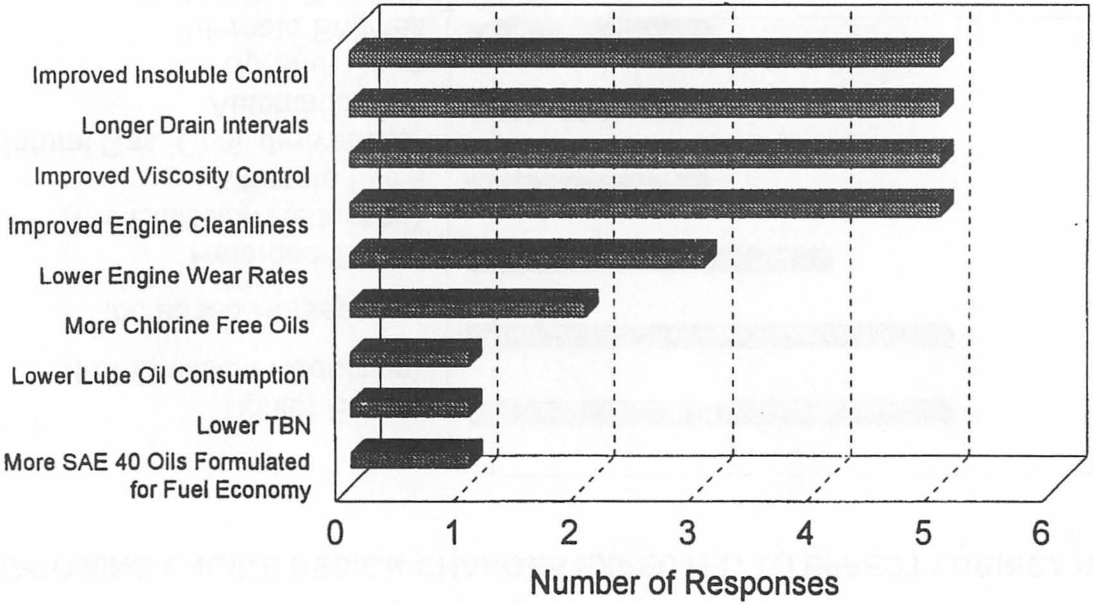
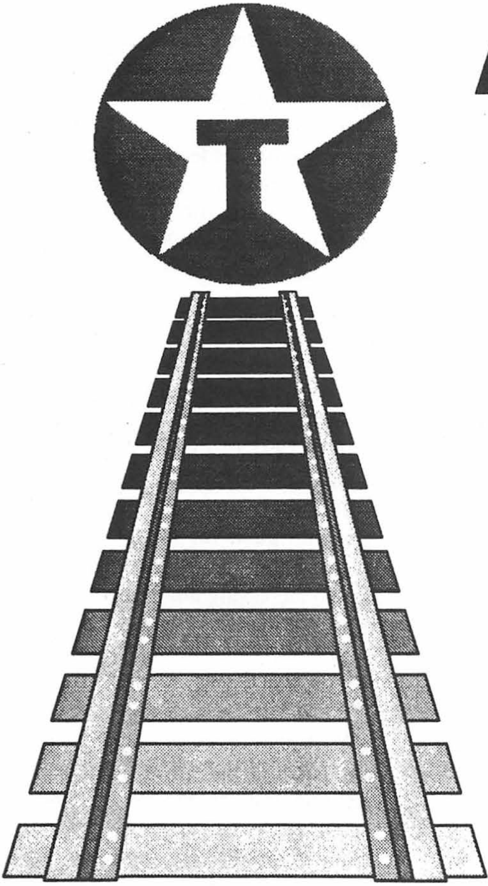


Figure 19



IV. LNG AS A RAILROAD FUEL

Presented by:
Scot Yoder, Amoco

Overview

During the last few years interest has grown in the possibility of using liquefied natural gas or LNG as a fuel for railroads. The Burlington Northern and Union Pacific railroads have had well publicized development programs and have presented some of their results through past LMOA meetings. There has also been considerable locomotive development activity by MK, EMD, and others, and their progress has also been discussed at past meetings.

This report provides a general overview of LNG and its use as a railroad fuel. We will cover briefly why interest has grown in alternative fuels in general, and specifically why interest in LNG has grown in recent years. The bulk of this paper will discuss exactly what is LNG, what kind of locomotives are required to use LNG, and how it is produced and handled.

Why alternative fuels?

Since the first internal combustion engine was developed, there has always been interest in developing "alternative fuels." At one time, furnace oil was considered an alternative to burning coal for heating. Diesel powered locomotives were an alternative to coal fired. During the early "shake-out" period of transportation fuels, gasoline and diesel were the clear winners, and they have dominated the transportation fuels market because they provide a low-cost, dependable, safe energy source. They are also easy to transport and store.

However, even with gasoline's and diesel's clear dominance, there continues to be development of alternatives such as fuel cells, hydrogen, methanol, soy diesel, and the list goes on. These alternatives continue to be studied for several reasons, but chiefly there is hope that one of these fuels will be cleaner burning, domestically abundant or lower cost, or ideally, all three!

These goals for a new fuel have been reinforced by the Clean Air Act amendments of 1990 that push the development of cleaner fuels and the Energy Policy Act of 1992, the purpose of which is to reduce America's dependence on foreign oil. Government actions aside, anyone who remembers the price fluctuation during the Gulf War in 1991 can understand why the search for a domestically abundant fuel is desirable. This combination of factors, the push for clean air and the desire to have a stable priced fuel, has lead to increasing interest in natural gas as an alternative transportation fuel.

Why natural gas?

With the above as a backdrop, how does natural gas fit as an alternative fuel? Natural gas, the gas that many of you have piped directly into your homes for heating and cooking, is made up primarily of methane. Typically at least 90% of natural gas is methane. Methane is a very clean burning gas, and as a result natural gas powered vehicles can be very clean burning as well. Methane has an extremely high octane number, estimated to be 130. Octane is an important measure of gasoline quality, and in general, the higher the octane the better, at least for spark-ignited cars. Unfortunately, as we will discuss later, high octane is not necessarily good for diesel or compression ignition engines.

Natural gas is also a *low cost* energy source. This is one of the most important factors driving the growth of natural gas as opposed to other alternatives. While it is clean burning, natural gas is also low cost. A gas cost of $2.00 / MM Btu is equivalent to approximately 30 cents/diesel gallon. There are additional costs for processing and distribution, but the raw cost of natural gas has always been less than crude oil in the United States. Natural gas is also abundant in the United States and Canada. This leads to more stable prices than imported crude oil.

It is important to note that liquefied natural gas or LNG is *NOT* the same as liquefied petroleum gases or LPG. LPG is primarily propane and has properties significantly different from natural gas.

If natural gas is so good, then why isn't it in widespread use? Unfortunately, there are two main reasons why natural gas has seen limited growth to date: 1) natural gas is a gas, which means it requires special storing and handling; and 2) it is not directly suitable in "diesel" type engines, which means it requires special engines and fuel systems.

LNG

Natural gas can be handled and stored in two ways: as a gas or a liquid. Most of us are familiar with natural gas as a gas --that is how it gets distributed throughout the country and into our homes. To get enough natural gas onto a vehicle, many light-duty vehicles used high pressure storage cylinders. The natural gas is compressed to 3000 psi and stored on the vehicles as compressed natural gas or CNG. Unfortunately, these storage tanks are heavy, they take up around 4 times the space of an equivalent gasoline tank, and it can take a long time to fill the CNG tanks.

Recently, liquefied natural gas or LNG has gained favor as a method of handling and storing natural gas. LNG is made by cooling natural gas to a temperature below its boiling point -- -260°F! LNG is not new. Many local gas utilities liquefy gas during the warm summer months and store the LNG until winter, and they have used this technology for decades. During cold winter months they regassify the LNG to help supply peak demand. They liquefy the gas instead of compress it because at -260°F, natural gas can be stored and handled using methods similar to other liquid fuels. We emphasize similar, because at this temperature, LNG is a cryogenic liquid and it still requires special handling.

The heavy-duty transportation industry is interested in LNG because it helps overcome several hurdles associated with gaseous fuels. First, as a liquid, LNG has greatly increased energy density compared to CNG. Liquefying natural gas increases it's density by around two times CNG. Fuel dispensing systems can be built that have fueling rates similar to diesel --around 400 gallons per minute. Finally, it can be distributed and stored as a bulk liquid.

Liquefaction also allows greater control over the quality of the fuel, because undesirable components that may be present in the pipeline can be removed or controlled. This leads to a more consistent and predictable fuel.

Fuel properties

LNG has fuel properties that make it different from diesel, several of which have already been mentioned. LNG has a high octane number which is good for spark-ignition engines and this is the technology used in the MK switch engines. However, significant engine changes are required to be able to use it in a diesel engine. Diesel engines typically require high cetane fuels and LNG has extremely low cetane, so changes must be made to diesel engines to accommodate LNG.

Table 1 shows a comparison of LNG and diesel fuel properties. While LNG is a very dense form of natural gas, it still has less energy per gallon than diesel. It takes 1.7 gallons of LNG to have the same amount of energy as one gallon of diesel. This has significant impacts on range-specifically, LNG road locomotives will require a *fuel tender* to have acceptable range. Also, LNG is a cryogenic liquid which means it must be stored in specially designed tanks that maintain the LNG at extremely low temperatures and moderate pressures. This requirement adds cost, weight and complexity to an LNG system. These costs must be offset by lower fuel prices for LNG to gain acceptance as a viable alternative.

LNG as a railroad fuel

With that background, let's look specifically at how LNG can be used as a railroad fuel. LNG locomotives have been developed and demonstrated through several programs.

During the 1980's the Burlington Northern Railroad ran two EMD SD40-2 locomotives on LNG. These locomotives were converted to run on dual-fuel (both LNG and diesel). The project was discussed in detail in a 1994 LMOA Diesel Mechanical Committee paper. This program is completed and the two locomotives are back in diesel service.

The Union Pacific Railroad embarked on a major LNG project several years ago. The original plan was to put six LNG locomotives into service ` switch engines, and ^ road locomotives. This project is significant because the intent was to develop OEM built LNG locomotives. The UP involved MK Rail, EMD, and GE in the development process. To date, MK Rail has delivered ` MK 1200G switch engines which are currently in operation in Los Angeles, however, there have been significant delays on the ` EMD 710s and ` GE-7FDL16s. The road locomotives have been delayed because significant development has been required for these high power, dual-fuel locomotives.

The Burlington Northern Santa Fe railroad has a project to evaluate LNG switch engines in Los Angeles, and it currently has ` MK 1200G engines in operation. These have been in operation since the fourth quarter of 1994.

Finally, there is a multi-client project called GasRail USA that is underway. Its goal is to develop an LNG powered low emission locomotive for passenger service for Southern California. Their development work is on the EMD 710 and recent technology developments look promising for meeting the goal of putting a low emission, high efficiency, high power passenger locomotive into field testing.

EMD, GE and MK have all contributed to these programs. In addition, Energy Conversions, Incorporated or ECI was involved with the original BN test and developed an aftermarket conversion for the EMD 645's.

Spark-ignited LNG locomotives

Two types of LNG locomotive engines have been developed to date: spark-ignited and dual-fuel and each technology has its merits.

The MK 1200G switching locomotive uses a spark-ignited engine. Details of this unit were given during last years LMOA meeting. The 1200G uses a Caterpillar G3516 engine that was originally developed for stationary use and is designed to take advantage of LNG's high octane quality. Both the UP and the BNSF railroads have had good operating experience with their units. Using a dedicated fuel (as opposed to dual-fuel) simplifies the switchers and provides a lower cost option than a dual-fueled engine because only one fuel system is needed. It also allows for enough LNG storage on-board so no fuel tenders are necessary.

Compared with traditional diesel power, the spark-ignited engines have two inherent traits that will limit their use to switching applications. Because they are throttled spark-ignited engines (like your auto's engine) they have higher fuel use than diesels - especially at idle. They also will have lower power output than a comparably sized diesel engine.

However, the combination of low emissions, fuel system simplicity and proven engine technology makes spark-ignition a logical choice for this application.

Dual-fuel locomotives

Because of the drawbacks of spark-ignited engines, they will likely never be seen in road units where power and fuel economy are of greatest importance. For these application, dual-fuel technology appears to be the best choice. EMD, GasRail USA, GE, and ECI have focused on developing dual-fuel technology.

Dual-fuel engines use natural gas as their primary energy source, and instead of a sparkplug, they use a small quantity of diesel fuel as a liquid sparkplug. They are unthrottled engines that maintain the high compression ratio of standard diesel engines; therefore they are able to retain high power and high efficiency. They are also capable of producing lower emissions than their diesel counterparts.

These engines are very similar to standard diesel engines, except that they have an additional natural gas fuel system. Most are designed to run on either dual-fuel or diesel only - this gives the added flexibility of running in areas where LNG is not available or continuing to run if there is a problem with the LNG system.

While this sounds like an ideal approach, there are still a few areas that have to be addressed. To keep the engines from knocking in high power applications, the natural gas must be injected very late in the compression stroke. This requires gas injection at extremely high pressures, and designing a reliable system requires significant development. In addition, these engines will require two fuel systems, one for diesel and one for LNG, so they will have added complexity.

However, because this approach offers high power, high efficiency and low emissions it continues to be the area that is getting the most development and will likely be the approach used in future road locomotives. However, the OEMs are also busy with AC traction and higher power locomotive development. This may slow the development of LNG technology.

LNG production and distribution

In addition to locomotive technology, LNG production, distribution and storage capability must also be developed.

There are currently many *potential* sources of LNG throughout the United States. These include peak shaving plants that are used by gas utilities to store gas for winter use, import terminals along the east coast, gas plants and chemical plants. Some produce transportation LNG today, but most would require some modification to be able to produce and distribute transportation grade LNG. There is currently only one facility that has been designed and built specifically for transportation LNG production; however as demand increases, new plants are likely to be built.

LNG is transported to fueling stations by truck transport, although there has also been talk about rail transport in the future. The likely scenario for a large rail project would be to build an LNG plant on an existing road and eliminate the need for transportation.

LNG is transported and stored using super-insulated containers similar to thermos bottles. These containers maintain the extremely cold temperatures and low pressures required to keep methane as a liquid. Technology for storing and handling cryogenic liquids is relatively mature. Nitrogen, oxygen and carbon dioxide are common cryogenic liquids that are transported and stored using technology similar to LNG. Liquid CO_2 is routinely delivered and handled for use as carbonation in beverages and its temperature and pressure is similar to LNG.

LNG safety and handling

Safety is always a big question when discussing any type of fuel. When evaluating safety of a fuel, several areas should be addressed. These include fire potential, handling and environmental impact.

In general, LNG is considered to be a very safe fuel; in fact it is currently in use in several major transit bus fleets -- applications where safety is an extremely high priority. LNG is safe because it has vapors that are lighter than air, and it has narrow flammability limits. In the event of an LNG spill, the natural gas vaporizes rapidly. Because it is lighter than air, it rises and dissipates rapidly, and because it has narrow flammability limits, there is little potential for a fire or explosion.

While fire potential is small in an open area, it is a concern in an enclosed area. Flammable mixtures are possible if leaks occur inside buildings, so adequate ventilation is required. Also, LNG is an odorless gas. It is so cold that the traditional odorant used in natural gas will freeze; therefore no odorant is added to LNG. Stations and locomotives must be equipped with special methane detection devices that will set off alarms in the event of a leak. This type of system is currently in use on bus fleets operating in Houston, Austin and El Paso and has proven to be a safe and effective approach. These fleets performed in-depth safety evaluations of LNG before they introduced it into their public bus systems and they found that LNG is a safe alternative to diesel.

Because LNG is handled at such a cold temperature, special training and precautions are necessary to ensure safe handling. Typically, a face shield, gloves, and protective smock are used when fueling. Handling cryogenic liquids requires caution, but as mentioned earlier, they are handled routinely and safely in many industries.

One interesting aspect about LNG is its environmental impact. In the event of a spill, LNG evaporates and dissipates quickly. This means that there is no soil or ground water contamination when handling LNG. It is also nontoxic and methane does not contribute to ozone formation.

Summary

The railroads continue to search for a low cost, low emission, domestically available fuel to replace diesel. Natural gas is one alternative that is low cost, domestically abundant and clean burning. Liquefied natural gas has the benefits of high energy density and handling characteristics of a liquid fuel. There are existing sources of LNG to supply early demonstration programs, and as demand builds, the technology exists to expand supply to meet

demand.

Continued development is necessary to ensure the availability of reliable, high power, high efficiency locomotives. Dual-fuel engines appear to be the logical choice for these engines and recent technology advancements on these fuel systems should lead to OEM products in the future. Panned projects by the Union Pacific Railroad and Gas Rail USA should provide valuable information on operating characteristics and economic viable of LNG.

If the OEM develop LNG locomotives, and LNG is able to deliver on the promise of reduced cost and reduced emissions LNG should prove to be a serious alternative to diesel fuel.

Table #1 Fuel Property Comparison of LNG and Diesel

Property	LNG	Diesel
Cetane Index	N/A	40 +
Octane Number (R+M)/2	130	N/A
Heat Content, BTU/Gallon	76,000	130,000
Diesel Gallon Equivalent	1.7	1
Temperature	-260°F to -220°F	Ambient
Pressure	60 psi to 275 psi	Atmospheric

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

TUESDAY, SEPTEMBER 17,1996
10:45 A.M.

BRIAN HATHAWAY, Chairman
Gen. Mech. Foreman
Florida East Coast
New Smyrna Beach, FL

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

COMMITTEE MEMBERS

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C. Wilkerson, Jr.	Asst. Mgr. Mech-Maint.	Norfolk Southern	Roanoke, VA
J. Youngwirth	Supvr. Tech. Service	Electro-Motive	La Grange, IL

PERSONAL HISTORY

Brian Hathaway

Brian was born in Ashtabula, Ohio on November 10, 1948 and moved to Florida at the age of 5 where he attended school. Brian began his railroad career in May 1970 as a draftsman for the Florida East Coast Railway in St. Augustine. He has a degree of Associate in Science in Drafting and Design Technology.

In January of 1978 he was relocated back to New Smyrna Beach and promoted to general foreman at the Locomotive Shop, then to general mechanical foreman of the shop in 1989 which he currently holds.

Brian is married and has two children.

IA. EMD SD80MAC HIGH VOLTAGE SAFETY

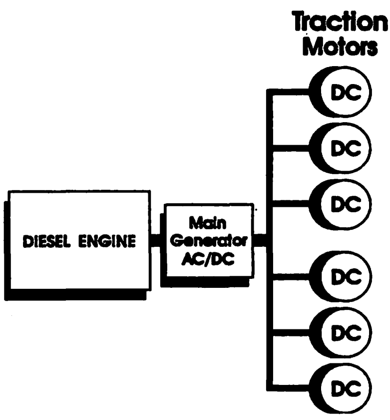
Prepared by: Michael A. Fitzpatrick, Conrail, and Jerry Youngwirth, Electro-Motive Division (EMD)

Overview

While the EMD SD80MAC locomotives increase productivity and efficiency, they present **new** safety considerations that **must** be addressed when these units are serviced. This paper should familiarize you with the new AC components as well as the proper procedures you must follow to insure that the locomotive on which you are working is a safe unit.

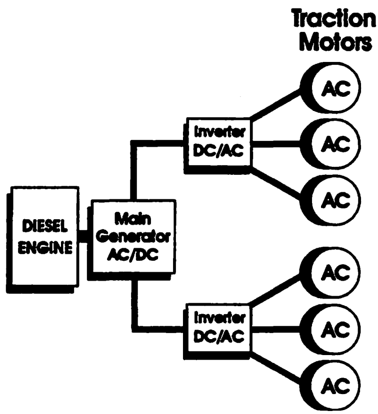
DC Locomotive Propulsion System

On older DC locomotives, the diesel engine turns the main generator. The 3 phase alternating current output of the main generator is rectified and applied, through switch gear, to the DC traction motors. The traction motor speed on DC locomotives is directly proportional to the main generator voltage. The higher the **VOLTAGE,** the faster the traction motors turn.



AC Locomotive Propulsion System

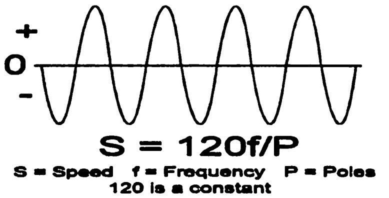
On AC locomotives, the diesel engine turns the main generator. The 3 phase alternating current output of the main generator is rectified and applied to the DC link capacitors that are part of the inverter. Acting as a buffer, these capacitors stabilize the input DC voltage going to the inverter. The inverters generate alternating current that drives the traction motors. The higher the **FREQUENCY,** the faster the traction motors turn.



On AC traction locomotives, the motor speed is dependent on the input frequency. The inverter takes the direct current link input and changes it to the required **FREQUENCY** and voltage to drive the AC traction motors at the desired speed.

Frequency

Frequency refers to the number of times that the voltage goes from a positive level to a negative level in a given time period. It is measured in cycles per second or Hertz - abbreviated Hz. The formula to determine the speed for a synchronous AC motor is $S = 120f/P$.



Since the number of poles is fixed by the construction of the motor, increasing and decreasing the FREQUENCY changes the motor speed.

Inverter Frequency	Motor RPM	Locomotive MPH
87	2610	60
48	1450	33
43	1300	30
20	600	14
10	300	7
0	0	0

AC vs. DC Locomotive Voltages

DC LOCOMOTIVES

- The maximum voltage output from the main alternator is about 1200 volts.

- When the throttle is returned to IDLE , or the generator field switch is in the OFF position, there is no high voltage output from the main generator.

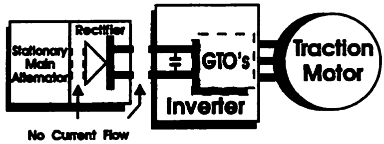
AC LOCOMOTIVES

- The voltage output of the main alternator on AC traction locomotives is much higher than the voltage on comparable DC locomotives.

- The main alternator is excited as soon as the reverser is thrown. The output rises to 600 volts.

- The normal 8th notch voltage from the main alternator is about 2600 volts. Voltages above 3000 volts may be generated under fault conditions

- In addition to the higher voltage levels, there is the complication of **STORED VOLTAGE POTENTIAL** due to the storage action of the DC link capacitors. There is high voltage present even when the throttle is in IDLE and the generator field switch is in the OFF position.



Electrical Equipment Safety Rule Review

- Work on, or about, electrical circuits, apparatus or equipment only if you are qualified and only if you know the operating voltage and service handled.

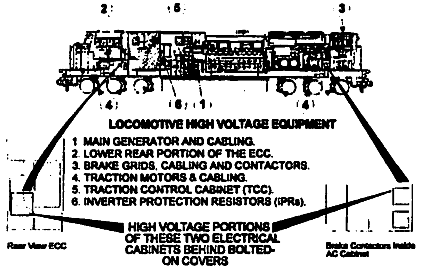
- Do not depend upon isolation, weather-proofing or covering on wire, electrical apparatus or equipment for protection against shock.

- Keep all doors and covers of electrical apparatus in place and secured except when necessary to open them for inspection or repair.

- Consult EMD's *Safety Precautions for SD80MAC's* for other rules pertaining to working on electrical equipment.

- Remember that **ANY AREAS OF THE LOCOMOTIVE THAT CARRY HIGH VOLTAGE MUST BE WORKED ON WITH EXTREME CARE.**

SD80MAC High Voltage Equipment



1. **Main Generator and Cabling -** DC link voltage is present when the isolation switch is in **RUN** and the TCC's (the DC link capacitors) are charged up. This voltage is dissipated when the isolation switch is put in ISOLATE.

2. **Lower Rear Portion of the Electrical Control Cabinet (ECC)** - DC link voltage is **only** present behind the bolted panel on the lower rear door of the Electrical Control Cabinet (where the VDCL feedback transducers and ground relay equipment are located). Care should be taken if this door is open and the isolation switch is in RUN. All other doors present only the "normal" hazards associated with electrical control cabinets.

3. **Brake Grids, Cabling, and Contactors** - as far as DC link voltage safety is concerned, the brake grids are used to either discharge the DC link capacitors or are disconnected completely from the DC link. Grid blower motor and grid shorting contactors are located inside the rear AC cabinet compartment, behind a bolted-on cover. If a series of faults occurs, DC link voltage may be present at these contactors. Therefore, perform the DC link discharge procedure before working on these contactors.

4. **Traction Motors and Cabling -** Even if the DC link is charged, traction motors at idle have no voltage across them ***unless a fault has occurred in the TCC.*** A dangerous condition might occur if a broken cable, a charged DC link capacitor and a TCC fault happen at the same time.

5. • <u>Isolate the unit</u> when direct contact with traction motors or cables may occur (such as during a motor or cable inspection).

Traction Control Cabinet (TCC) - The traction control cabinet (TCC houses the DC link capacitors. These capacitors must be discharged before work on the power circuits can be performed.

NOTE:

A TCC **computer** door can be opened without danger as there are only 24 VDC and 74 VDC circuits inside that part of the TCC. The TCC computer circuit breaker should be switched off before any TCC computer modules are removed.

6. **Inverter Protection Resistors (IP Rs)** - The IPRs are mounted on the inertial filter compartment wall, behind a wire screen and are at positive potential (+300 or +1300 V above ground_ whenever the DC link is charged. The IPRs are discharged when the DC link capacitors are discharged.

   • The high voltage on the DC link **MUST** be discharged before working on any part of the high voltage system.

   • The SD80MAC has redundant systems for discharging this voltage.

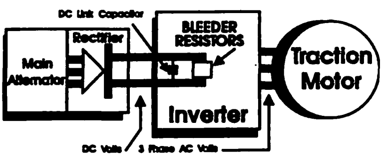
- All of the discharge paths lower the DC link voltage to less than 50 volts DC in less than 2 minutes when functioning properly.

- When the voltage drops to this low level and the isolation switch is thrown, the DC link switchgear is driven TO disconnect the Inverters from the Generator. The inverter is shorted out and tied to ground.

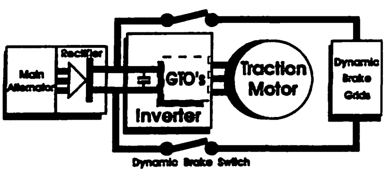
SD80MAC Stored Voltage Discharge Systems

The SD80MAC has redundant systems for discharging the stored voltage.

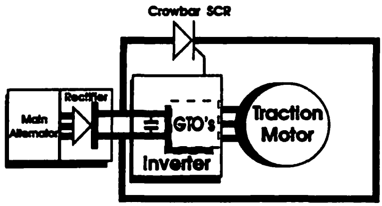
- The first discharge path is through a set of high impedance resistors that are mounted inside the traction control cabinet. They act to constantly "bleed" - the charge from the DC link capacitors. The presence of these resistors makes the maximum discharge time two minutes.



- The second discharge path is through the dynamic brake resistor grids. These connect across the capacitors whenever the isolation switch is placed in the ISOLATE position.



- The third method for discharge is an electrical "crowbar" that is triggered by a critical subsystem in the traction control cabinet. The "crowbar" creates what is essentially a direct short circuit across the DC link capacitors that discharges them instantly. The "crowbar" is generated at other times to protect the inverter.



System Self Test For High Voltage Discharge

From the ICE Operational Display, select "LOCO TEST". From the SELF TEST MENU, select "NEXT" and then "DCL SHORTING". The entry conditions are displayed.

- The reverser must be centered.

- The diesel engine should be running.

- The isolation switch should be in the RUN position.

- Both TCC's should be cut-in.

- The generator field switch should be in the UP position.

- Press "CONTINUE" to start the test. The DC link will be charged up to 600 volts and then discharged to zero through the braking contactors.

You will be prompted to "PUT THE ISOLATION SWITCH TO ISOLATE". This action causes the DC link switchgear to short out the inverter and connect it to ground. You may now press "END TEST."

Successful System Self Test

If the test reveals that the high voltage system has been discharged, shut down the diesel engine and place a DO NOT START tag on the Engine Stop Switch.
NOTE: AS AN EXTRA PRECAUTION, YOU MUST USE A METER WITH A HIGH VOLTAGE PROBE TO VERIFY THAT NO HIGH VOLTAGE REMAINS. Attach the meter to ground and insure that there is no voltage on the DC link bus.

Unsuccessful System Self Test

If the system self test reveals that the high voltage has **NOT** been removed, you will be notified by ICE screen messages and the sounding of an alarm. Follow these procedures to discharge the DC link.

- Shut down the diesel engine.
- Place the isolation switch in ISOLATE.
- Make certain that the ground delay cut-out switch is in the closed position.
- Place the DO NOT START tag on the Engine Stop Switch.

Wait two minutes for the DC link voltage to discharge through the bleeder resistors. Use a high voltage probe and a meter to verity that the DC link capacitors are discharged.

If voltage is still present, wait five minutes and repeat the voltage test until the DC link capacitors are discharged.

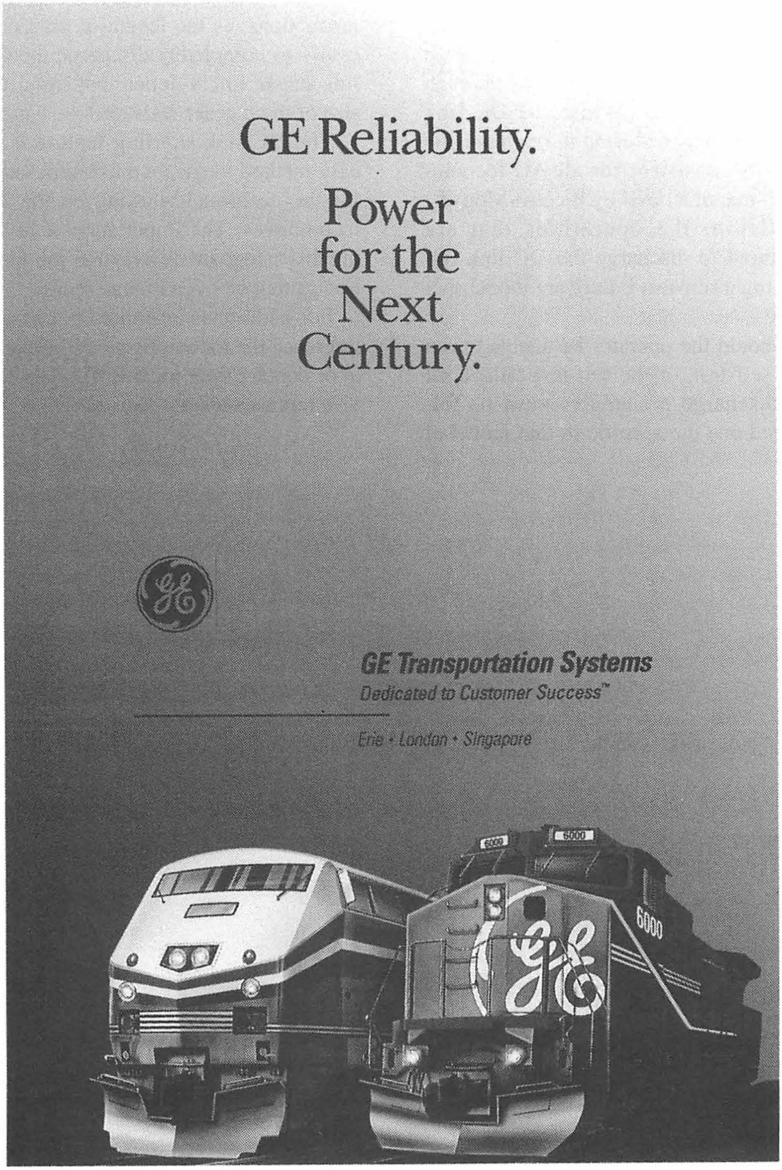
Make certain that the DC link switchgear is in the shorted and grounded position before you proceed with the inspection and maintenance.

In Summary

To summarize, the AC locomotive contains DC link capacitors that are not found on the traditional DC locomotive. These capacitors store large amounts of energy that must be dissipated prior to servicing the electrical system. Under normal conditions, this energy is dissipated anytime excitation is removed from the main alternator. The rate at which it discharges depends on the operating state the locomotive was left in and the model type. For example, if the unit is left idling, with the isolation switch in the run position and the reverser centered, discharge on the SD80/90 MAC will take approximately 2 minutes. On a SD70MAC this takes approximately 40 minutes. If the locomotive isolation switch is moved to the isolate position, or the locomotive engine is shutdown, the DC link capacitors will discharge within one second. This is true for all AC locomotive manufactured by Electro-Motive.

Electro-Motive designed the DC link shorting feature into its locomotives to ensure the safety of the operating and maintenance personnel while performing their duties onboard the locomotive. It was designed to provide the users with a simple, yet reliable method to verify discharge of the DC link and shorting of the DC link to ground, by incorporating the DC link shorting test into a display self-test function. The design criterion was that the operation be quickly understood and easily undertaken as this test should be performed anytime work is to be done on equipment operating at DC link voltage levels.

In the event the self-test should fail, the operator will be alerted via an


GE Reliability.
Power for the Next Century.
GE Transportation Systems
Dedicated to Customer Success™
Erie • London • Singapore
6000

alarm bell and crew message. The operator should then follow the discharge procedures for a non-startable engine outlined on the placard that is mounted on the front panel of the high voltage cabinet. While the DC link shorting test conducted through the display is consistent for all AC locomotives manufactured by Electro-Motive Division, the operations that are required to discharge the DC link following a self-test failure are model specific.

Should the operator be unable to run the self-test, or the self-test fails, a set of discharge procedures must be followed that are specific to that model of locomotive. It is imperative that the operator not deviate from the posted instructions, as the length of time necessary to completely discharge the DC link capacitor is dependent upon the size of the bleeder resistors.

The DC link shorting feature is an easy method to ensure maximum safety for the personnel working on the AC locomotives. The importance of utilizing this safeguard as a regular job function cannot be overemphasized.

For additional information, one can reference the locomotive service manual or contact their local EMD field service representative.

IB. GENERAL ELECTRIC AC LOCOMOTIVE ELECTRICAL SAFETY FEATURES

Prepared by: John Chessario
General Electric (GE)

The purpose of this paper is to review electrical safety on AC locomotives and specifically how they differ from DC units. High voltage circuits are present on both DC traction motor and AC traction motor locomotives but some of the system design elements of the AC locomotive may be unfamiliar to those responsible for servicing the locomotive. We will discuss the methods to discharge DC link capacitors on GE AC4400 and AC 6000 locomotives. If you have additional questions refer to the running maintenance, backshop and operator's manuals or ask your GE field service representative. Please remember to heed all warning labels and follow your specific railroad rules and instructions.

On GE Dash-8 and Dash-9 locomotives the majority of the high voltage circuitry is contained within the auxiliary compartment located directly behind the operator's cab. The AC4400, AC6000 convertible and AC6000 share the same design philosophy in this respect and the method to reduce personnel exposure to high voltage circuits is similar but not identical. The key factor here is prevention and it starts at the entrance door to the Auxiliary Compartment.

On DC Dash-8 and Dash-9 locomotives a door interlock switch (DIS) is used for circuit isolation in the control areas contained within the auxiliary compartment. When the access door to the compartment is opened the DIS disables the XFC auxiliary alternator field contactor which removes auxiliary alternator excitation and all high voltage electrical power (above 75 volts) from the control areas.

This can also be accomplished by moving the BFCO auxiliary alternator field cut-out switch located in the operator's cab CA1 electrical compartment to the cut-out position. This switch also disables the XFC auxiliary alternator field contactor and is in series with the door interlock switch. Both switches have feedback to the control system and an appropriate summary message is displayed on the DID panel.

Voltage levels on GE AC locomotives are comparable to those seen on Dash-8 and Dash-9 DC units. However the AC traction motor system design utilizes higher sustained voltages than those seen on the DC units. By keeping the maximum voltages identical we were able to utilize proven alternator and insulation system designs and reduce the likelihood of system grounds. While both units can operate at 1400 volts, the AC unit will operate at higher voltage levels over a greater portion of the speed range. These high voltage characteristics require the use of stored energy in DC link capacitors located in the auxiliary compartment behind the inverter stacks. Since these voltages may be as high as 1400 volts the capacitors in the Inverter circuits must be discharged before entering the auxiliary compartment or before working on the traction motor leads or propulsion system. The GE AC4400 and AC6000 utilize redundant systems to discharge the stored energy.

There are several caution labels located on the locomotive to alert personnel to the high voltage potential. We will now discuss the redundant discharge paths. There are three methods for discharging the capacitors, one manual and two automatic.

The first thing one will notice upon opening the auxiliary compartment door is a panel located directly above the entrance way that contains a series of LED lights. This is known as the CDI - capacitor discharge indicator panel. The CDI provides a quick and easy visual method to determine if high voltage is present on the inverter circuitry. The front panel contains six columns of LED's, with each column consisting of four LED's, two primary and two redundant. Each LED and it's redundant counterpart are individually wired to the inverters. If any LED is illuminated it signifies that high voltage is present on the indicated inverter circuitry. The capacitor must be discharged prior to entering the compartment. First let's discuss the method for manual discharge.

Manual discharge of the capacitors can be accomplished through engaging the CDS capacitor discharge switch. This is the AC equivalent of the DIS door interlock switch with one major difference - the DIS operates automatically whenever the door is opened, whereas the CDS must be closed manually by lifting the auxiliary compartment entry barrier bar to the full upright and latched position.

The CDS connects the filter capacitor discharge resistors across the line filter capacitors, which are also referred to as link capacitors. Switch closure rapidly discharges the capacitors through the 500 ohm resistors to below 50 volts in less than 30 seconds.

Closing the switch also disables auxiliary alternator excitation. The status of the charge on the link capacitors can easily be ascertained by viewing the series of LED's on the CDI panel located directly above the door. Wait until ALL lights on the CDI are extinguished before entering the compartment.

As an extra precaution the barrier bar can be locked into the vertical discharge position by securing a padlock in the upper supplied hole. This will keep the capacitors tied to the resistors while performing routine maintenance.

There are two automatic discharge features built into GE AC locomotives that are not readily apparent but work behind the scenes to discharge the capacitors. The difference between the two is the speed of the discharge; one works as a quick discharge path and the other path constantly bleeds off the charge. There are several ways in which the quick discharge sequence will initiate. When the control system senses one of three "non-powered" modes of operation automatic discharge is accomplished by dissipating the stored energy in the capacitors through the dynamic braking resistor grids. The commands to initiate this type of discharge come from the PSC - propulsion system controller on AC4400 units and the LPC-locomotive process controller on AC6000 units.

Discharge occurs whenever the control system detects the start or ready - no power mode. The start mode is the process of starting the locomotive which utilizes the inverters and capacitors to crank the diesel engine. The capacitors will automatically discharge after cranking. The barrier bar must be down in order to start the locomotive. If it is not down a summary message will appear on the DID panel on AC4400 units or VID panel on AC6000 units that states: "Won't crank: barrier bar open". Having the barrier bar up will also prohibit battery jog and loading. If the locomotive is in the start mode and the DC link voltage is greater than 50 volts and the engine is not cranking or about to be cranked the system will call for capacitor discharge. Discharge is accomplished by closing dynamic brake contactors for up to 4 seconds or until the DC link voltage drops below 50 volts.

The best way to describe the ready-no power mode is to first explain the ready-powered mode. In the ready-

powered mode link voltage is applied to the inverters and therefore the link capacitors via the traction alternator. This will only occur if all the switches are in the run position (such as EC in run, reverser direction call and generator field on) or if the control has just come out of a powered mode which normally occurs in over the road operation. On AC4400 units, if no changes are made by the operator for 30 seconds the control will go to the ready-no -power mode. For example, when a locomotive comes into the ready track and the reverser is centered, if no other changes take place for 30 seconds an automatic discharge will take place by activating the system to pick up the DB contactors. The thirty second timer was used to improve train handling response time during yard or switching operations since it is common for the operator to move from motor to idle often. On AC6000 locomotives the discharge is initiated immediately after centering the reverser. The 30 second timer is not required on the AC6000 due to the faster response time of the new control system.

If the DC link voltage does not discharge within 3 seconds upon DB contactors being energized, a fault is logged and displayed on the DID or VID panel. This fault requires a manual reset with no restrictions to normal operations. The control will continue to attempt DC link discharge at a rate of once every 10 minutes as long as the fault is active and the voltage is above 50 volts, which is unlikely due to the next feature called the bleed-off resistor.

As a final precaution there is another path to discharge the capacitors. Each link capacitor has a 18K-ohm bleed-off resistor that constantly discharges the capacitor. At maximum voltage it would take about 20 minutes to go below 50 volts. It is unlikely that it would take this long in normal operations since lower notches require less voltage and the resistors are constantly bleeding off the stored energy.

In summary, there are three paths available to discharge the stored energy in the link capacitors. The first method is manual and involves raising the barrier bar to connect the capacitors to the discharge resistors, which takes less than 30 seconds. In one of the automatic modes the link capacitors are connected to the dynamic braking circuit to initiate a quick discharge, roughly 4 seconds or less. The other automatic mode allows the link capacitors to discharge in approximately 20 minutes through a bleed-off resistor. These times all represent the maximum time required to drop below 50 volts with a full charge on the capacitors. In most cases the capacitors will be at less than full charge and will probably be discharged before anyone enters the auxiliary compartment. In any event the maintenance personnel must always heed the warning of the LED's on the capacitor discharge indicator panel before entering the auxiliary compartment. It is not necessary to perform any system self-tests to determine the charge state of the capacitors. If any of the LED's are illuminated on the CDI it indicates that voltage is present and must be discharged before working on the equipment. If you are unsure it is always best to refer to the manuals or ask a GE field service representative.

II. EMI ON AC LOCOMOTIVES

Prepared by: Sam Anoo
Union Pacific

The role of electrical energy in our everyday lives has grown by leaps and bounds. Experts in most fields take a direct approach to achieving their goals, without overdue concern for the negative side effects of their technological innovations, and locomotive builders are no exception to this rule. One big problem which stemmed out of AC technology and AC motors was unacceptably high-levels of electromagnetic disturbances which prevented the satisfactory performance of cab signal equipment. The first concerns regarding this date back to mid-1992, and since then the locomotive builders, cab signal equipment manufacturers and the railroad have conducted numerous tests with different designs till the end of 1995. The first working cab signals on AC4400/6000 convertibles were manufactured by Harmon Electronics.

Electromagnetic Interference

If an electronic device/apparatus is unable to operate as designed due to electromagnetic radiation from other devices operating in the same environment, then we can conclude that the electronic apparatus under consideration is subjected to EMI.

Farady's law of physics (Figure 1) states that when current flows through a conductor, magnetic lines of forces are formed around the current carrying conductor and the direction of these lines of flux is dependent on the direction of flow of current. This magnetic flux or lines of force is electromagnetic radiation. Now, if the magnitude/level or direction of this current is changing with time then the magnitude of the electromagnetic wave changes in correspondence. When this electromagnetic wave manifests itself in unwanted places it is called noise or electromagnetic noise.

Cab Signaling System Overview

A current source is placed between the rails at one end, and a terminating "impedance bond" is placed at the other end. Current travels from the current source, along the rail, through the impedance bond, and back along the second rail to complete the circuit at the current source. As the current travels along the rails, it generates a magnetic field around each rail (Figure 2).

In ATC (automatic train control) systems used on the former CNW territory the presence or absence of a 100Hz carrier signal defines a go or restrictive condition, respectively. In CCS (coded cab signal) systems used on the major part of UPRR, the information contained in the frequency of the 60Hz carrier modulation defines which aspect is displayed (Figure 3). The locomotive enters the track circuit at the end opposite the source. The locomotive wheels and axles shunt the current from one rail to the other, bypassing the impedance bond.

In a typical cab signaling system, the receivers on the underside of the locomotive sense the magnetic field surrounding the rails. The receivers consist of laminated steel bars surrounded by a multi-turn coil. AC flux from the rails is concentrated in the laminated bar, and is directed through the coil. The AC flux passing through the coil generates a voltage in the coil, which is sent to filtering and processing electronics carried on the vehicle (Figure 4).

Problem With AC Traction

AC motors and inverters can contaminate the cab signal system. Since the frequency of the motor drive varies with speed, at certain speeds, the noise generated by the inverter is within the frequency range of the cab signal frequency.

As observed by one cab signal manufacturer, notch 8 motoring produced contamination of 60 Hz signal at 23 MPH on GE locomotives and at 47MPH on EMD locomotives, and 100Hz contamination on EMD locomotives at 70HMPH and 40MPH on GE locomotives. Also, notch 8 dynamic braking at 46MPH on GE locomotives produced 100Hz contamination (Figure 5). The primary source of noise flux leakage was from the "back-iron" of the motor stator.

Tests indicated that the receiver coils were picking up leakage flux from the motor, which was interfering with the carrier signal picked up from the rails.

Testing Approach

AAR supported the testing of signaling suppliers, performing flux mapping of areas in proximity of the lead traction motor and each cab signal antenna coil. Also plots were made of cab signal coil interference voltage outputs to establish the locomotive emission cab signal "footprint".

The cab signaling equipment test setup for the suppliers was somewhat different. One supplier used its cab signal "front-end" consisting of "tuned" antenna coils with 60Hz and 100Hz bandpass filters; measurements were made at both antenna and filter outputs. The other supplier used only its antenna coils since its cab signaling equipment, including front-end filter, is all digital.

At the present time UPRR has 180 GE AC4400 locomotives with working Harmon cab signals. Also the SD90MAC EMD locomotives being delivered to the UPRR will have Harmon systems. UPRR will have 75 EMD SD90MACs by the end of 1996.

Critical Components

1. The position of the receiver coils in relation to the lead motor and the underframe is very critical to the operation. As iron (conducting material) can change the flux patterns, any kind of underframe change to the locomotive needs extensive analysis and testing.

2. The routing of the lead motor cables also plays an important role. Any re-routing is not advised as it can change the flux patterns.

3. The software and some hardware on the AC cab signal systems are incompatible with similar systems used on DC locomotives.

4. The amplitude levels of the track circuit signals need to be at the rated levels, as any attenuation can cause the noise levels to exceed signal level and result in cab signal drop outs.

In conclusion EMI was a big factor in the performance of cab signal systems; however extensive testing and advanced technology have helped in coping with it. Something which railroads have to keep in mind is that with the increase in electronic equipment on board locomotives, specifications that stringently restrict EMI have become necessary. Proper care has to be taken during maintenance and modification, as changes will make invisible impacts on electronic equipment.

EMI ON AC LOCOMOTIVE

FARADAYs LAW

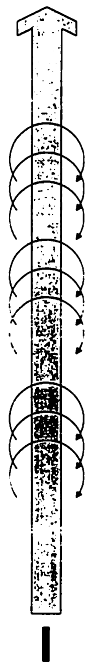
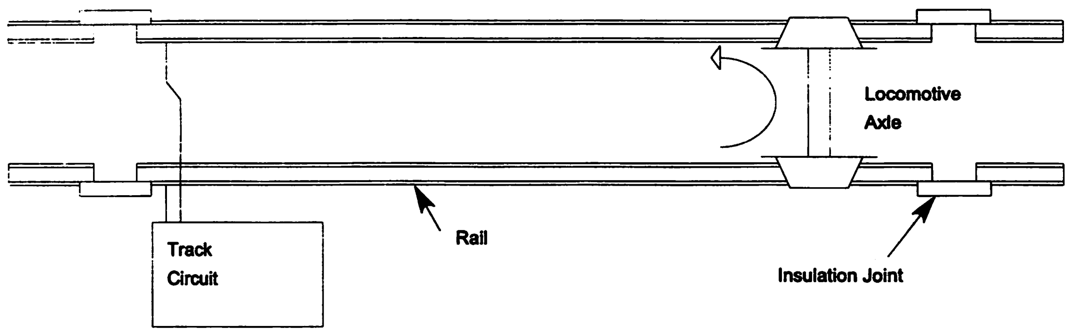


FIGURE 1

EMI ON AC LOCOMOTIVES

TRACK CIRCUIT



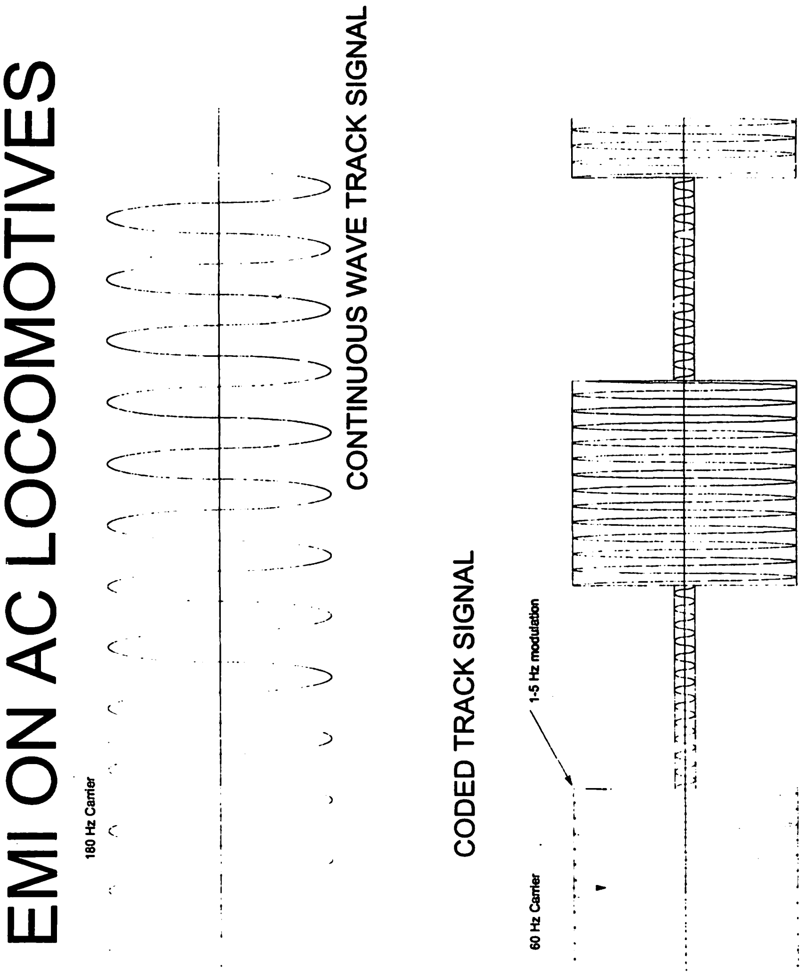

EMI ON AC LOCOMOTIVES
180 Hz Carrier
CONTINUOUS WAVE TRACK SIGNAL
CODED TRACK SIGNAL
60 Hz Carrier
1-5 Hz modulation

FIGURE 3

EMI ON AC LOCOMOTIVES

CAB SIGNAL RECEIVERS

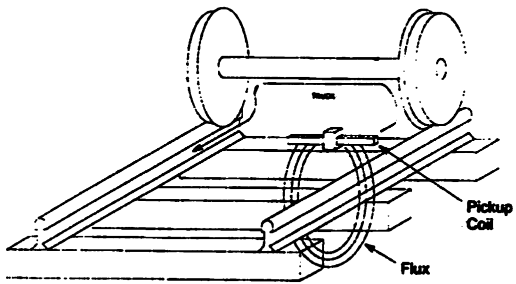


FIGURE 4

EMI ON AC LOCOMOTIVES

INTEFERENCE SPEEDS

FREQUENCY	SPEED	UNIT	BRK/PWR	T.NOTCH
60 Hz	23 MPH	GE AC 4400	POWER	NOTCH 8
100 Hz	47 MPH	EMD SD --MAC	POWER	NOTCH 8
	40 MPH	GE AC4400	POWER	NOTCH 8
	70 MPH	EMD --MAC	POWER	NOTCH 8
	46 MPH	GE AC4400	DB	NOTCH 8

FIGURE 5

III. QTRAC 1000 ADHESION CONTROL SYSTEM

Prepared by: Les White
Canadian National
and
Keith Gilbert
Q-Tron Ltd.

In 1993 Mr. Dan Smith of Montana Rail Link presented an overview of some of the alternate adhesion systems that were available on the market. With the installation of 150 of one of these systems on Canadian National it was felt by the committee that it would be a good opportunity to present more detail on the Q-Tron QTRAC 1000 system.

Some of you may be asking yourself why Canadian National would change from its in-house designed system to another. This requires some explanation as both systems are equivalent in dispatch adhesion levels. The locomotives that we have equipped with the QTRAC system (Figure 6) are GP 40-2's that were purchased in 1974 and 1975, and it was found that the problems being experienced with the original system were basically age and environment related.

A crystalline joint is somewhat similar to a cold solder joint and can cause numerous intermittent failures. These cracks normally occur around the leads of the heavier components and are extremely hard to detect until such time as they open enough to fail completely.

The existing system had given us at least 20 years of reliable service, but it became evident that due to age we had reached a point of time where the complete system would have to be reworked or replaced to regain the original reliability. Once we had come to this realization and had done some basic costing it was decided to examine the systems that were available in the market. Numerous considerations were taken into account, not only the advantages of the various systems but the projected fleet renewal and retirement of locomotives in our fleet. It became clearly evident that the projected retirement of our locomotives would become a key factor in our selection process.

You might wonder how the retirement of locomotives would become a key factor in selecting an adhesion system. In our case the in-house designed systems were installed on our locomotives in various time frames, and when we looked at this we found that the QTRAC system had a very big advantage. That is, because of its microprocessor design it could easily be removed from a GP 40-2 and reapplied on a SD 40-2. This would allow us to obtain immediate improved reliability on our older locomotives and then cascade the QTRAC onto other locomotives in time to avoid age related problems on their systems. The QTRAC system also provided us with a short changeover time as it works on speed sensors, as does our in-house design. This meant that we could switch the system in a matter of one shift, reducing down time. I believe that this explains the main reasoning behind the decision to convert to the new system.

As with most new systems there is a certain debugging period, and so far we have run into two problems. It was found that the adhesion algorithms used for the four-axle locomotives needed some fine tuning. This was accomplished by yard testing with some dynamic brake locomotives and editing the algorithms while in operation. Once this was done it was a simple matter of uploading the new program from a laptop computer.

An interesting problem occurred when the extreme cold weather started. Some of the systems would go into a low 74 volt condition and cause the

locomotive to unload. It was found that a design change to overcome a prototype problem had introduced some new components that would change tolerances in the extreme cold. Once identified it was easily corrected through new software. In both cases the onboard diagnostics and download capabilities of the QTRAC system helped in identifying the key areas of the problems.

Features of the Q-Tron System

First I will take a few moments to present a little background information on both myself and Q-Tron. I will then proceed with a brief description of the QTRAC 1000 Adhesion System and how it evolved during the CN project. We will touch on how it fits into the existing locomotive control system and also how many of the older modules that it replaces. Finally we will look at how the QTRAC can assist in troubleshooting the locomotive.

I began my railroad career as an apprentice electrician at the CN Point St. Charles Shops in Montreal, Quebec in 1970. In those days an apprentice served short stints at various maintenance locations around Montreal in order to gain exposure to all aspects of the operation. One of my assignments was at the Technical Research Center where I was fortunate enough to work with the development team of the CN designed adhesion system that Les has already mentioned.

Upon completion of the apprenticeship program in 1974 I was offered a position at Technical Research as an Engineering Assistant where I spent the next 11 years involved principally in the development and maintenance of that same CN adhesion system.

In 1985 I moved on to the position of Technical Officer with the Mechanical group at System HQ in Montreal. I left CN in 1991 to join Q-Tron as a Manager of Business Development.

Q-Tron was founded in 1974 in Calgary, Alberta as a repair shop for locomotive and industrial equipment. As time progressed the company moved into the design and manufacture of various control systems for the railroad and petroleum industries. Today, railroad products count for about 95% of annual sales.

Very early in the game the founders discovered that product quality meant survival, a view that was not always shared by a sub-contractor. The end result is a company that is extremely vertically integrated, to the extent that PC board lamination and paint are the only two processes not done-in-house. The company is still located in Calgary. U.S. sales and service is now provided by Q-Tron USA Inc. in Denver, Colorado with sales support from the Montreal office.

The product line has also grown along the way (Figure 7).

The QTRAC 1000 is a microprocessor adhesion control system that was specifically designed for EMD locomotives of Dash 2 vintage or older. The control computer is housed in a module enclosure roughly the size of the WS-10 that can be installed in a standard Dash 2 module rack. The rear connector area of the module rack is modified to allow the use of high density connectors for the input/output functions. The controller was designed to extend beyond the adhesion control function and as a result it also replaces the following modules. WS 10, RC, TH, TR, DE, and DR.

In the early 1960's the French started looking at the wheel/rail interface and discovered that if a wheel was allowed to turn at slightly more than track speed the available adhesion increased and the locomotive would develop more tractive effort. This discovery later became known as controlled creep or wheel creep and is now the basic strategy of every modern adhesion control system from the CN designed system of the 1970's to the latest and greatest from both of the builders.

The QTRAC system uses speed input information from each axle to develop a creep control strategy that can increase the pulling power of a Dash 2 or non Dash 2 locomotive by 20 to 25%. A temperature sensor provides information for the motor management system so that a QTRAC equipped locomotive can run in the "short time" ratings until the traction motors warm up-. The system will then reduce power before motor damage occurs. A current input from each motor provides the necessary information for pinion slip/open motor protection.

The CN project provided the opportunity to install QTRAC 1000 on 150 GP 40-2 locomotives. CN recognized the potential benefits of the QTRAC system and decided to go ahead with an extremely aggressive installation program that saw most of the 150 systems installed within 3 months. The goal was to have the new systems installed before the winter began and that goal was met.

As already noted, there were a few teething problems. The QTRAC was already on the market on six-axle locomotives when the CN project began, but for the first time Q-Tron was receiving feedback from operating people who were already used to running high adhesion GP 40-2's. It was also soon reminded how big a difference there is between a SD and a GP in terms of dynamics. There were complaints about poor performance under certain adhesion conditions, as well as reports of poor performance and intermittent operation under extremely cold conditions in the -40 to -60 degree range.

Fortunately both of these shortcomings were corrected in software, and now the CN has a system that performs up to the level it expected.

The final problem area is probably the hardest to fix and that is "shop familiarization". Until the shop forces become a little knowledgeable about a new system, that new system is going to be blamed for any and all problems on the locomotive. Q-Tron developed a simple yet powerful computer program to assist the maintenance personnel in troubleshooting not only the QTRAC system but also a great deal of the excitation and power systems as well. This QVIEW program provides the ability to download fault data, view the fault packages and also print the data for inclusion in work reports, etc. Other ancillary functions include onboard clock setting, uploading new software and modern communications for remote downloading of alarms over a cellular link (if the locomotive is so equipped). The QTRAC has sufficient onboard memory to store 500 alarm packets containing information on the status of the inputs and outputs of the system at the time of the alarm. The sample list shows how the alarms are presented as to date and time, alarm type, etc. (Figure 8 & 9)

In the list we see several Ground relays and EQP Drop-outs. We also see that each motor was in turn cut out as the engineman tried in vain to stop the Ground relay action. My next example is a snapshot of a Ground Relay fault. We can see that the locomotive was operating in the 6th notch at approximately 12 mph at the time of the GR action. We can also see that the #2 traction motor was cut-out at the time. As it turned out, the ground fault was ahead of the traction motors such that motor cut-out could not eliminate the problem. By viewing the list of alarms and noting their sequence of occurrence the troubleshooting electrician was able to make an informed decision as to where to start looking for the problem. Because he was able to see that the ground occurred regardless of which motor was cut out he decided to not start at the traction motors but to look instead around the AR 10. He eventually discovered his problem was in the clean air compartment. In this case he probably saved a couple of hours by not looking at the traction motors first.

In summary, we have looked at a brief profile of Q-Tron and some of its major products. The QTRAC 1000 has been discussed as a product and also as part of the CN strategy to improve locomotive availability by increasing reliability.

FIGURE 6

Major Products

- *Optical Axle Alternators*
- *Custom Cable Assemblies*
- *Speedometers, Speed Controls*
- *Event Recorders, Vigilance Systems*
- *Microprocessor Control Systems*
- *Adhesion Control Systems*

FIGURE 7

Record #42:	GR POWER	Time: 11:10:40	Date: 96:03:04
Record #43:	TM4 CUTOUT	Time: 11:31:19	Date: 96:03:04
Record #44:	EQP DROP	Time: 12:28:45	Date: 96:03:04
Record #45:	GR POWER	Time: 12:28:45	Date: 96:03:04
Record #46:	EQP DROP	Time: 12:31:09	Date: 96:03:04
Record #47:	TM3 CUTOUT	Time: 12:39:00	Date: 96:03:04
Record #48:	TM2 CUTOUT	Time: 12:39:04	Date: 96:03:04
Record #49:	EQP DROP	Time: 13:44:03	Date: 96:03:04
Record #50:	GR POWER	Time: 13:44:03	Date: 96:03:04
Record #51:	TM1 CUTOUT	Time: 13:50:01	Date: 96:03:04
Record #52:	EQP DROP	Time: 13:54:00	Date: 96:03:04
Record #53:	GR POWER	Time: 13:54:00	Date: 96:03:04
Record #54:	TM2 CUTOUT	Time: 13:55:44	Date: 96:03:04
Record #55:	EQP DROP	Time: 14:55:41	Date: 96:03:04
Record #56:	GR POWER	Time: 14:55:41	Date: 96:03:04
Record #57:	EQP DROP	Time: 20:26:05	Date: 96:03:04
Record #58:	GR POWER	Time: 20:26:05	Date: 96:03:04
Record #59:	EQP DROP	Time: 20:36:32	Date: 96:03:04
Record #60:	GR POWER	Time: 20:36:32	Date: 96:03:04

FIGURE 8

EQP DROP UNIT:9566 Record # 61 Time: 14:28:29 Date: 96:02:23

DIGITAL IN1

AV:L BV:L EQP:L
CV:L DV:L BR1:L
GR:H MR:H GFC:H

DIGITAL IN2

IPS:L B:L GR:H MCO:2
SSPD:L RV:* NOTCH:8
TM TEMP: 16 AIR: 8

DIGITAL OUT

SB1:L WSR:L SAND:L
PSR:L GF:H N4DB:L
DC123: * PR:L

TM AMPS

TM1: 690 TM2: 0
TM3: 687 TM4: 683

CONTROL REF

REF:50.0 RC:41.9
LRW:42.3
EXC RED: EQP

ANALOG IN1

DB: 0.0 HP: 921
MGV: 320 MGA:2060
LR:42.4 LRW:42.3

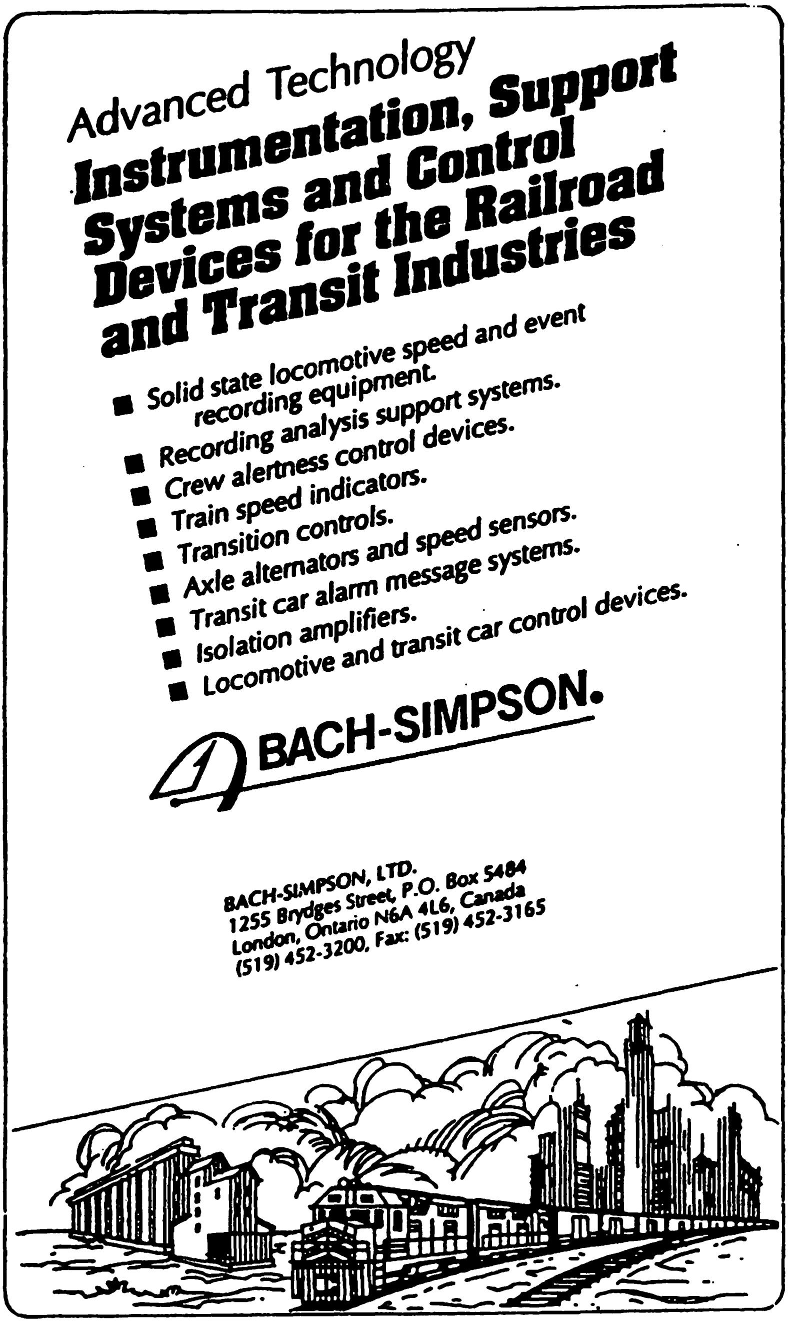
AXLE SPEEDS

A1:13.05 A2:12.98
A3:13.01 A4:13.00

LOCO TYPE

TRK:10.0V GP
DB: 9.8V DB

FIGURE 9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IV. LOCOMOTIVE HEALTH MONITORING
The Key To Improved Maintenance

Prepared by: Thomas O'Brien
Peerless Instrument Co., Inc.
Transportation Systems
Technology Division

Abstract

All railroads, including freight, commuter, heavy and light face a common problem - how do you control equipment maintenance costs while maintaining the optimal availability of equipment for revenue service? New Technology, in the form of Health Monitoring systems (HMS) , is solving this problem.

Health Monitoring Systems (HMS) take locomotive maintenance to a new level, by providing the information maintenance personnel have lacked - complete documentation of when and where a failure occurred. This proactive approach to maintenance - quickly and accurately identifies equipment problems, significantly decreases costly and often erroneous failure diagnoses, enables faster equipment processing through the maintenance facility, and results in increased equipment availability. Operational safety is also enhanced because equipment is much less likely to be returned to service with hard to detect intermittent problems and the HMS is designed to automatically notify the maintenance of any potential problem, by criticality, via digital radio.

Based upon a marriage of advanced diagnostics coupled with the latest in event recorder and radio technology, Health Monitoring Systems provide key failure data to car maintenance and engineering personnel. In addition, this data also provides data indicative of safe operating practices and rail car condition. Health Monitoring Systems provide the dual benefit of increased revenue through reduced repair costs and improved safety.

This paper will explore the benefits of Health Monitoring Systems, their operation and unique features, and discuss the empirical data currently being gathered by the MTA Metro-North Railroad's new Health Monitoring System currently being integrated into their existing M-series rail car fleet.

Introduction

Freight, commuter rail, heavy, and light railroads spend a significant portion of their operating budget on problem diagnosis and maintenance of equipment subsystems and systems. The diagnostic task associated with the maintenance activities is an area that has a substantial influence on overall maintenance costs as well as on locomotive and EMU rail car reliability and availability. Although little has been done to quantify the "diagnostic" portion of the total maintenance cost to railroads and transit agencies, it is significant. Costs related to misdiagnoses of equipment, leading to inappropriate repairs or to "no defect found" (NDF), can also be substantial.

A feasibility study conducted by the Bay Area Rapid Transit District in July of 1991 indicated an annual budget of $35 million for their primary maintenance. Primary maintenance, in this instance, is defined as the "evaluation of a car that has indicated some operating problem, identifying the source of the problem, and either removing or replacing the problem component". The report also stated that approximately 90 percent (31.5 million) of the total direct expense was for unscheduled maintenance and that 53.7 percent of their schedule delays were vehicle related. (1)

Impact of Health Monitoring Systems

In a period of unprecendented growth in electronic technology ranging from pocket communications to the information highway, Peerless has developed a Health Monitoring System that provides railroads with a tremendous leap in diagnostic capability. This innovative, pro-active approach to maintenance provides CMO's with material and human resources - real-time diagnostic status of all their equipment. Typical benefits are shown in Table 1:

Peerless Instrument Co., Inc (Peerless) under contract to the MTA Metro-North Railroad, has developed and is producing a new Health Monitoring System (HMS) that takes maintenance to a new level of productivity. It is designed to significantly lower maintenance costs and repair time while improving equipment availability and customer satisfaction. Based upon a marriage of advanced diagnostics and the latest event recorder technology, the system provides key failure diagnostic data to car maintenance and engineering personnel. With this data, available at the repair location, maintenance personnel are guided to the corrective action that results in a rapid, effective repair of the defect. As an additional convenience, all diagnostic data can be remotely accessed, using an integral radio datalink, to provide maintenance crews advanced notification of a car's performance status and for planning required repair activity.

Currently, the HMS being provided to Metro-North Railroad is for the M-Series Electric Multiple Unit (EMU) car pairs and triplets (i.e., 315). The HMS evolved from our experience designing and developing more than 570 event recorders for the Long Island Rail Road and the Northern Indiana Commuter Transportation District. The Metro-North system addresses and satisfies two completely different and independent functions: health monitoring with diagnostics to support maintenance and event recording to fulfill an FRA mandate. As independent systems, they can be combined to the Health Monitoring System function installed separately should an event recorder be present.

The Peerless HMS developed for Metro-North was designed for railroad environment with maximum flexibility in mind. By utilizing the latest advances in solid-state technology, the HMS incorporates built-in-test to ensure system integrity. It comfortably accommodates retrofit as well as new installation in both diesel and EMU serial data communications. This is particularly advantageous when integrating the system into equipment already crowded with existing wiring and where "through the coupler" spare wires are limited or already assigned.

HMS System Architecture

Peerless HMS provides the basic capability to acquire data, process it for digital storage, store it in non-volatile memory and then transfer the digitally stored data for subsequent analysis. The system is made up of the following key subsystems: a Central Unit (CU), a Radio Datalink, a Download Unit (DLU) and up to 12 remote Data Acquisition Nodes (DANs). The CU accepts direct inputs, as well as data from the DANs, for diagnosis of system failures as well as monitoring all Federal Railroad Administration (FRA) mandated signals. It also provides the computational processing and data storage along with the capability to transfer data via either the PC CIA credit card memory using the DLU, a RS-232 port or a radio data link to the maintenance facility, all of which are connected to the Central Unit. Transferred data is an image of the data contained within the CU and is used for critical event and diagnostic analysis. The system's components are shown in Figure 10.

Detailed analysis of the HMS train data by railroad personnel is performed with a Microsoft Windows™ compatible software program. This program provides the ability to review the entire train database, in either graphical or tabular format, and analyze both intermittent and hard "flagged" failures, as well as "non-flagged" operations. Detailed analysis can be performed based on the previously received failure data pinpointing the specific "Problem/Locomotive/Date/Subsytem" to assist in locating the event within the train database. Repairs can be effected based on the detailed or transmitted alert. Representative graphical presentations are shown in Figures 11a, 11b, and 11c. An example of "Radio Reported" alerted failures, by criticality, is shown in Table 3.

In addition to analysis of the train database, the HMS maintains a history of "faults" in a separate area of memory saving at least 2 "snapshots" of each category of "fault". A snapshot contains 3 to 10 seconds of operational data surrounding each fault. The oldest faults within each category are only written over by a new fault of the same category. HMS candidates for diagnostic analysis include: traction power, auxiliary power, propulsion, braking, powerplant, ATC, HVAC, communications, and various miscellaneous subsystems.

The HMS Approach To Signal Acquisition

Our HMS design was primarily driven by the need to capture key signals to perform failure diagnostics so maintenance personnel would have the necessary information to effect the proper corrective action. For our Metro-North effort, the initial step involved breaking down the equipment subsystems by functional areas, classifying the required signals and mapping where those signals were available on the rail car. Typical functional areas are power, propulsion, train control, HVAC, braking, door systems and miscellaneous functions. However, signals are signals so some examples typical of both Electric and Diesel Locomotive analog and discrete signals are shown in Table 2:

These signals,. dispersed throughout the locomotive, must be captured and returned to the CU. Multiple DANs (up to 12 per CU) are distributed at various locations within the rail cars. Each DAN processes, digitizes and transmits the input signals back to the CU over a serial data link carried on existing train wiring. As an example, the Metro-North system is configured to handle 30 to 48 analog and 80 to 128 discrete signals over and above those mandated by the FRA. The current Peerless design, without modification, is suitable for diesel locomotive or EMU applications, and is capable of accommodating up to 81 analog and 224 discrete digital signals. By employing the system's expansion network, designed in for future growth, 72 analog and 192 digital signals can be added.

DANs and the serial data link that was selected resolved a major system design obstacle common to installation of any new system on existing rail car equipment. The Metro-North Railroad HMS was no different. Diagnostic signals were numerous and located at diverse points within the rail car. These signals could not be connected directly to the Central Unit because of signal attenuation caused by long cables, pos-

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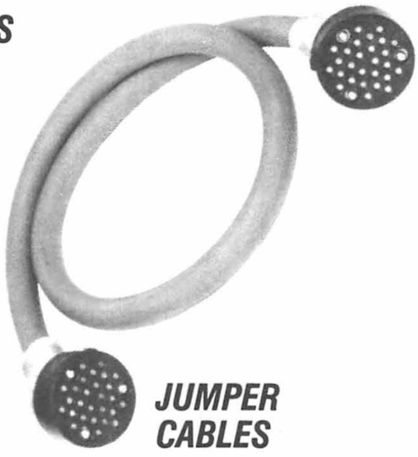

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sible contamination by electrical noise and the absence of sufficient wires in the car coupling to carry these signals. In addition, the amount of labor and technical difficulty associated with installing new cables in the cars also had to be considered. Far smaller than the CU, DANs could be physically located near the signals that needed to be monitored, thereby eliminating signal attenuation and noise interference. The use of DANs thereby eliminated the problems associated with accurate signal acquisition. However, transmitting the data acquired by the DANs back to the CU, by using existing train wiring and available connections through the coupler, required a novel communication medium. Hence, a new technology developed by Echelon was selected. It is also gaining acceptance in new equipment designs.

HMS communication Network

The network communication that was adopted for MNR was Echelon's Local Operating Network (LON®), known as LONWorks®. In addition to many other benefits, it enabled the development team to use existing train wiring to carry serial data from the DANs to the CU. Acting in concert, the DANs and LON completely offset the system design problem of monitoring signals distributed throughout the rail car and transferring signal data without requiring additional wiring for the data link.

Each DAN is identical to all the others and monitors 16 digital channels, six analog channels including two frequency channels used to measure any combination of speed, code rate, etc. Every DAN contains LON circuitry that is also located in the CU. The LON circuitry transfers data over existing lines within the rail car. Each DA accesses the same wiring that is also connected to the Central Unit to form an integrated communication network. At the heart of the LonWorks communication device enables network communication at data rates up to 10,000 bits per second over wires that are unpowered, or carry AC or DC power voltages.

In order to provide orderly communication, each DAN and the CU are assigned a position identification within the network so that communications between the CU and a specific DAN can be managed and controlled. The position identification also enables software to identify the DAN's physical location and the specific signals connected to its digital, analog and frequency channels. Position identification is set by jumper wires in an external input connector so that this information is available to the DAN at the time of installation. If a DAN is relocated, the cable connector at the new location will carry the position identification data for use by the DAN in its new location. This allows the DAN design to be identical, yet enables tailoring the operation to suit a specific location at installation time.

At predetermined intervals, each DAN samples the signal inputs and, after a time period extending over many samples, processes the data. After processing for diagnostic evaluation, the data is formatted into a data packet that also contains the particular DAN position identification which is then transmitted, over the LON network, to the CU. Upon receipt, the data packet is processed, time stamped, compressed and stored by the CU. The position identification code embedded within the data packet is used by the CU to "label" the DAN data transmitted so that it can be properly interpreted and related to the signals monitored by the specific DAN sending the data. All network communication tasks are built into the LON protocol and are therefore transparent to the programmer. This eliminates the time consuming task of developing and debugging a network protocol and allows the programmer to fully focus upon the application code, the program that implements the specific communication requirements.

The HMS Central Unit

All data is accumulated by the HMS CU, which contains a multiprocessor computational capability. Upon receipt of LON data by the HMS CU, initial handling of the data as well as control of the LON network is performed by a neuron microprocessor chip. The processor then transfers the data, using a dual port memory, to an Intel 486 microprocessor which is the master controller, acting in accordance with its executive routine, of the CU and the entire HMS. Signals mandated by the FRA for monitoring are connected directly to the CU where they are processed into digital data.

As master controller within the HMS, the 486 microprocessor performs a number of key functions. It collects all train data including diagnostic information from the DANs and that which is mandated by the FRA, performs analysis and fault detection, and controls communication between the system's microprocessors.

Another microprocessor accepts data processed by the 486 microprocessor, via a dual port memory, and provides management of data storage in a nonvolatile FLASH memory. Processing of data at this point, includes application of a "compression algorithm" to the stored data. This algorithm operates on data activity to perform the compression.

Use of the "compression algorithm" provides more efficient usage of the FLASH memory available in the CU, storing the amount of data necessary to reconstruct the entire data sequence. The algorithm provides the additional benefit of significantly reducing the time necessary to transfer data via the DLU to its transfer medium, a PCMICIA credit card memory. Once transferred, the compressed data can then be analyzed using the Microsoft Windows compatible Office Playback Software which reconstructs the entire data string using a "decompression algorithm". Decompressed data can then be displayed or printed out, in tabular or graphical form, using an IBM compatible PC system. Additionally, this processor also controls an RS-232 communications interface to a remote laptop PC and as well as the radio modem link. This interface can be sued with the remote PC for field reprogramming of the Health Monitoring System. The radio modem link is used to transmit fault data to the main central site maintenance computer via a cellular phone link and a Cellular Digital Packet Data (CDPD) protocol.

Concluding Remarks

The bottom line for all railroads, whether operating in passenger or freight revenue service, is achieving a high level of service in a cost conscious and resource restricted environment. Faced with time consuming and often unscheduled maintenance demands and limited service facilities, it is not unusual to have over 30 percent of the fleet out of service. Maintenance demands drive cost of ownership upwards while reducing vehicle availability and diminishing revenue returns. In such a lose-lose cost situation coupled with vehicle maintenance problems creating approximately 50 per cent of all delays, modern health monitoring systems can significantly and favorably impact operating and service readiness.[1]

HMS brings a new generation of electronics to today's railroads and represents an integrated and complete technical solution to the acquisition, processing and management of data required to enhance diesel locomotive and EMU maintenance operations. Rapid and accurate correlation of intermittent and hard fault symptons to their causes, identification of corrective action and automated generation of documentation enables mechanical officers to better plan and use available, existing resources to meet maintenance demands. Maintenance costs are lowered and fleet availability is improved thereby increasing revenue income. Accomplished with advanced hardware, firmware, communications and comprehensive analytical software, this innovative technology encompasses and resolves all locomotive and EMU health monitoring requirements. Health Monitoring Systems, technology available today that is "*the key to improved maintenance.*"

Acknowledgements:

The information contained and views expressed in this paper are those of the authors alone.

References:

1. I.P. Mulhollnad and R.R. Orn, "Artificial Intelligence for Transit Rail Car Diagnostics", Transit Cooperative Research Program, TRCP Report 1, Transportation Research Board/National Research Council, National Academy Press, 1994.

Revenue Service	Personnel/Resources	Inventory Control
• Immediate Failure Confirmation • Reduced Diagnostic Time • Accurate Fault Identification • Reduced Repair Time • Improved MDBF	• Rapid Diagnosis Reduces Labor • Improved Shop Management • Improved Utilization of Shop and Resources • Reduction in Unscheduled Maintenance • Automated Paperwork	• Improve Spares Management • Eliminates Unnecessary Repairs • Automated Documentation • Database for Inventory Planning
Result: Increased Equipment Availability	**Result:** Lower Labor & Shop Costs	**Result:** Lower Spares Costs & Effective Inventory Planning

Table 1
Benefits of Health Monitoring

Traction Power • AC & DC Master Relays • Traction Alternator	**Powerplant** • Temp/Press/Air & Fuel Flow
Auxiliary LVS/HEP • Motor Alternator/Battery System	**ATC** • Speed/Aspects/Acknowledge • Wayside Signal Strength
Propulsion • Throttle Position • Traction Motor Current • Traction Motor Blower	**HVAC** • Temps/Compressors
Braking • Dynamic & Blower • Eq. Reservoir/Cylinder/Pipe/Snow • Wheel Slip Slide	**Doors** • Indicators & Relays
	Miscellaneous • Horn/Bell • Sanding Lever Switch

Table 2
Sample of Diesel Locomotive/EMU HMS Diagnostic Signals

Unit	Time	Fault Condition	FCode	Train
8802	10:53A	Hot Car - Freon Compressor	2410	1312
8412	**11:00A**	**Door Open - Cabside B End**	**1123**	**1514**
8744	**11:17A**	**Air Brake Did Not Function**	**1120**	**1534**
8810	**11:20A**	**Cab Signal - False Proceed**	**2182**	**1623**
8728	**11:27A**	**Cab Signal - Code No Aspect**	**2183**	**1532**
8736	**11:56A**	**No Dynamic**	**1138**	**1612**
8546	12:07P	AC Propulsion Fault - No P3-P4	2188	1231
8528	12:25P	Direction - Trainline Fault	2233	1423
8508	12:36P	Motor Alternator Failure	1260	1351
8418	**12:58P**	**Speedometer Fail - #3 SS**	**1183**	**1243**

Critical Faults

Table 3
Examples of Radio Reported Failures

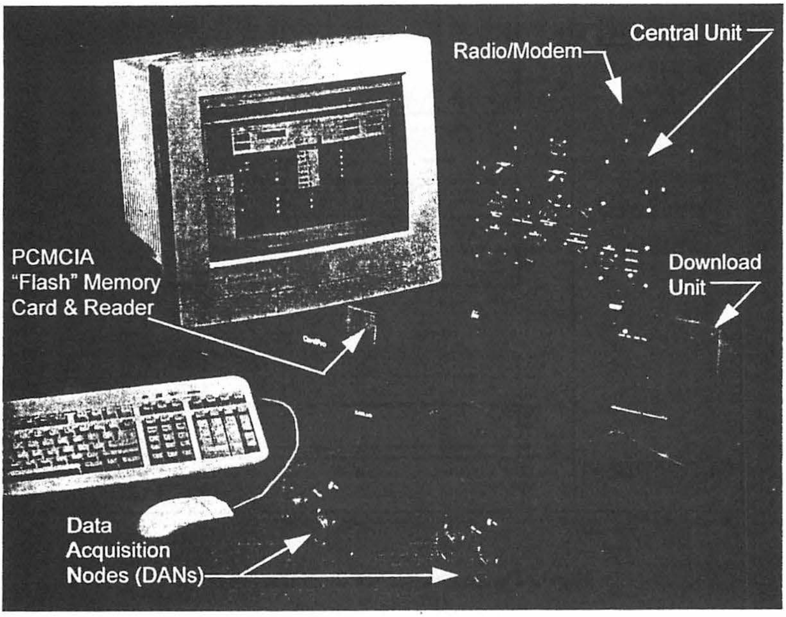


Figure 10
Model 1250 Capable of Handling 12+ DANs

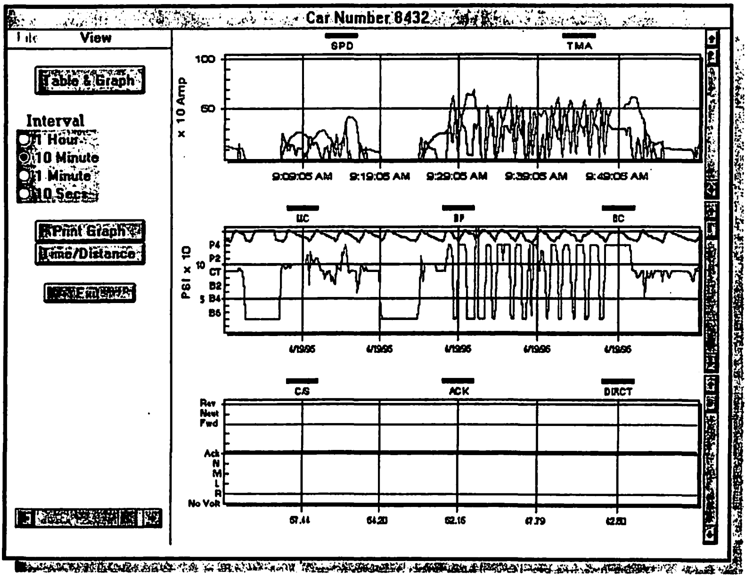
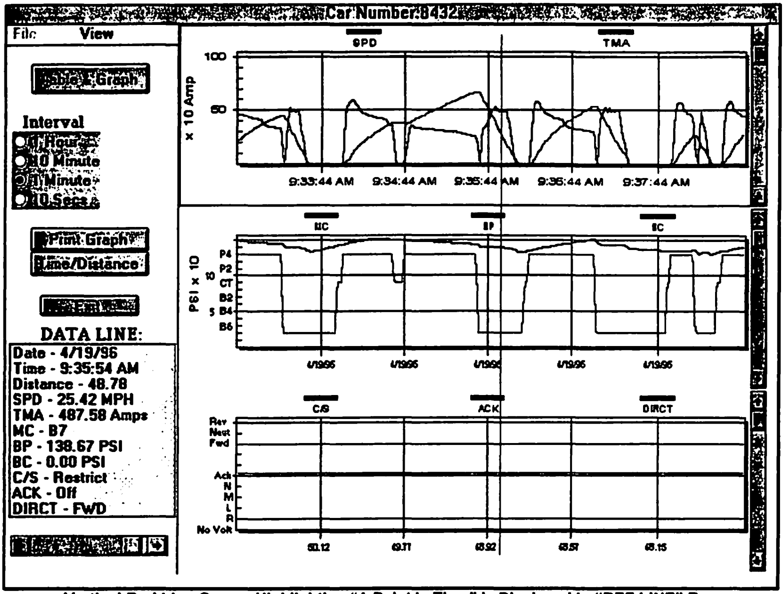


Figure 11a-Representative Graphical Presentatin (10 Minute Scale)



Vertical Red Line Cursor Highlighting "A Point In Time" Is Displayed In "REF LINE" Box

Figure 11b-Representative Graphical Presentation (10 Minute Scale)

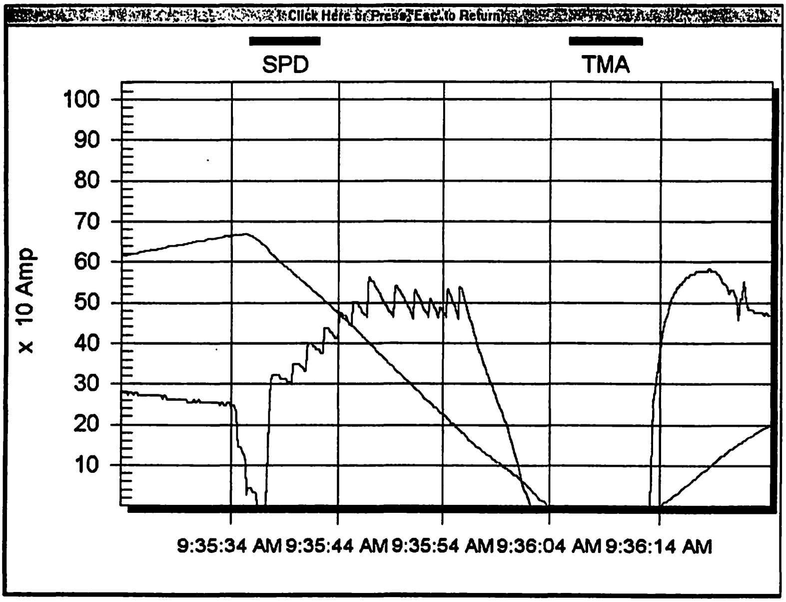


Figure 11c-Representative Graphical Presentation (Selected Channels - 10 Minute Scale - Zoom Mode)

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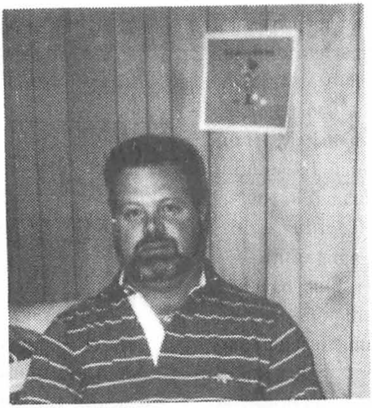

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PERSONAL HISTORY

William Lechner

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

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

Bill and his wife Debbie have two children: Wendy Jo, 22, and Todd William, 20, and both are currently attending Penn State University. They currently live in Altoona where Bill is Manager Material and Production Control and also General Foreman of Air Brake Shop for Conrail.


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I. TECHNOLOGY TRANSFER, THE HOT PROCESS OF THE 90's- CONDITION BASED MAINTENANCE

Presented by:
Wayne Boblitt, U.S. Navy

Prepared by:
Wayne Boblitt and John Brawley, Amtrak

The subject of technology transfer was presented to the annual LMOA meeting in Chicago in 1993. In that presentation, it was suggested that technologies from other, non-railroad sources and/or the Department of Defense could provide a large advantage to our industry, a kind of "don't re-invent the wheel" approach.

This year we offer for your consideration a technology developed in part by both the U.S. Navy and private industry. This technology, or actually business process, is called condition-based maintenance, commonly referred to as CBM.

The business process of conditioned-based maintenance has numerous benefits, including:

1. reduction in inventory levels of a number of equipment parts and components;
2. reduced purchasing and materials costs; and
3. more cost effective maintenance.

There are other benefits that will be reviewed later. But first a few comments about condition-based maintenance.

You may already have heard the terms reliability centered maintenance, commonly called "RCM", and conditioned-based maintenance, "CBM".

RCM had its beginnings in the early 1970's with the advent of the Boeing 747 aircraft. Because of the then restrictive FAA maintenance reporting systems, United Airlines designed a maintenance reporting process which, it was able to convince the FAA, was far superior to what the older FAA reporting system was able to do, especially with new complex aircraft such as the 747.

After the commercial airline industry adopted some or all of the RCM process, the nuclear power industry and the U.S. Navy did the same.

However, with advanced sensors and monitoring technology has come a new discipline that many in the preventive maintenance area believe is far superior to RCM. This is the process called condition-based maintenance or CBM.

One of the country's leading experts on the subject defines CBM as: "Maintenance whereby the process is delayed until a monitoring system alerts the operator that it is time to conduct a particular maintenance action."

To implement condition-based maintenance, several capabilities are necessary.

(1) monitoring by sensors;
(2) the accurate detection of a particular fault;
(3) the accurage diagnosis of the particular fault;
(4) an understanding of the precise definitions of CBM terms;
(5) the accurate prognosis to reliability;
(6) the ability to make an intelligent decision concerning who does what and how to repair the equipment, i.e. the repair action involved;
(7) The ability to predict *remaining useful life* of the machinery in service.

The definition of " remaining useful life" is: the operational time from the present until a system will not be able to successfully complete its next "mission" because it:

(1) won't be safe within acceptance confidence limits;
(2) won't meet predefined minimal tolerance levels; i.e. either noise or dimensional accuracy

of machined parts;

(3) will operate below cost-effective efficiency;

(4) will fail catastrophically;

(5) will cause collateral damage or failure to some other part.

Time is defined in terms of operational time rather than calendar time because the utilization rate will so strongly effect the relation between calendar and operational time.

By implementing a CBM program a railroad can realize many benefits in addition to those outlined earlier. These include:

(1) increased availability of locomotives and other equipment;

(2) a reduction in overall maintenance costs;

(3) improved assurance of equipment operations;

(4) increased safety of operations.

Industry is changing today due to both maintenance cost constraints and the need to run equipment longer, and in some cases, harder. As an example: because of government downsizing and other reasons, the military has equipment that has been in "inventory" for at least ten years. In the commercial sector older equipment is utilized as long as possible. Witness the airline industry with many planes that are at least 15-20 years old or older. In our industry, many of the SD-40-2's, a workhorse locomotive, date back to the mid 1970's.

In the Navy's case, instead of a phased maintenance schedule based on hours, with little or no relation to the actual operational health of the equipment, the Navy can move to programmed, but continuous maintenance to maximize the availability of equipment for a given mission. This will be accomplished by continuously monitoring equipment condition and maintaining it only when objective evidence of a fault problem exits. At the operational level, this will provide sufficient warning of the evolving fault to enable the *maintenance action* to be scheduled to minimize impact on the equipment's availability before significant damage occurs at a inconvenient time.

For example, the Navy can realize continued use of parts that previously would have been scrapped; parts such as helicopter transmission gears that had merely reached a pre-established number of hours.

Two major associations, the Electric Power Research Institute and our own Association of American Railroads (AAR), concur that the top priority to them is the development of the capability to accurately predict the remaining useful life of a critical component or system without reducing its operational time.

The second priority identified is the ability to extend such a prognostic capability from parts and components made of currently used materials to materials of the future, i.e. space age materials, which may have fundamentally different dominant failure modes than are encountered at present.

Now, let's look at two other important CBM precisely defined terms:

Critical Prediction Horizon

The time before the end of a piece of equipment's useful life required by the operator to conveniently and/or safely take the required action for the specific failure trajectory. The timing process for this mode is a function of:

- time between convenient repair opportunities;
- the consequences of a failure; and
- the difficulty of the required action that is to be undertaken.

Critical Detection Horizon

In order to refine the estimate of the remaining life sufficiently, it is necessary to detect the evolving failure mode at some time before the operator is alerted

to the evolving problem. The time at which this failure evolution is detected is called the *Critical Detection Horizon.* The time required to refine this projection of the remaining useful life is a function of:

- time to conduct analysis required to make a prediction; and
- the consequences of a " false alarm" or " missed" prediction which affect the accuracy and certainty of the prediction.

Finally, some other considerations:

(1) Utilize decision support methodologies to allow the user to make informed operational decisions in a "real-time" environment based on information provided by the CBM system.

(2) Use "data fusion" to accept all the sensing and monitoring devices and enhance the quality of the condition assessment..

Like all business process reeingineering (BPR), CBM takes time and dedication by both management and staff to make it a success.

However, based on the experience of the U.S. Navy and other industries CBM is a successful process that works and accomplishes what it was intended to do.

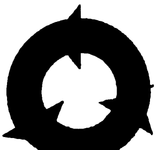
II. WAREHOUSE AUTOMATION

Presented by:
D.C. Van Hooser,
Haggard & Stocking

The following presentation is intended to provide a simple overview of the complex topic and to promote and commend the concept of warehouse automation.

WAREHOUSE AUTOMATION

- What it is
- What it does
- What are the benefits?
- What it takes
- Who ya gonna call ?



The term " Warehouse Automation" is very broad. This presentation will attempt to provide an overview of concepts, equipment and processes involved in planning for " state-of-the-practice" in the field of warehouse automation.

We will discuss what warehouse automation is and is not, why to consider it at all, and what we should expect from it.

WHAT WAREHOUSE AUTOMATION IS:

- Not just **Automatic Storage and Retrieval**
- Not just **Powered Conveyors**
- Not just **Computerization**
- Not just **Bar Codes**
- Not just **Programmable Controls**
- Not just **Portable Computers**
- BUT...ALL OF THE ABOVE ....
  ....AND MORE

" Warehouse automation" means different things to different people. While the above list includes many of the things necessary for warehouse automation, these things do not of themselves constitute a system.

As important to a successful system as they are, the **compatibility** and **integration** of the above are at least as important.

The integration of the above systems certainly creates a system which is greater than the sum of its parts.

WHAT WAREHOUSE AUTOMATION IS:

Application and Integration of Material Handling and Information technologies.

All material handling hardware and controls must be fully integrated.

Today's warehouse requires information to flow alongside every movement. Constant feedback from materials being handled to computer software allows instantaneous reaction by material handling devices and the ability to communicate real time with operators and management.

WHAT WAREHOUSE AUTOMATION IS.... NOT

- Magic
- Total elimination of work force
- A substitute for management
- The cure to all problems
- The end in its self

Part of knowing what warehouse automation is, is knowing what it is not.

The above refers to some of the common misconceptions about automation. Automation for automation's sake often results in limited success.

WHAT WAREHOUSE AUTOMATION DOES

- Enriches the work force
- Provides Tools for management
- Provides Solutions for problems
- Becomes the means to the end

Part of knowing what it is, is knowing what it does. Looking at the previous illustration and then at the one above, you can see the differences. Automation should be the means by which management can meet the customer's requirements.

WHAT IT TAKES

- HARDWARE
- SOFTWARE
- PLANNING
- A VISION

There are four basic requirements for creating a properly automated warehouse. The first two on the list above are rather obvious. What are often overlooked or given less than equal weight, are the other two.

Actually, this list is compiled in reverse order of importance. The presentation to follow will deal with the issues as listed above.

However, the decisions made at each step will be easier and less critical if the **Vision** is focused and the up-front **Planning** thorough.

WHAT IT TAKES

- **HARDWARE**
- SOFTWARE
- PLANNING
- A VISION

Hardware as used above covers a lot of ground. In the next few illustrations we will explore some of the types of automated storage and material handling equipment available for application in a warehouse automation project.

HARDWARE

- HIGH DENSITY STORAGE
- PRODUCT MOVEMENT
- PRODUCT PICKING
- PACKING, LABELING, WEIGHING

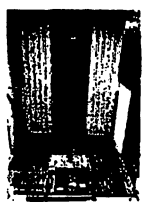
These are the basic categories of warehousing hardware. (Computers not included here.)

High density storage is not a prerequisite for warehouse automation but most projects include an effort to optimize space as well as automating specific activities.

Materials movement can take many forms. Which methods and hardware to select will depend upon size, shape, weight, fragility and many other factors.

HARDWARE FOR HIGH DENSITY STORAGE

- AUTOMATIC STORAGE AND RETRIEVAL (ASRS)
  - Unit Load
  - Mini Load
  - Vertical Carousels
  - Horizontal Carousels
  - Storage Towers



High density storage devices aren't an absolute requirement. However, most warehouse automation projects include an effort to maximize space utilization and work flow.

Automatic storage and retrieval systems vary in size, shape and throughput characteristics.

An ASRS as pictured above uses space very well while providing high security. There is, however, a trade off in through-put and productivity over carousels.

Good data analysis is needed to make the correct hardware selection in this area, as it is with other material handing hardware.

HARDWARE FOR
HIGH DENSITY STORAGE

- Live Aisle Systems
- Pallet Flow Rack
- Push-Back Rack
- Drive-In-Rack
- Selective Pallet Rack
- Modular Cabinets

Live aisle systems utilize selective pallet rack mounted to mobile carriages which move as required. This allows multiple rack rows to share aisle space. This method is the most dense storage method that provides 100% product selectivity. It also allows access by conventional lift trucks.

Flow rack, push-back rack and drive-in rack all utilize space very effectively, but limit selectivity and productivity.

HARDWARE FOR
PRODUCT MOVEMENT
AUTOMATION

- AUTOMATIC GUIDED VEHICLES
- COMPUTER DIRECTED FORKLIFT TRUCKS
- IN-FLOOR TOW SYSTEMS
- TRAILER TRAIN TOW TRUCKS
- CONVEYOR SYSTEMS

There are many variations of these kinds of hardware. Many systems require more than one from the above list and then complete integration of the various methods.

The movement methodology depends on many factors, such as load size, load weight, number of moves, variability of travel path.

As with all the hardware discussed here, analysis is necessary to make final choices of hardware.

CONVEYOR TYPES

- High Speed Sortation
- Low Speed Sortation
- Accumulation
- Extendible
- Gravity
- Overhead
- Transportation

Each type of conveyor in the above list could include another list of variables just as long as this one. Experience is necessary for dealing with the many application choices available.

Most conveyor applications utilize several types of conveyors integrated into a single system. Some automated warehouse systems apply high speed conveyors for up to 90% of product movement. More often conveyors are used in the more basic "on/off" mode with little additional control.

We refer to highly controlled conveyor systems which interface with computer systems for automatic routing of materials as " Smart Conveyor."

HARDWARE FOR
ORDER PICKING

- Carousels
- Flow Rack
  - Case Flow
  - Pallet Flow
- Automatic Dispensing Machines
- "Man-up" Orderpicking Trucks
- ASRS End of Aisle
- "Man-aboard" ASRS
- Remote Picking Systems

There are many types of order picking methods. Hardware selection is based on what is being picked, i.e.....;

Full cases
Less then case
Uniform shaped items
Pallet loads
Fragility.

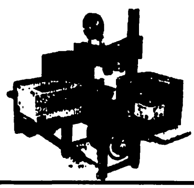
Other important conditions:

High/low volume throughput
High / low volume SKU
Size / weight of product
Order size
Packaging requirements
Shipping method
Facility layout.

This is why it is critical to understand what needs to be accomplished, under what conditions, to insure an effective system.

OTHER WAREHOUSE AUTOMATION HARDWARE

- **Packaging**
- **Wrapping**
- **Weighing**
- **Labeling**
- **Manifesting**



These functions are often the first ones automated in distribution applications. They are automated in many warehouses where there is no other desire for automated warehousing.

Like everyone, we tend to say "automation" when we may only mean "mechanization". Indeed, if we are considering just one task or segment of an operation, simple mechanization may be all the automation we need.

WHAT IT TAKES

- HARDWARE
- **SOFTWARE**
- PLANNING
- A VISION

Computer software may just be the most crucial link in the chain of components to be selected. The following illustrations will demonstrate the broad range of capability required for implementing a fully automated warehouse system.

Warehouse Management and Control Software

- **The heart that pumps life into hardware**
- **The eyes that monitor the activity**
- **The brain that makes decisions so the hardware functions as an integrated system**
- **The memory for creating management reports**

It is software which brings " Life" to a mechanical system.

Warehouse Management and Control Software

- **Must be dynamic**
- **Must be flexible**
  - **To adapt to changing expectations**
  - **To grow in various functionality**

By dynamic we really are thinking of the force or energy that causes a system to perform many functions at once. The idea of software bringing material handling systems to " life" is indicative of dynamics in software.

Flexibility is important because we cannot be sure of what form growth or change may take. The two needs in this area are " modularity" and " user configurability".

A system should be able to start with basic functionality and add more functions as conditions require. A modular design is the answer to method of implementation. **You should not have to buy functions you don't need.**

Warehouse Management and Control Software

- Must be compatible with:
  - Various computer hardware
  - Various other software
  - Material Handling hardware
  - Material Handling controls
  - Interactivity devices

Compatibility is an important factor in software selection. Avoiding being" locked in" to specific peripheral systems or component hardware, keeps ongoing costs down and reliability up.

Many so called warehouse management software packages do not interface with any " interactivity" devices. Some are designed to interface with only one type, in an effort to "lock-in" their own products.

WHAT TO LOOK FOR IN SOFTWARE

* Real Time operation
* Real Time Interface with other system components
- Interface with and control Material Handling hardware such as
  - Conveyors
  - Carosels
  - ASRS
- Produce and read bar codes
- Control bar code scanners and printers

Even if there is not a plan to utilize certain material handling equipment today, it is wise to be sure your software system can **interface** with and **control** the devices you may want to implement tomorrow.

SOFTWARE

- Have various "pick modes"
  - Single order picking
  - Batch picking
  - Wave picking
  - Parallel picking
  - Kitting
- Track multiple locations of parts
- Support "primary" pick zones
- Establish and adjust order priorities
- Operate in "paperless" environment

As business practices change over time, it is advantageous if the warehouse management and control software can easily be reconfigured in the field by the users.

This helps minimize the amount of future (expensive) customized programming.

If all facets of the warehouse operation are fully integrated, it will be unnecessary to print or handle any paperwork until a contents list or shipping label is required.

SOFTWARE

- Operate Radio Frequency data transfer devices
- Provide "HOT" backup
- Track productivity
- Include Training and on-line Support
- Modularity
- Allow preplanning of work
- Assign put away locations (by multiple rules)
- Manage Cube Usage
- Manage cycle counts and annual inventory

This may seem like more functionality than necessary, but the functionality that is unnecessary today may be the function critical to success tomorrow.

If the system is not implemented with all these functions, be sure that they are all available for future implementation.

SOFTWARE

- Generate standard reports
- Provide SQL report writer
- Run on various platforms
- Interactivity

Every warehouse operation has its own report requirements. A good warehouse management and control software package will provide the user with the ability to create custom reports from the database.

A standard query language (SQL) report writer will allow data to be exported to any standard report software such as Microsoft XL.

The ability for software to run on various platforms will reduce the likelihood of obsolescence by virtue of future computer platform developments.

The last line in this illustration is your introduction to a new term embodied in the warehouse automation concept: **Interactive Warehousing. Interacivity** is the key ingredient in today's warehouse.

INTERACTIVITY?

The ability to allow

people,

information

hardware

to interact dynamically in real time.

The automated warehouse of today is the **"Interactive Warehouse."** Interactivity is the key to **accuracy** and **productivity.**

TODAY'S AUTOMATED WAREHOUSING MUST BE...

INTERACTIVE WAREHOUSING

Interactivity is the key to controlling timeliness and accuracy of activities and materials on a real time basis.

INTERACTIVITY

- Workers
- Computers
- Material Handling Devices
- ID Systems
- Managers
- Customers

The warehouse management and control software must connect all of the above together. There should be seamless interaction of all phases of operation.

INTERACTIVE WAREHOUSING DEVICES

- Pick-to-Light Devices
- Radio Frequency Data Transmission
- Bar Code Scanners
- "Smart" Conveyors
- PCs
- PC Networks
- Hand Held Computers

Today's automated warehouse must be " interactive".

These are the devices which allow the software to communicate with and interact with people and equipment.

WHAT IT TAKES

- Hardware
- Software
- **Planning**
- A Vision

PLANNING

- Structured approach vs. traditional approach
- Structured approach
  - Design processes, Equipment and integration together and "UP-FRONT"
- Traditional approach
  - FIRST - Purchase Equipment
  - LAST - Integrate

In the past it was possible to buy material handling and storage equipment, install it and then find a way to integrate the functionality.

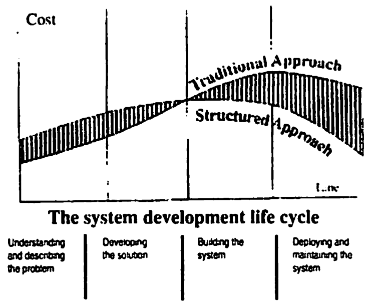
Interactivity between hardware and software and people was not required or expected.

The same thing can be done today, but it results in higher costs and longer implementation time.

A "structured approach" to planning limits overall costs and shortens implementation time.

Structured vs. Traditional

- System Project Life Cycle



The above graph demonstrates the time and cost differential of the traditional approach compared to the structured plan approach.

Up-front planning reduces costs and shortens the project life cycle.

STRUCTURED PLANNING SAVES ......

- PROJECT TIME
- PROJECT COSTS
- MISTAKES
- SURPRISES
- EMBARRASSMENT
- PROJECT MANAGER'S JOB

These are some other savings that good planning can offer.

WHAT IT TAKES

- Hardware
- Software
- Planning
- **A Vision**

The vision does not need to be

absolute. However, a clear vision helps keep project design and implementation on track.

A VISION

- **Understand and define current problems**
- **Understand and define what should be accomplished.**
- **Don't be afraid to DREAM**
- **Be sure to ask....What if?**
- **If you can't define the vision, how will you know when you have achieved it?**

The vision needs to be based on reality and should foresee and solve as many problems as possible.

There is usually a theoretical ultimate solution, but the real world causes compromises, yet still allows most requirements to be met.

WHO YA GONNA CALL?

- **FOLKS, Don't try this at home!**
- **CALL a Professional**
- **An experienced Consultant**
  - **Inside the company**
  - **Outside the company**

Most corporations today don't staff for "special" projects. Today the trend is to look outside the corporation for specialists to complete projects which require specific knowledge or resources that won't be needed after completion.

Why a Consultant ?

- **Objectivity**
- **Experience**
- **Resources**
- **Specific application knowledge**
- **Exposure to other operations**
- **Verification/Affirmation of data, concept, approach, etc...**

These are a few of the things a consultant can bring to the table.

Some corporations have consultants on staff who go from facility to facility consulting within the organization.

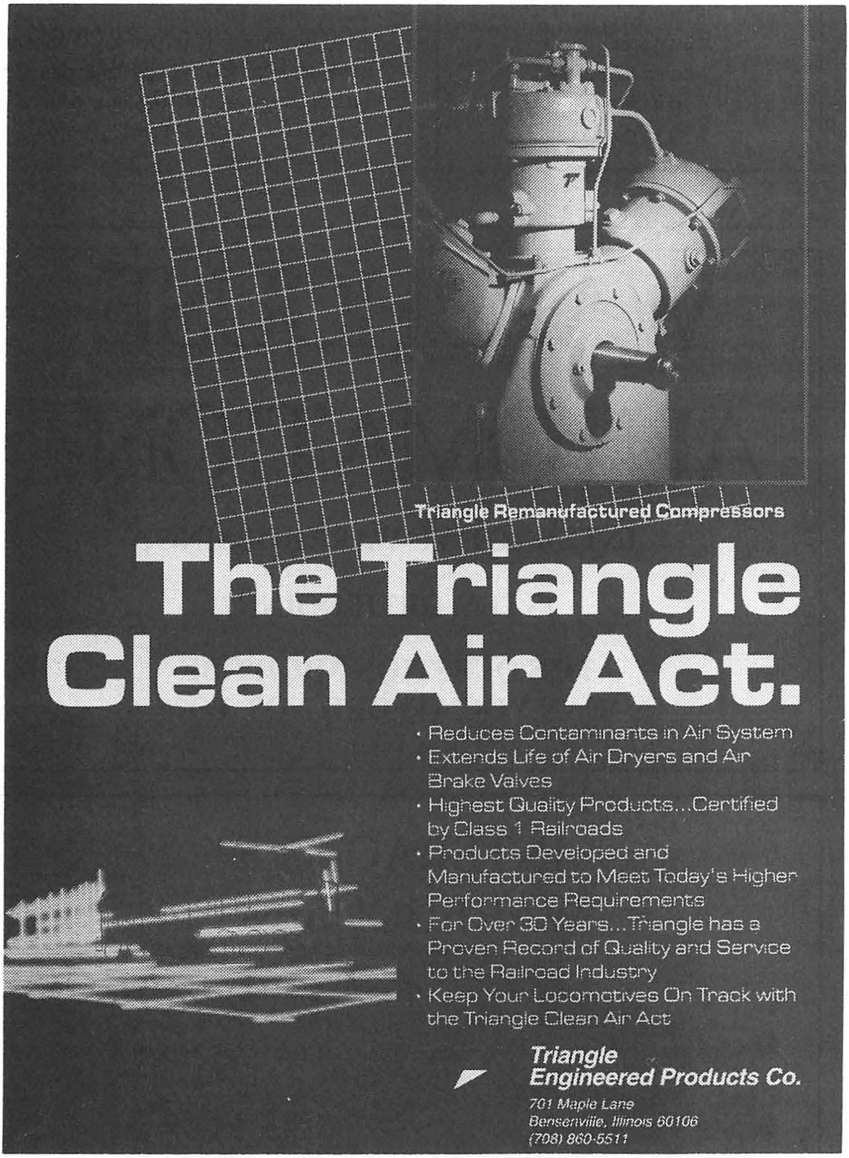
If your corporation doesn't have one of these, then contracting is a good alternative.

HOW YA GONNA KNOW ?

- **Do your HOMEWORK**
- **Check their work, not just their name**
- **Who is doing the work?**
  - **the one with the experience?**
- **Do they understand the vision?**
- **Do they work for a manufacturer?**
  - **potential agenda conflict?**
- **Be careful! If it's FREE, it may be worth what you pay for it.**

There are some well known names in the warehouse design and consulting business. Any of these can probably develop a workable plan. However, the individuals who created the "names" are likely not to do the actual work. They often send out young engineers with little or no practical experience.

Confidence comes with a little homework.


Triangle Remanufactured Compressors
The Triangle Clean Air Act.
• Reduces Contaminants in Air System
• Extends Life of Air Dryers and Air Brake Valves
• Highest Quality Products...Certified by Class 1 Railroads
• Products Developed and Manufactured to Meet Today's Higher Performance Requirements
• For Over 30 Years...Triangle has a Proven Record of Quality and Service to the Railroad Industry
• Keep Your Locomotives On Track with the Triangle Clean Air Act
Triangle Engineered Products Co.
701 Maple Lane
Bensenville, Illinois 60106
(708) 860-5511

WAREHOUSE AUTOMATION

- What it is
- What it does
- What are the benefits?
- What it takes
- Who ya gonna call ?

The beginning of the presentation promised an overview of the topic of warehouse automation. If we have done anything, it is our hope that we have at least conveyed the idea that Interactive warehousing is a beneficial concept.

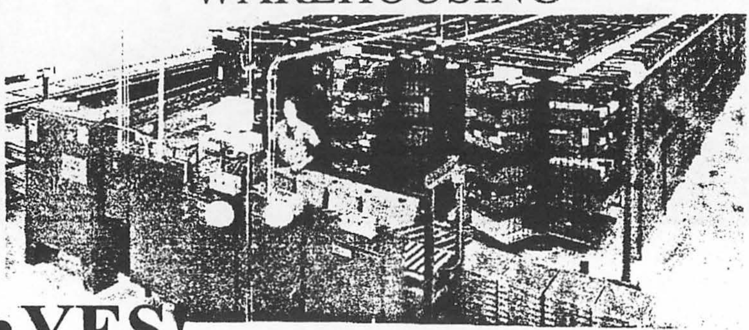
WAREHOUSE AUTOMATION?

INTERACTIVE WAREHOUSING?

IS IT WORTH DOING?

THE QUESTION MIGHT BE
'CAN YOU AFFORD NOT TO?"

INTERACTIVE WAREHOUSING



• YES! INTERACTIVE WAREHOUSING IS THE FUTURE

...................................AND THE FUTURE IS NOW!

CONSTITUTION AND BY-LAWS LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

Article I - Title:

The name of this Association shall be the Locomotive Maintenance Officers Association (LMOA).

Article II - Purpose of the Association

The purpose of the Association, a non-profit organization, shall be to improve the interests of its members through education, to supply locomotive maintenance information to their employers, to exchange knowledge and information with members of the Association, to make constructive recommendations on locomotive maintenance procedures through the technical committee reports for the benefit of the railroad industry.

Article III - Membership

Section I - Active Railroad Membership shall be composed of persons employed by a railroad company and interested in locomotive maintenance. Membership is subject to approval by the Board of Directors.

Section 2 - Associate Membership shall be comprised of persons employed by a manufacturer of equipment or devices used in connection with the maintenance and repair of motive power, subject to approval of the Board of Directors.

Associate members shall have equal rights with active members in discussing all questions properly brought before the association at the Annual Meeting, but shall not have privilege of voting or holding elective office.

Section 3 - Honorary Membership: Honorary Membership may be issued at the discretion of the President, subject to the approval of the Board of Directors. Honorary Members may not vote or hold elective office; all Honorary Membership shall expire at the end of the current membership year.

Section 4 - Life membership shall be conferred on all Past Presidents. Honorary life memberships shall be conferred on others for meritorious service to the Association, subject to approval by the General Executive Committee.

Section 5 - Dues and fees: Membership dues for individual active and associate membership shall be set by the Board of Directors and shall be payable on or before September 30th of each year. The membership year will begin on October 1 and end September 30. Life and honorary life members will not be required to pay dues. Members whose dues are not paid on or before the opening date of the annual convention shall not be permitted to attend the annual meeting, shall not be eligible to vote and/or shall not be entitled to receive a copy of the published Pre-Convention Report or the Annual Proceedings of the annual meeting. Failure to comply will result in loss of membership at the end of the current year. A registration fee will be set by the Board of Directors for those attending the annual meeting. Life, life honorary, and honorary members will be entitled to receive a copy of the Pre-Convention Report and Annual Proceedings.

Article IV - Officers

Section 1 - Elective Officers of the Association shall be President, First Vice President, Second Vice President and Third Vice President. There will be one Regional Executive for each technical committee. Each officer will hold office for one year or until successors are elected. In the event an officer leaves active railroad service, he may continue to serve until the end of his term.

Section 2 - Board of Directors: There shall be a Board of Directors composed of the President, Vice Presidents, and all Past Presidents in active official railroad service. In the event a member of the Board of Directors becomes inactive, he may continue to serve until the end of his term of office.

Section 3 - General Executive Committee: There shall be a General Executive Committee, composed of the Board of Directors, the Regional Executives, and the Technical Committee Chairpersons.

Section 4 - Secretary-Treasurer: There shall be a Secretary-Treasurer, appointed by, and holding office at the pleasure of the Board of Directors, who will contact 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 official active railroad service shall automatically become members of the Advisory Board.

Section 8 - The Board of Directors are entrusted with all public relation decisions within LMOA and coordinated associations with confidentiality.

Article VII - Technical Committees

The technical committees will consist of:

Section 1 - A chairperson, appointed by the President and approved by the Board of Directors.

Section 2 - A vice chairperson, selected by the chairperson and approved by the President.

Section 3 - Committee members will be made up of:

A. Representatives of operating railroads and regional transit authorities submitted by their Senior Mechanical and Materials Officers and approved by the President of LMOA.

B. Representatives of locomotive builders designing and manufacturing locomotives in North America.

C. The Fuel and Lube Committee will include members from major oil companies or their subsidiaries as approved by the General Executive Committee.

D. At the discretion of the General Executive Committee, non-railroad personnel may be allowed to participate in committee activities, subject to annual review.

E. All individuals who are on technical committees must be LMOA members in good standing. (See dues and fees, Article 3, Section 5).

Subjects for technical papers will be selected and approved by the General Executive Committee.

Article VIII - Proceedings

The Locomotive Maintenance Officers Association encourages the free interchange of ideas and discussion by all attendees for mutual benefits to the railroad industry. It is understood that the expression of opinion, or statements by attendees in the meeting, and the recording of papers containing the same, shall not be construed as representations or statements ratified by the Association.

Article IX - Rules of Order

The proceedings and business transactions of this Association shall be governed by Roberts Rules of Order, except as otherwise herein provided.

Article X - Amendments

The Constitution may be amended by a two-thirds vote of the active members present at the Annual Meeting.

Article XI - The Constitution and By-Laws have been amended at the Annual Convention on September 19, 1988.

DIESEL MECHANICAL MAINTENANCE COMMITTEE FIFTEEN YEAR INDEX

1995

1. General Electric New 7HDL 6000 HP Diesel Engine
2. LMOA Best Practices Series - Low Oil Pressure Troubleshooting 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 Comparison
4. Between Regionals and Class I Railroads.
   Amtrak Document Management.

1993

1. EMD's Three-Axle Radial Steering Truck
2. The Natural Gas Locomotive at BN RR
3. Locomotive Waste Oil Retention
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 Locomotives 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 Remanufactured Locomotives.
2. The EMD 710G3A Engine
3. Improving Performance of Traction Motor Friction Suspension 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 Requirments: EMD, GE and Bombardier.

1984

1. Mechanical Aspects of New Locomotive Designs.
2. Maintenance of Locomotive Components.

1983

1. Leaks: Cooling Water, Lube Oil, Fuel Oil and Air.
2. Torquing Recommendations.
3. Update on Fuel Efficient Locomotives.
4. Radiator Screens
5. Alternate Starter Systems

1982

1. Fuel Conservation - Effects on Maintenance.
2. Fuel Conservation - What It Costs.
3. Diesel Fuel Receipt and Disbursement.
4 Turbochargers.

1981

1. Running Gear.
2. Filtration.
3. FRA Rules.
4. Follow-up on Previous Topics.

DIESEL MATERIAL CONTROL COMMITTEE
FIFTEEN YEAR INDEX

1995

1. Warranty and Reliability Management
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 Distribution 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 Feedback.
3. Paperless Requisitions.
4. A Practical Application of Bar Coding in the Railroad Industry.

1987

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

1986

1. The In-House Electronic Requisiton System.
2. Electronic Data Interchange.
3. RAILING and Electronic Purchasing.
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. Forcasting 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 Productivity Through Computerized Data.
2. Inbound Material Inspection.
3. Minimize Maintenance Cost Through Material Management Systems.
4. New Ideas In Material Storage Containers.

1982

1. Use of kits in locomotive maintenance.
2. Cost effective methods of shipping material from vendors.
3. Union Pacific's Component Inventory Maintenance System (CIMS).
4. Advantages of using shipping containers.

1981

1. Disposal of Unserviceable Component Parts: What is the Most Profitable Method?
2. Innovations in Stores Material Handling, Via Computer Technology.
3. Locomotive Held for Material: an Update for the 80's.
4. The Best Approach to Procuring Material; New, UTEX, Repair and Return or Shop Repair.

SHOP EQUIPMENT COMMITTEE
FIFTEEN YEAR INDEX

1995
1. Pre-Maintenance Inspection
2. Railroad Turntable Modification
3. Mobile Locomotive Service Vehicle

1994
1. Electronic Fuel/Unit Injection Tooling.
2. Locomotive Roller Support Bearing Tooling.
3. Fall Protection and Man Lifts.
4. Locomotive Washing Systems.

1993
1. Dynamic Balancing for GE Dash 8 Model Locomotives
2. Air Compressor Automated Station
3. Ergonomics in the Work Place
4. Hydraulic Traction Motor Shimming Table

1992
1. Automated Test and Production Equipment
2. Safety Corrective Action Team
3. Automated Locomotive Wheel Shop
4. Cleaning and Surface Preparation with Sodium Bicarbonate Based Abrasive Blasting
5. Trainline Continuity Tester
6. BN - Railroad Power Assembly Shop of the 1990's.

1991
1. Economic Separation of Emulsified Oil from Waste Water Using Ultra Filtration Membranes.
2. EMD Cylinder Head Valve Seat Machining.
3. Automated Barring Over Machine for EMD Diesel Engines.
4. New Equipment for Testing EMD Engine Protectors.
5. Compressed Air for Railroad Facilities Issues and Solutions to Achieve Clean, Dry, Oil Free Air.

1990
1. EMD Valve Bridge Machine
2. GE Traction Motor Roller Suspension Bearing Replacement Equipment and Procedure.
3. Locomotive Component Replacement Forklift Attachment.
4. Locomotive Sanding, Fueling and Drop Tables.
5. Hazardous Waste Disposal.

1989
1. Automated Locomotive Wheel Shop.
2. Laser Guided Material Handling Vehicles.
3. Bulk Rail Lubrication Storage & Fill System.
4. Pilot Plate Straightening Equipment.

1988
1. Fuel Management Control Systems.
2. Locomotive Mounted Rail Lubrication Fill Systems.
3. Comparison of Shop Air Compressors.
4. Locomotive Toilet Servicing Equipment.
5. Innovations in Blue Flag and Derail Protection.

1987
1. Modern Servicing Facility for Improved Reliability and Availability.
2. New Developments in GE Tools.
3. Implementation of a Quality Process.
4. A Quality Traction Motor Shop.
5. Wheel Truing Machine Technology.

1986

1. Robotics Update 1986 - Now What?
2. CNC Machine Tools.
3. A New GE Power Assembly Area.
4. Locomotive Wash System - 1986.

1985

1. Computer-Assisted Preventative Maintenance.
2. New Tools for Material Handling and Overview of Balancing Technology.
3. Effect of Governmental Regulations on Locomotive Finishing.

1984

1. Shop Tools.
   A. New Tools.
   B. Shop-Made Tools.
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 equipment.

1981

1. Training Aids.
2. Testing Devices Inspired by New FRA Laws.
3. Tools and Training for Productivity.
4. Changes to Shop Facilities Required by Newly Adopted EPA & OSHA Regulations.
5. Tour Through Conrail Altoona Shop.
6. Supply/Service Facilities.
7. GE Assembly Shop.

DIESEL ELECTRICAL MAINTENANCE COMMITTEE FIFTEEN YEAR INDEX

1995

1. Canadian National Battery Water Usage
2. Remote Diagnostics-Radio Download
3. Programmed Preventive Maintenance
4. Commutation Monitoring in Locomotive DC Traction Motors
5. The EMD Diesel Engine Control (EMDEC) System

1994

1. Safety First - Video on Electrical Safety.
2. Locomotive Health Monitoring Systems.
3. Event Recorder Update.
4. SD60 Dynamic Brake Improvements

1993

1. Automatic Engine Shutdown and Restart System
2. Layover Systems/Standby Power Systems
3. CN North America - Electronic Temperature Control
4. Speed Sensing Devices
5. Adhesion Alternative
6. Modern Tooling Update

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 Loocmotives
5. Flange Lubricators

1991

1. Locomotive Rebuilding - Something Old - Something New.
2. Standardization of Electrical Equipment.
3. Locomotive Batteries
   a. Storage Handling Procedures.
   b. Recommended Maintenance Procedures.
   c. Recommended Repair Procedures.
4. Amtrak's AC Traction Locomotives.
5. Modern Tooling for Electricians

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

1983

1. Ground Relay Trouble Shooting.
2. Specification for remanufactured D87 Traction Motor Frames (Using D-77 Armature Coils)
3. Locomotive Storage (Electrical).
4. Water Cooling and Refrigerating Methods for Locomotive Cab Application

1982

1. Tests on Traction Motors.
2. Transition Trouble-Shooting.
3. Onboard Diagnostic Systems.
4. Starting Systems.

1981

1. Evaluation of Improved Test Methods.
2. Teflon Bands.
3. New Generation Locomotives.
4. Electrical Troubleshooting.
5. Batteries and Charging Systems.
6. Troubleshooting EMD AC Auxiliary Generator System.
7. Selection of Locomotives for Major Locomotive Overhauls.

NEW DEVELOPMENTS COMMITTEE
FIFTEEN YEAR INDEX

1995
1. Beltpack Locomotive Control System
2. The MK1200G Switching Locomotive
3. Advanced Traction Motor Testing

1994
1. Electronic Fuel Injection Systems.
2. Status of Distributed Power in Freight Trains.
3. Advances in Distributed Power-Iron Highway..

1993
1. New Technology to Solve Old Problems
2. Developments in Off-Shore Technology
3. Updates on AC Traction Developments

1992
1. Talking to the "Smart' Locomotive
2. Cab Noise Abatement
3. Electronic Management of Locomotive Drawings
4. Update on High Productivity Integral trains
5. AC Traction - A New Development

1991
1. Locomotive Cab Integration and Accessory Management
2. Improvements in Locomotive Adhesion Performance.
3. The Role of Duty cycles in Locomotive Fuel Consumption.
4. What's New in Gadgets and Black Boxes: What do our Locomotives Really Need?
5. Failure Analysis

1990
1. Motor Driven Air Compressors for Diesel-Electric Locomotives
2. Locomotive Cab (HVAC) Heating, Ventilation and Air Conditioning Systems.
3. Effect of Technology on Standardization of Cab Control Equipment.
4. Locomotive Durability, Reliability and Availability - Understanding Your Abilities.

1989
1. A Rational Approach to Testing Locomotive Components.
2. New Developments in Locomotive Cab Design.

1988
1. Amtrak F69 PH AC Passenger Locomotives
2. New Component Developments Retrofittable to Older Model Locomotives
3. Locomotive Applications of Catepillar Engines.
4. Wheelslip Control for Individual Axles.

1987
1. Electronic Fuel Injection Systems.
2. Update on Electronic Governors.
3. Recent Advances in Steerable Locomotive Trucks - the E.M.D. 4 Axle, 4 Motor HT-BB Articulated Truck.
4. Converting an F40 Locomotive to A.C. Traction.

1986
1. Future Train Control Systems.
2. Bringing Future Train Control Systems Back to Earth.
3. Low Maintenance Locomotive Batteries.
4. Electronic Engine Control Systems.

1985
1. The Sprague Clutch for E.M.D. Turbocharged Engines.
2. A.C. Traction Locomotives Update.
3. Natural Gas Locomotive Update.
4. Ceramic Coated Engine Components.
5. Locomotive Cab Developments.

1984
1. G.E. Dash 8 Locomotives.
2. E.M.D. 50A Series Locomotives.
3. Natural Gas Locomotives.
4. Appraisal of the A.C. Traction Locomotive.

1983
1. Microprocessors for Locomotive Control and Self Diagnosis.
2. Locomotive Fuel Tank Gauges.
3. Locomotive Aerodynamics
4. Bombardier HR 616 Locomotive.
5. Missouri Pacific - Phase III Locomotive Heavy Repair Facility, N. Little Rock, Arkansas.

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE FIFTEEN YEAR INDEX

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE FIFTEEN YEAR INDEX

1985

1. Disposal of Lube Oil Drainings.
2. Non-ASTM No. 2 - D Fuel.
3. Oxidation Analysis.
4. Wheel Flange and Rail Lubrication.

1984

1. Locomotive Filters
2. Traction Motor Gear Lube Field Test.

1983

1. Field Test Update of Mulitgrade Oils.
2. Update of Alternate Fuel Testing.
3. A Review of Locomotive Fuels.

1982

1. Energy Conserving Lube Oils.
2. Alternative Fuels Update.
3. Availability of Medium and High Viscosity Index Railroad Oils.
4. Journal Box Oil and Aniline Point.
5. Traction Motor Gear Lubricant Update.
6. Traction Motor Gear Case Seals.

1981

1. Effects of Using Alternate Fuels on Existing Diesel Engines.
2. Update on Cold Weather Procedures for Fuels.
3. New Techniques in Lube Oil Analysis.
4. Traction Motor Gear Lubrication.
5. Multi-Viscosity Oils as an Energy Conservation Technique.

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