LMOA

Locomotive Maintenance Officers Association

Proceedings of the 59th Annual Meeting
Chicago, September 15-17, 1997

1997 ADVERTISERS INDEX

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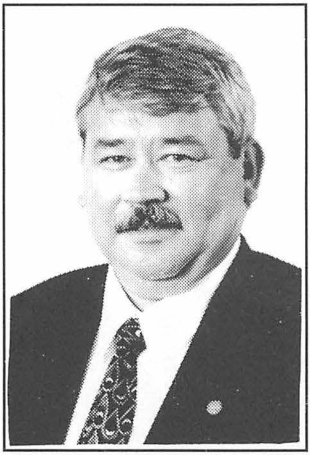

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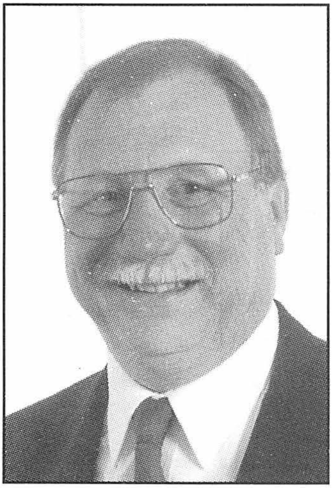

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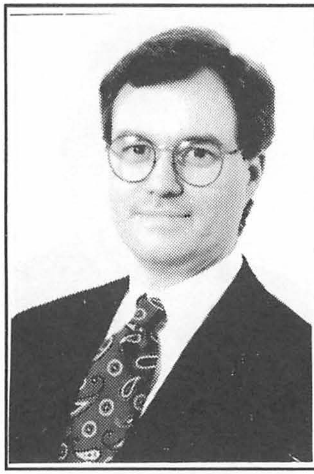

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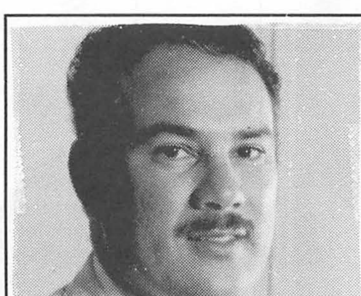

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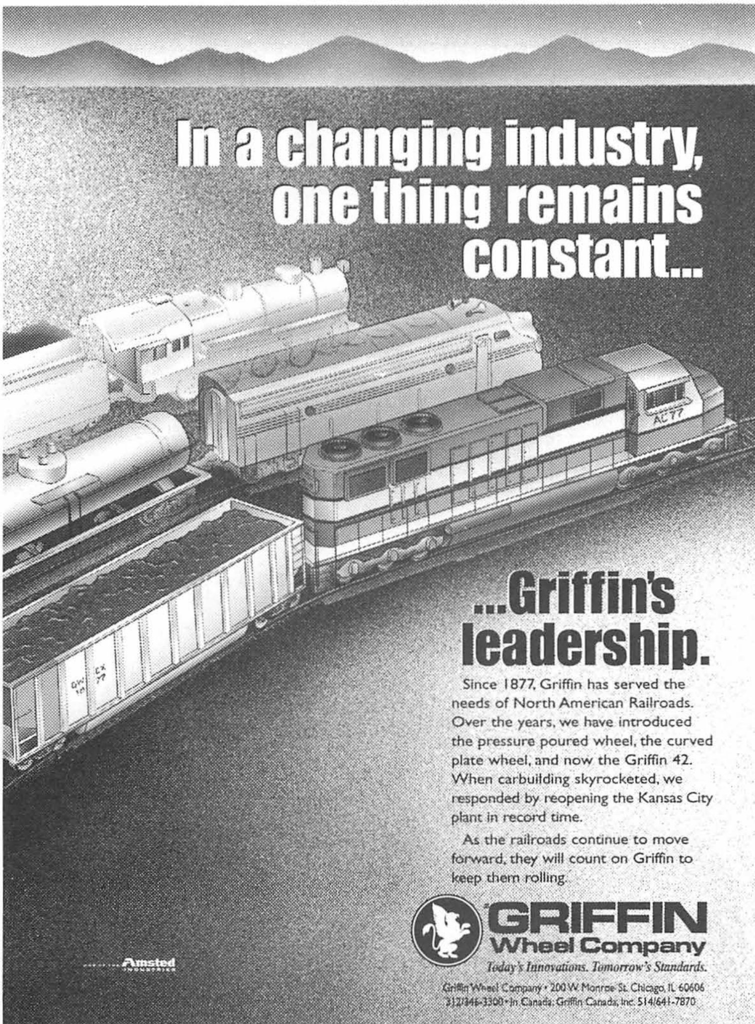
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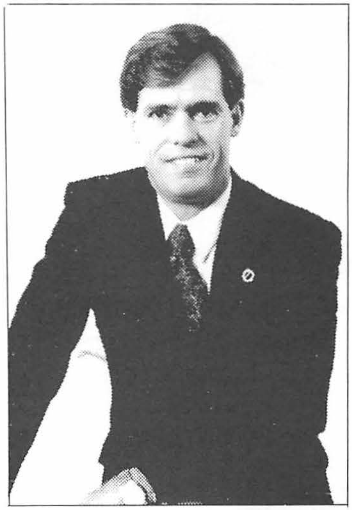

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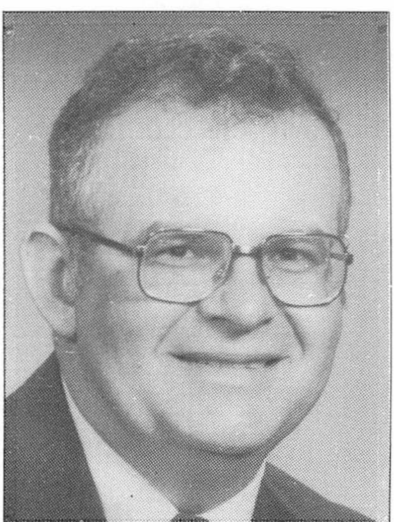

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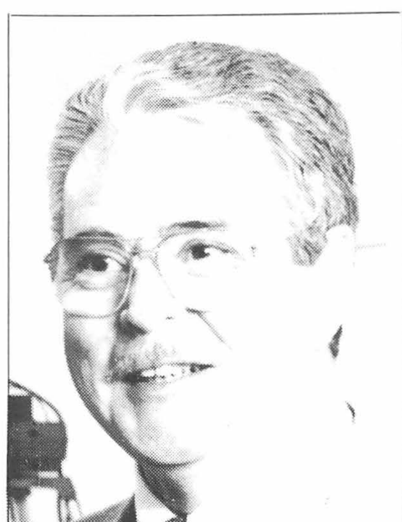

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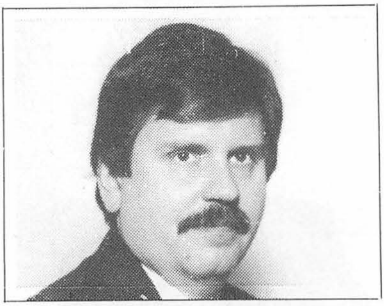

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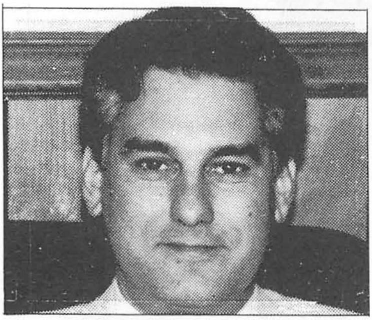

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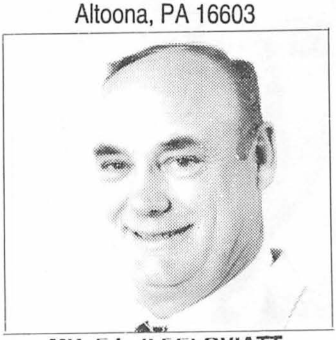
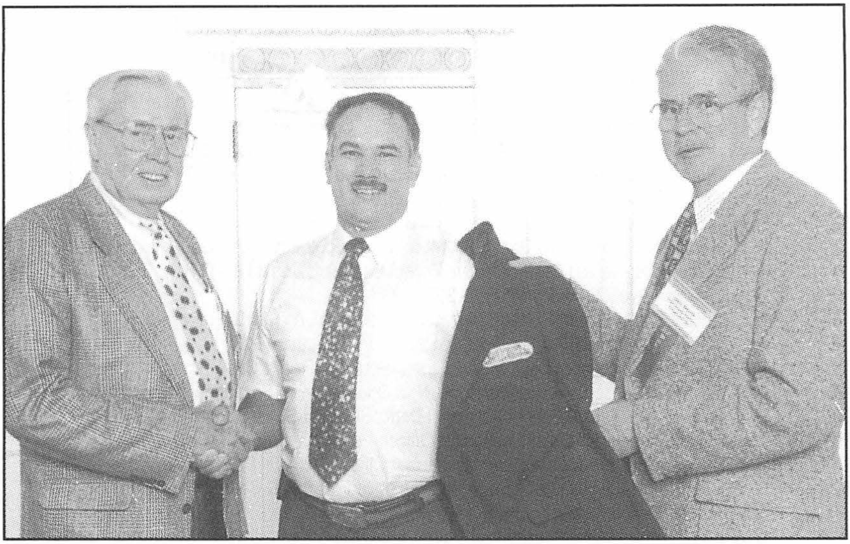


MR. E.L. (LEE) OVIATT
Manager-Loco. Maint.
DM& IR Rwy.
Proctor, MN
(early retirement on 7/29/97)

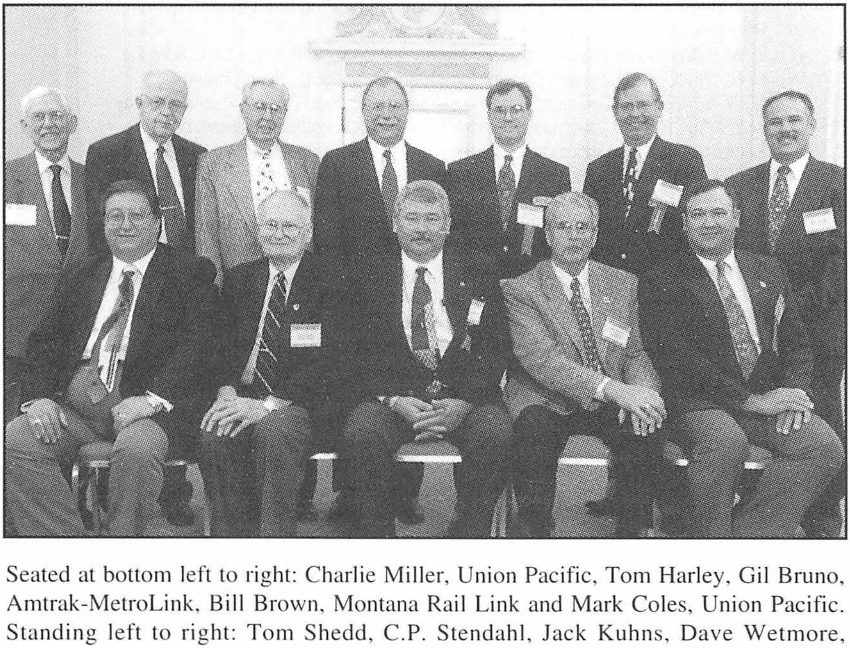
MR. ROBERT RUNYON
Engineer-Loco. Design
Norfolk Southern Corp.
Roanoke, VA 24042

Past President Mark Coles, Union Pacific, presents Past President's Pin to outgoing President Gil Bruno, Amtrak-MetroLink, which was witnessed by newly elected President Dave Wetmore (r), formerly of CSX now with Amtrak.

Chairman of the Board Charlie Miller, Union Pacific, presents General Desk Set to outgoing President Gil Bruno, Amtrak-MetroLink, as newly elected 1st Vice president, Mike Pennell (r), Ellcon National looks on.



Past President Bill Brown, Montana Rail Link, assists newly elected 3rd Vice President Jake Vasquez, GWI Switching Services with his LMOA blazer. Honorary Member Jack Kuhns (l) was in attendance.



Seated at bottom left to right: Charlie Miller, Union Pacific, Tom Harley, Gil Bruno, Amtrak-MetroLink, Bill Brown, Montana Rail Link and Mark Coles, Union Pacific. Standing left to right: Tom Shedd, C.P. Stendahl, Jack Kuhns, Dave Wetmore, Amtrak, Doug Corbin, Norfolk Southern, Mike Pennell, Ellcon National, Jake Vasquez, GWI Switching Services.

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1960 - W. E. LEHR (Deceased) Chief Mechanical Officer, Pennsylvania R.R.
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1962 - R. E. HARRISON (Deceased) Manager-Maintenance Planning & Control, Southern Pacific Co.
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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
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1970 - G. R. WEAVER (Deceased) Director Equipment Engineering, Penn Central Co.,
1971 - G. W. NEIMEYER (Deceased) Mechanical Superintendent, Texas & Pacific Railway
1972 - K. Y. PRUCHNICKI (Deceased) General Supervisor Locomotive Maintenance, Southern Pacific Transportation Company
1973 - W. F. DADD, (Deceased) Chief Mechanical Officer, Chessie System
1974 - C. P. STENDAHL, Retired General manager M.P.-Electrical, Burlington Northern Railroad, 1052 W. California Ave., St. Paul, MN 55117
1975 - L. H. BOOTH, Retired Assistant C.M.O.-Locomotive, Chessie System, 906-13th Ave., Huntington, W.V. 25701
1976 - J. D. SCHROEDER, Retired Assistant C.M.O.-Locomotive Burlington Northern, Railroad, 244 Carrie Drive, Grass Valley, CA 95942
1977 - T. A. TENNYSON (Deceased) Asst. Manager Engineering-Technical, Southern Pacific Transportation Co.
1978 - E. E. DENT, (Deceased) Superintendent Motive Power, Missouri Pacific Railroad,
1979 - E. T. HARLEY, Retired Senior Vice President Equipment, Trailer Train Company, 289 Belmont Road, King of Prussia, PA 19406
1980 - J. H. LONG, Retired Manager Locomotive Dept., Chessie System 5454 Cleander Drive, Cincinnati, OH 45238
1981 - R. G. CLEVENGER, Retired General Electrical Foreman, Atichison, Topeka & Sante Fe Rwy.
1982 - N.A. BUSKEY (Deceased) Asst. General Manager-Locomotive, Chessie System
1983 - F. D. BRUNER (Deceased) Asst. Chief Mechanical Officer-R. & D. Union Pacific Railroad
1984 - R. R. HOLMES, Retired Director Chemical Labs and Environment, Union Pacific
1985 - D. M. WALKER, Asst. Shop Manager, Norfolk Southern Corp., 793 Windsor St., Atlanta, GA 30315

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1988 - D.G. GOEHRING, Retired, Supt. Loco. Maint., National RR Passenger Corp., 1408 Monroe, Lewisburg, PA 17837
1989 - WILLIAM A. BROWN Mgr., Loco. Projects, Montana Rail Link, Silvis, IL
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. Regional Process & Quality Union Pacific RR, 6400 Martin Ave.-Bldg. B, Kansas City, MO 64120
1994 - M.A. COLES, Senior Mgr.-Loco. Engineering & Quality, Union Pacific R.R. 1416 Dodge St., Omaha, NE 68179
1995 - C.A.MILLER, Mgr.-Loco. Engineering & Quality, Union Pacific RR. 1416 Dodge St., Omaha, NE 68179
1996 - G.J. BRUNO, Dir.-Equipment Maint, Amtrak-MetroLink, 1555 San Fernando Rd.-Rm. 215 Los Angeles, CA 90065

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Address of President Gilbert J. Bruno

September 16, 1996

Welcome, ladies and gentlemen, to the Monday afternoon session of the Locomotive Maintenance Officers Association. I would also like to extend a special welcome to all LMOA members, RSA members, visitors from foreign countries, railroad mechanical officers and guests. 1996 marks the 58th year for the LMOA. As you know, this is also an exhibit year and promises to be one of the best ever.

Serving as your president for 1996 has been a milestone in my career and I have found it to be a very fulfilling experience. As I was going through the proceedings of past years trying to write a speech for today, I was really going to try to plagiarize the speeches of my predecessors, I found a common thread in each of their themes. And that common thread is change. It was something that was talked about in 1984 when I first became affiliated with the LMOA and it is something I am going to talk about today.

It has been my experience over the years that one thing that is constant in this world and that is change. And the railroad industry is no different. There has been change in the railroads physical makeup with mergers, change in personnel due to buyouts, retirements and job reductions, and a change in technology, which is probably most important to us all.

The responsibility of the modern day maintenance officer is to cope with these changes in order to keep his competitive edge. This is where the LMOA has demonstrated its value in a modern day maintenance environment. Members of LMOA are able to stay on the crest of the wave of change rather than fall off into backwater. Our six technical committees have brought us a wealth of information and knowledge that has enabled us to keep up with all the technical advances over the years; and for that we are deeply indebted. This is because the most valuable asset the LMOA has is the professionalism and dedication and willingness of its committee members to share and exchange information and also the invaluable support of the general membership and our RSA supporters.

It is a challenge for us today not to fear or dread change because it is as inevitable as death and taxes. Therefore, we should embrace it; again to stay on the crest of the wave of change because unless you're the lead dog, the scenery doesn't change very much.

As you know, the major builders are developing bigger and more powerful locomotives and they are computer controlled, self-monitoring, and require very little maintenance as compared to previous generations of locomotives. Therefore, we should seize the opportunity to incorporate these technological changes into our every day maintenance practices.

This is also an election year and there has been a lot of talk of building bridges to the 21st century. I submit to you that that bridge is a trestle, and that the nation's railroads, including Amtrak, will take America across that trestle into the next millennium, with steel wheels on steel rails. But (at the same time) we must not dismantle our trestles to the past, for a wise man once said that he who forgets history is doomed to repeat it. This is especially true in light of the mergers that have taken place this past year. And of course we all remember past attempts at merging that have failed miserably for one reason or another.

In the last 10 years, short line and regional railroads have sprung up across this nation like wildflowers on the prairie. The LMOA must reach out to these regional railroads and offer them the benefit of our years of knowledge and experience. Our archives are packed with a host of pertinent topics that are applicable to older locomotives that make up the general fleet of the regional railroads. In this the regional railroads can be well served by LMOA.

When it comes to change, the LMOA must also conform or adjust to our ever-changing environment. Over the years we have lost some good leaders from our ranks. This is partly due to our restrictive by-laws. The Executive Committee believes that once a elected officer severs his railroad affiliation, we should not be deprived of his experience and knowledge. Therefore we will be placing before the membership a proposal to revise Article 4, Section 1 of the existing by-laws. It is in this way that we can preserve our trestles to the past while we continue to build our trestles to the future. Thank you.

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

MONDAY, SEPTEMBER 15,1997 1:45 P.M.

Pre-Convention Presentation Southern & Southwestern Rwy. Association

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

July 11, 1997
Ponte Vedra, Inn
Ponte Vedra, FL

Vice Chairman
LES WHITE
Electrical Specialist
CN Rwy.
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T. Fitzgerald	Electrical Foreman	Illinois Central	Homewood, IL
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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.

The Diesel Electrical Committee wishes to thank the Southern & Southwestern Rwy. Assn. for hosting their Pre-Convention Presentation in Ponte Vedra, Florida on July 11, 1997.

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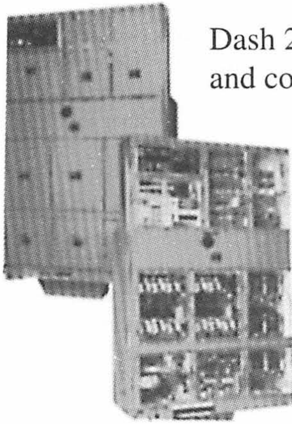

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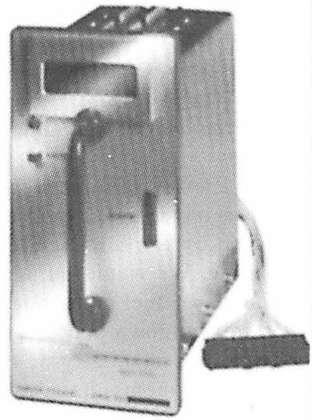

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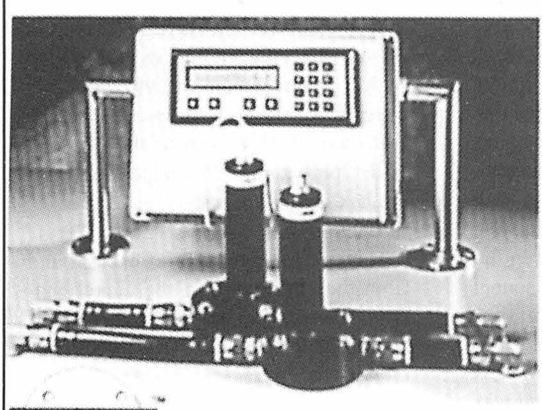

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I. REVIEW OF BATTERY MAINTENANCE AND AVAILABLE OPTIONS

Presented by
Les White,
Canadian National Railway

This is a review of some of the previous papers on diesel locomotive batteries given by the Diesel Electrical Committee. We would all agree that the coming of fuel conservation and increased shut down policies, whether accomplished manually or through automated systems, have impacted both short line and Class I roads in the maintenance and use of batteries. Both of these developments affect the bottom line, one in labor and the other in material costs, not to mention the high cost of an on-line failure where a locomotive fails to restart due to poor batteries.

The Committee hopes that the review of these previous presentations will give you a reference that can be used when addressing problems in your particular operations, and ultimately save you time. These presentations have all been published in the LMOA books issued to members. It is recognized that not everyone has access to these books and to make information more accessible the LMOA is establishing a web site that will contain these books. We hope that this will be completed in the near future as this will give personnel an excellent source of information when looking for reference literature.

The first paper we will review was entitled **Locomotive Batteries** and was presented by Mr. John Nixon in 1991. The three main areas addressed by this paper were:

1) Storage Handling Procedures

This section itemized the two different types of storage that can be done, DRY and WET. The preferred method for the railroad industry is wet, and some tips of what to do and watch for were given.

2) Recommended Maintenance Procedures

The recommended maintenance procedures were split into two parts, one detailing the minimum battery procedures for locomotive batteries on a 92 day inspection, and the other the minimum required for a 12 month inspection.

3) Recommended Repair Procedures

This section stressed the importance of a repair specification and gave the committees recommendations for a thorough repair specification. In addition, stages of qualifying for repair and ready for service were given.

This paper was concise and addressed the key areas that should be followed to retain a good battery life. In short, an excellent source of reference to review to double check your established procedures or to set up new procedures.

The second paper we will review was entitled **Nickel-Cadmium Batteries As An Alternative** and was presented by Mr. Mauro Pasini in 1992. Mauro's paper was very interesting as it showed that there is an option to the old lead acid type battery. This paper was split into six main sections:

1) Background

This section gave a brief background from the conception of the nickel cadmium battery in 1901 to the use of this type of battery in starting a diesel locomotive.

2) Battery Design and Types

Battery design and types basically covered the processes in the battery and the different types of casings available. Clear plastic was the preferred for viewing the electrolyte level.

3) Battery Characteristics

This is probably the single most important section as it details the main characteristics of the modern vented Ni-Cad battery and is worth repeating. The Ni-Cad battery characteristics are as follows:

- very good discharge performance at high rate
- high performance at low temperatures
- important weight and volume reduction compared with other batteries (30 to 50%)
- low maintenance requirements
- no electrolyte freezing even at very low temperatures
- no toxic or corrosive fumes and gases
- very long storage whatever the state of charge
- about 35% of maximum breakaway performance with battery half discharged
- no memory effect

4) Maintenance

The maintenance section details the periodic maintenance that is required on these batteries and the suggested work that should be done at a periodic overhaul.

5) Lifetime

This section basically predicts up to a 20 year life for these batteries based on laboratory tests, such as the "life test" specified by the International Union of Railways (leaflet 854 R). There are three main areas to watch in order to obtain this life expectancy; they are battery size, battery boxes and maintenance practices.

6) Economics

This is the section that sends a cold chill up a CMO's spine, as the price of these batteries is approximately 4 times that of its lead acid counterpart.

It is safe to say the jury is still out on this one because of the initial cost and predicted life expectancy. However, we did check with Via Rail on the status of its test and was informed that it now has all its FPH40-2 Locomotives equipped; they are performing very well. It is critical in Via's operation that the batteries be in good condition as the majority of its trains run with a single locomotive. The key questions we must ask ourselves are:

- What is the cost of an on line failure due to poor batteries?
- Will these batteries last 20 years and can we afford to wait to find out?

Once we start asking ourselves questions like these and with the distinct characteristic benefits of these batteries, more of us may become interested in using them.

The final paper we will review was entitled **Canadian National Battery Water Usage** and was presented by Les White in 1995. This paper opened by explaining that the new 180-day periodic inspection implemented by CN was the driving force that caused the need to review this particular problem. The three main areas addressed by this paper were:

1) Review And Examine Internal Battery Design

This section demonstrated that by simply examining different suppliers' battery design it is possible to get a 54% increase in the water reserve above the plates.

2) Review And Examine Add-On Options

Two optional add-on items were presented. One was irrigation systems and the other was a catalyst battery cap that replaces the regular battery cap. The tests conducted at CN showed that by using the aforementioned battery with a 54% water reserve above the plates and the catalyst battery cap, an overall improvement of 94% is achievable.

3) Review And Check Voltage

Regulation

This section showed how minor voltage variations in battery charging rates can dramatically effect the gassing of the batteries and stressed the importance of setting voltage regulators correctly.

In conclusion the Committee hopes the review of these presentations demonstrates our commitment to best practices, detailing available options and ultimately giving Class I and short lines a quick source of reference.

II.BATTERY CHARGER/BOOSTER

Presented by
Ronald Lebold, CSXT

Background

CSXT has an average fleet size of 2750 locomotives. In 1993 we had experienced over 1400 dead battery incidents, many of which resulted in train delays or unnecessary substitution of power. Although there are many causes for a battery to become discharged to the point where the locomotive cannot be started, a disproportionate number of them occurred within a short period after a locomotive's quarterly maintenance.

CSXT has inspection shops (92-day and 122-day) at Waycross, GA, Corbin, KY and Cumberland, MD. Our practice is to "jog" the locomotives through the shop utilizing the locomotive battery. At the last Q-shop work station, the unit is started and placed in a ready status for assignment to a train. Fuel conservation procedures required that a unit not scheduled for service within a half hour be shut down, hence many units were being released from the shops with their battery capacities lower than desired to sustain now more frequent engine shutdown/startup requirements. Batteries can be charged, but locomotive starting extracts a portion that requires more than a half hour of running in idle can replace.

We were made aware of a piece of equipment made by Transtronic, Inc., Quebec, that CN was using in its shop for both charging batteries and providing a "boost" when starting. The combination charger/booster is designed to charge the battery at a fixed current rate when connected and, when the locomotive starting sequence is initiated, provide a "'boost' to supplement battery starting current and preserve a large portion of battery capacity that would have normally been used in the starting process.

We contacted Transtronic, and we developed a charger/booster model similar to CN's but suitable for CSXT's operations to be used in our quarterly maintenance shops. It was to be used at the last station in each Q-shop to: 1) charge the batteries at a 100 ampere rate while other services are being performed on the locomotive at that station; and, 2) provide a 600 amp boost automatically when the locomotive is started. After an initial prototype test period at one of our shops, some minor changes (to suit our operating environment) were made, and three additional units were purchased and in use in our three Q-shops and one heavy shop. Since implementation, dead battery incidents occurring within 10 days of regular maintenance periods performed at shops using the charger/booster as intended have dropped 40%.

The booster/charger for CSXT was designed to operate on utility power of 440VAC-3 phase, 60Hz. It provides an output of 100 amps in charge mode of 12 to 74Vdc, and 600 amps in boost mode from 12 to 60Vdc.

Description of Operation
(reference figures 1 and 2)

Charging Mode

When connected to 3-phase 440VAC (*) source and closing the main breaker (MB) the "DEFAULT" indicator lights up until the charger/booster output is connected to the locomotive battery. The unit is self-protected against incorrect battery connections and short circuits. The default indicator stays on until the minimum voltage condition with correct polarity is satisfied. Output voltage and current will not be

supplied until these conditions are met. Charging is not allowed until polarity is correct, and boost mode is not allowed until the battery meets the minimum voltage requirement.
(*) 120/220-240VAC option also available

Boosting Mode

When the "DEFAULT" indicator turns off, charging mode is initiated by pushing the "START" indicator push button. If the locomotive battery is less then 60Vdc, the indicator flashes indicating that the "BOOST" mode is prohibited, and the charging mode is in process. When the battery reaches the minimum of 60Vdc, the "START" indicator stops flashing and remains lit indicating a "ready to boost" status. Three tries, each less than 20 seconds, or one try of more than 20 seconds are allowed, after which a 150 second recover interval is imposed.

Summary

In summary, the charger/booster has contributed to reducing the number of dead battery incidents on the fleet, especially those occurring upon recent release from a shop. It is easy and safe to use for the operator. There is no possibility of connecting it in the wrong polarity, and there is short circuit protection. The charger/booster also has the flexibility of being used in either mode (charging or starting battery boost) independently, depending on need.

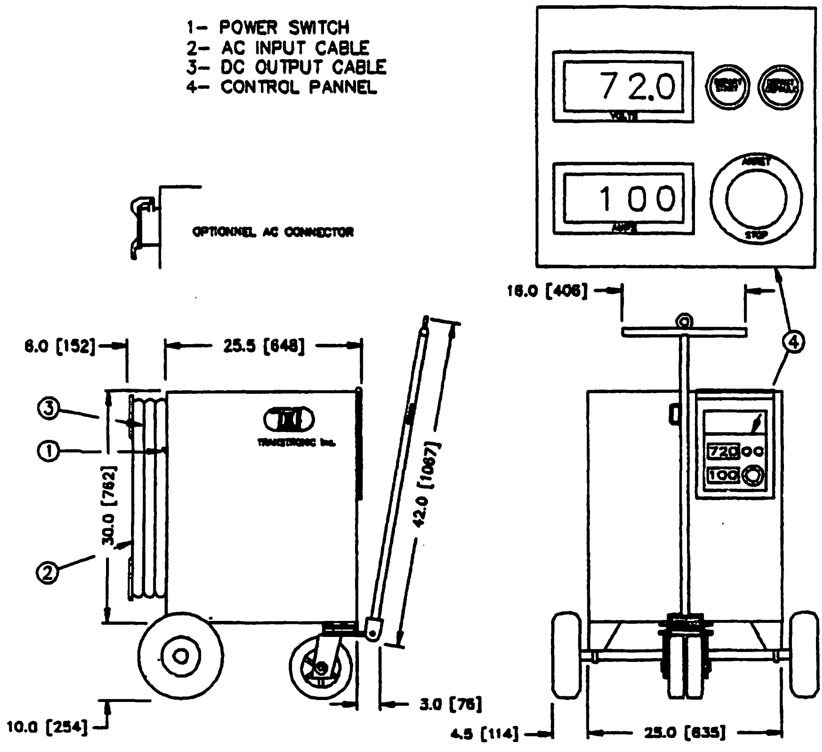


Figure 1 - Mechanical Diagram

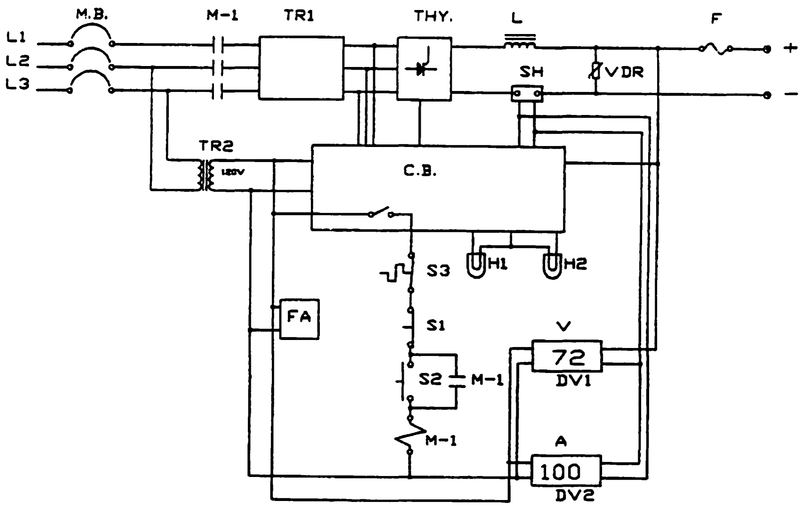


Figure 2 - Electrical Schematic

Electrical Schematic Legend (reference figure 2)

L: Safety Coil

SH: Current Shunt

VDR: M.O.V. for output voltage protection

C.B.: Control board

F.A.: Cooling Fan

S1: Emergency stop button

S2: Start button, (with H2 lighting feature)

S3: Thermal breaker (connected on the thyristor's' radiator)

H1: Default lamp

H2: Dual modes lamp: flickering = on charge
continuous - ready for "boosting"

DV1: Output voltage indicator

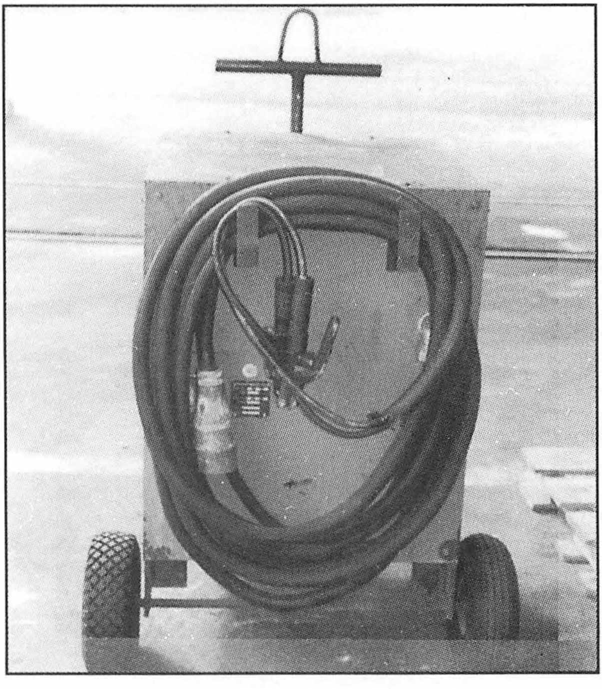
DV2: Output current digital indicator

F: DC output fuse

Photos:

Front view showing controls -

Rear view showing 440VAC connector and locomotive connection cables -



III. LOCOMOTIVE SYSTEM INTEGRATION

Prepared by
Sam Anoo, Union Pacific

Introduction

As electronic devices have become cheaper and more powerful, they have replaced electro-mechanical and mechanical systems on locomotives. The number of electronic devices on locomotives increased at a blistering pace, providing more capabilities in the late 1980's and early 1990's. The proliferation of electronic devices increased the necessity for more resources on the railroads. So did the confusion as to who was responsible for interfacing two devices when it was required. Further, the numerous devices were not interchangeable, were incompatible, were incapable of accommodating technology changes and were fostering monopolies by manufacturers. Concern regarding this unmanageable growth necessitated a standard for the future that would integrate the various devices.

In last 1989, the AAR Mechanical Division General Committee formed a task force to "develop a practical approach towards the integration of electronic components on new locomotives". The task was to provide a standard electrical, logical and physical interface for all third-party electronic components, such as the electronic airbrake, cab signals, distributed power and end-of-train devices. As the project progressed, a task to define the content and format of the operating display was added. This project was called the Locomotive System Integration, or LSI, project.

The railroads were motivated by several issues. First, as stated earlier, there was a need to rationalize the proliferation of electronic components in the cab. Second, an approach like LSI would reduce maintenance costs. Third, the use of cab electronics in general would reduce the cost of some operational tests, like the initial terminal road train air brake tests. Fourth, LSI would reduce the cost of electronic components by up to 30% through the form, fit, function approach. Fifth, LSI would allow for easy addition of other boxes provided for functions like the dynamic AEI tag and intra-train communications.

This paper focuses on the philosophy behind LSI; its specified components, and its benefits and opportunities.

Background

The basic philosophy was to produce a standard to provide significant value added to the cab electronics. The development of standards was to address a variety of concerns including:

• Interoperability - defined as the capability of operating seamlessly from railroad to railroad. This requirement was applied to the minimum set of functions for the display screen.

• Interchangeability - defined as the ability to replace components. This, along with interoperability, provides "plug and play". This requirement was applied to most of the third-party boxes in the architecture.

• Accommodating technology changes - defined as the ability to add features or functions easily. The architecture was designed around this capability to reduce "the proliferation of electronic devices" in the cab.

• Competition - defined as the ability of the system to provide for non-proprietary devices, increasing the supplier market.

Functional Components

Figure 1 shows the configuration of the architecture chosen. LSI uses a 19,200 baud rate packet switch network. The communications protocol is HDLC, and the physical connections to/from the packet switch are RS422. The communications protocol follows the Open Systems Interconnect 7 layer model. The packet switch star local area network was chosen after considering a variety of data bus architectures. Alternate data bases and LAN systems were considered but were rejected because of poor performance, or because the application was inappropriate. Some components of the LSI architecture are:

1. Integral Locomotive Computer (ILC): The ILC is supplied by the original equipment manufacturers (OEM) as the central processor for the system architecture. The ILC is the link between the other systems on the locomotive, which ILC also acts as a message router and protocol converter. The ILC is not interchangeable and has several required and option functions/devices incorporated. Among those devices are the displays, slow speed controller, flange lubricator, core and auxiliary packet switches and the alerter/recorder. The ILC is a fast packet switch that must be capable of processing at least 20 packets per second.

2. Operating Display: The operating display is the principal screen used by the engineer in operating the locomotive. Essential information is displayed in a format determined from, input from railroads and suppliers.

3. Vehicle ID unit: The vehicle ID unit provides the locomotive identification number to other LSI components via the core processor. Each LSI component provides its component ID to the core processor.

4. Intelligent Brake Controller: This device is the microprocessor-based air brake controller. When present, it is the only connection between the air brakes and other intelligent devices in the LSI architecture.

5. Core Processor: The core processor is the packet switching device and provides the locomotive configuration (i.e., what devices are connected to the core processor). If any configured device fails to function or communicate, an alarm is sent to the display. The core processor may physically reside within the ILC. The core processor shall have a minimum of 16 synchronous ports.

6. Central Power Supply: The power supply will provide 48 volts conditioned power to the peripheral devices, with the exception of the intelligent brake controller, as shown in Figure 2, Equipment Interfaces. It will filter the noise and voltage spikes from the nominal 74 volt dc input locomotive power.

7. End-of-Train (head end) Unit: The head end portion of the end-of-train unit reports brake pipe pressure, and optionally motion detection, to other system peripherals.

8. Alerter/Recorder Functions: The two functions provided are event recording and operator vigilance. These functions were combined and reside within the ILC. There is an option to have a separate device, but there shall be only one alerter/recorder operating at a time. The event recorder is a data logger for general recording of diagnostic information and for accident information. The alerter monitors engineer activity is detected, and sends a message to the intelligent brake controller if the alarm does not produce an appropriate activity.

9. Cab Signaling unit: The cab signaling unit picks up the track signal and provides the appropriate signal aspect to the operating display. As an option, it may supply a message to apply the brakes for units where the limits of movement authorities are enforced.

10. Slow Speed Controller: This device is designed to control speed of the locomotive in the range of 0.1 to 10 MPH. This function is incorporated into the ILC.

Architecture Features

The architecture has several value added features for the railroads that make it easier for third part suppliers and system integrators to meet the standard. First, the boxes are interchangeable, although the box manufacturers may determine their own internal design configurations. Second, the architecture calls for the boxes to fit in an electrical cabinet designed by the locomotive manufacturer. Third, there is no requirement for forced air cooling, provided the electrical cabinet is properly vented. Fourth, there is a provision for using the display screens for establishing remote sessions to download software to each box.

The LSI specification defined a central power supply. A 48 volt power supply was chosen because it was the highest voltage level for which existing commercial dc-dc converters were available.

The required reliability of the LSI components is shown in Table 1, Minimum reliability Requirements. These design goals provide a mean time between failure level for the critical system components of 25,000 hours.

The LSI cabinet is defined by the locomotive manufacturer. Figure 3 shows a photograph of the cabinet used in EMD locomotive. The cabinet must provide the capability of accepting the boxes built using the Air Transport Racking packaging form. This form factor does not apply to the displays, the brake controller, the ILC or any device incorporated into the ILC.

The packaging form selected is the ARINC specification 600 system. Boxes built to this specification are readily available. With properly designed electrical cabinet, convection alone can cool the sealed LSI boxes. A thermal analysis is included as a part of the architecture specification.

Display Screens

The objective in the development of the operating display specification was to define the minimum set of information and format for specific screen functional areas, and to allow the railroads and suppliers to define the "appearance". The requirement for standardization of the operating display was driven by the increasing interchange of locomotives among railroads.

The display screen format is shown in Figure 4, Display Functional Areas. Figure 5 shows GE and Figure 6 shows EMD operating screens designed using the LSI guidelines. The LSI display screen format identifies "real estate" for displaying brake, speed and acceleration, control settings, alarms, messages and soft key descriptions. Soft keys provide for retrieval of optional information in the space provided. The display is typically an 11" diagonal flat panel.

Two displays are required by the architecture. The second display is called the man-machine interfact (MMI). It is designed to display train control information. In case of a failure of the operating display, the information on the operating display would default to the MMI.

Message Specification

The message specification defines the standard set of messages between the LSI boxes. The messages may either be broadcast or addressed to a specific box. Broadcast messages are the preferred choice because they do not require new software for the existing box when a new box is added, as do specifically addressed messages.

The message specifications are designed to:

- Specify the functions to be performed by the LSI components.
- Specify the pieces of information that must be exchanged between the components.
- Specify the bit patterns to be used to encode the information to be transmitted.
- Specify how the information is to be placed into messages.

The message specification uses PTS (ATCS) messages where possible. This cuts down the quantity of new messages required. As the LSI technology matures, the message specification is the most likely source of change to accommodate new boxes, functions, and applications.

Benefits and Opportunities

Clearly, the railroads are the beneficiaries of the LSI specification. The specification has allowed the railroads to use the OEM's as technical owners for the various devices that are used on the locomotive. This has allowed the railroads to use their scarce resources better. Modifications and product enhancements have been reduced to mere software changes for the most part and freed up railroad labor for maintenance. The development and implementation of the specification has forced open previously strained communication channels amongst the various vendors and the railroads. Vendors have not lost in this deal. They can now manufacture one product to fit both locomotive builders. This will allow them to lower their manufacturing costs. The builders are happy as they have better control over the reliability of the various devices since they are held to high performance standards. All this would not have been possible without the efforts and cooperation of the railroads, builders, vendors and the leadership of AAR.

All new things come with challenges and so have the LSI specifications. The message specification is probably the area that has the most opportunity for improvement. Most of these challenges are driven by railroad operating differences. It is imperative that these differences be resolved in order to create a detailed specification that will allow seamless interchange - the key to the success of the railroad industry. Further, the LSI specification has pushed integration to the forefront. Good integration and integrators have become a necessity for reliability and safety. Laboratory testing and virtual locomotives for testing are becoming increasingly vital for a reliable and safe operating locomotive. LSI has pushed maintenance to a new era, where laptops and semiconductor chips are preferred to wrenches and modules, and where a technician is required in place of a mechanic.

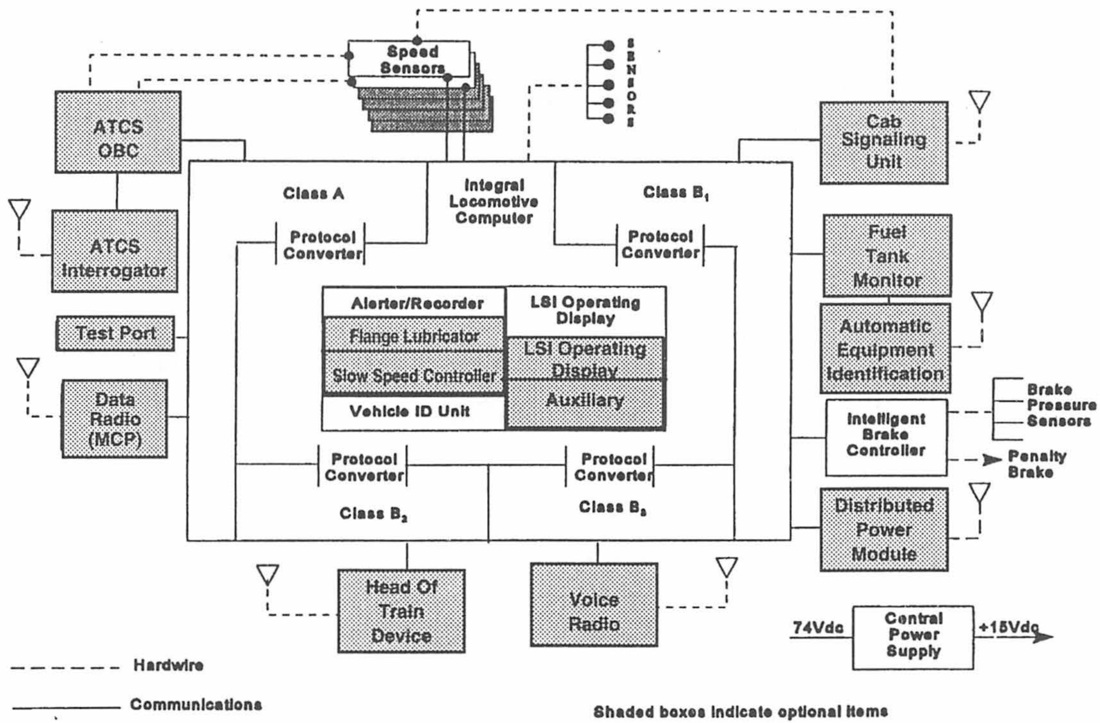
Conclusion

The LSI specification is a well-documented guideline for integration of electronic devices. The specification allows for growth, interoperability, interchangeability and enhancement of electronic devices in a systematic and consistent manner. It has also brought about challenges in the area of integration that need to be resolved and has started a race for the role of integrators.

1. Moody, Howard G.,. "Update on Locomotive Systems Integration Standards and Specification".

2. Moody, Howard G., Pruitt, Gary., "LSI - Locomotive System Integration".

Figure 1 Configuration 1 LSI Architecture



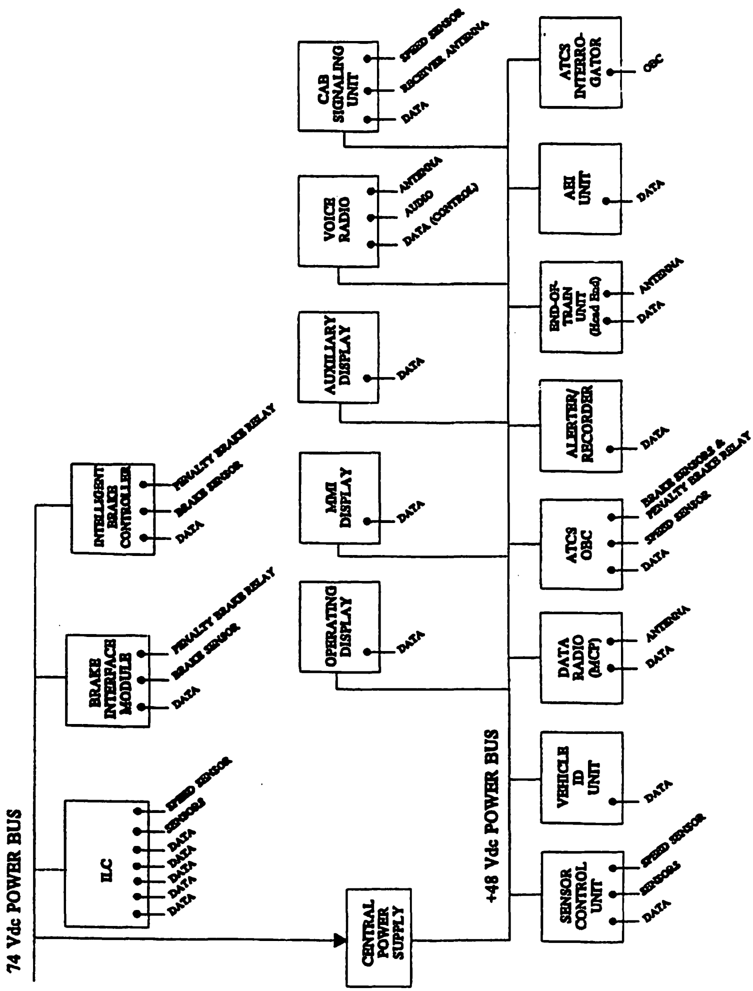


Figure 2 - Equipment Interfaces

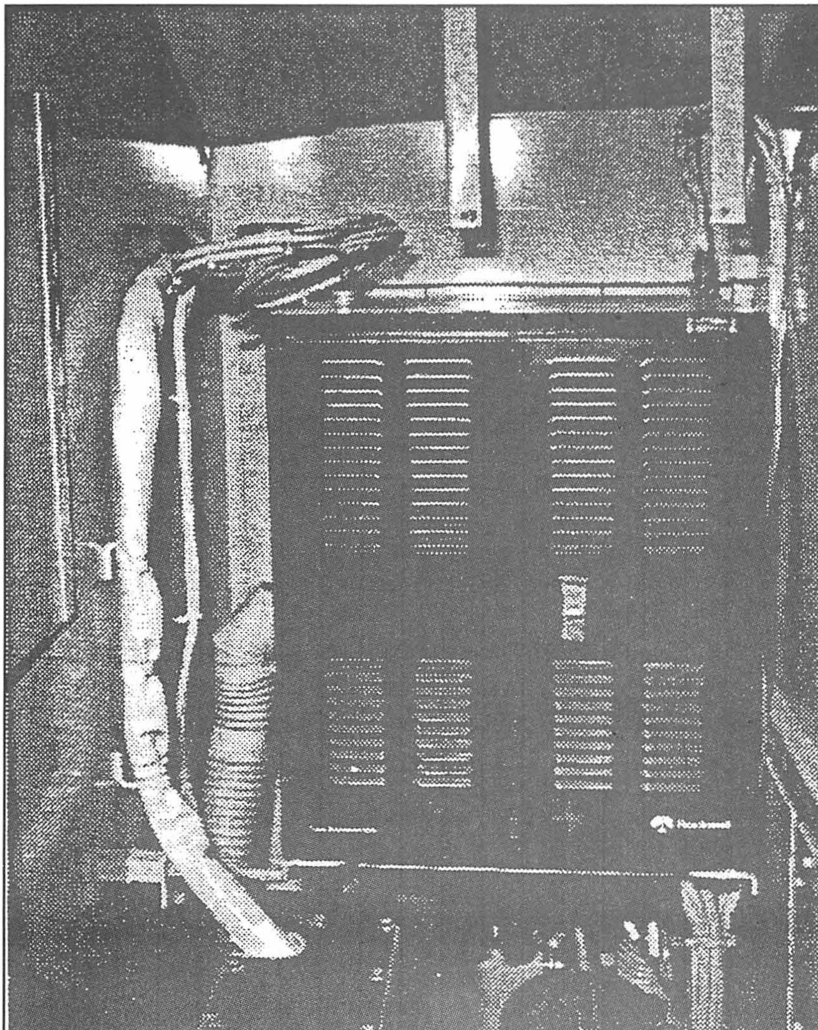


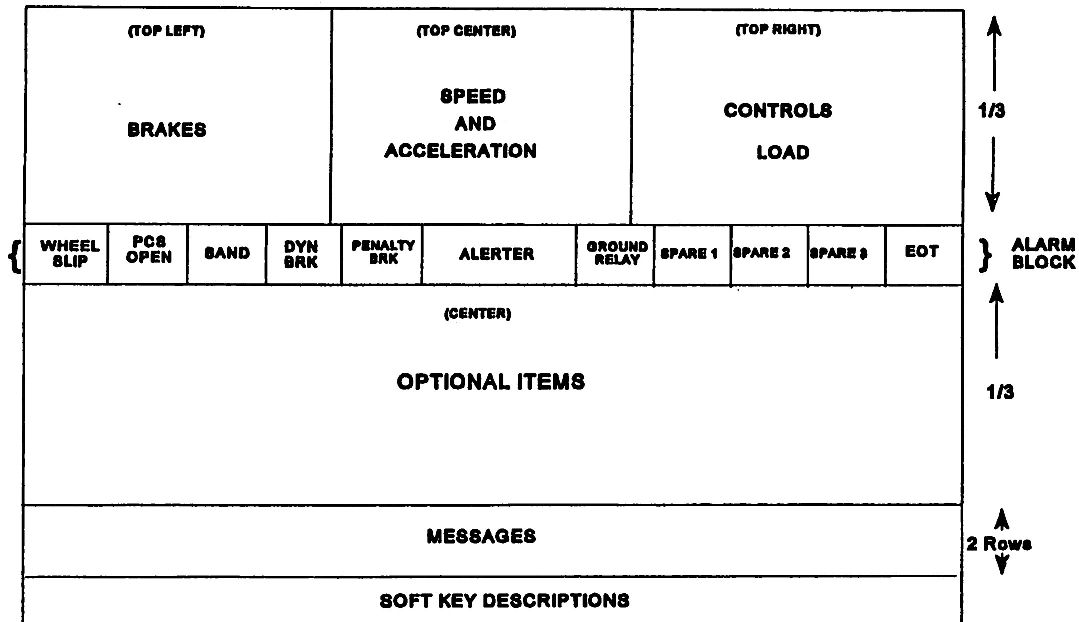
Figure 3 - TEU "Train Enclosure Unit"

TABLE 1. MINIMUM RELIABILITY REQUIREMENTS

Component	Minimum MTBF in Hours
Core Processor	125,000
Operating Display	125,000
Vehicle ID Unit	125,000
Brake Module	125,000
MMI Display	30,000
Auxiliary Display	30,000
Data Radio	25,000
Brake Controller	125,000
ATCS OBC	125,000
ATCS Interrogator	25,000
Auxiliary Processor	25,000
Alerter/Reçorder	25,000
End-of-Train Unit	25,000
Cab Signaling Unit	125,000
Automatic Equipment Identification Unit	25,000
Central Power Supply	200,000

Figure 4

OPERATING DISPLAY SCREEN LAYOUT



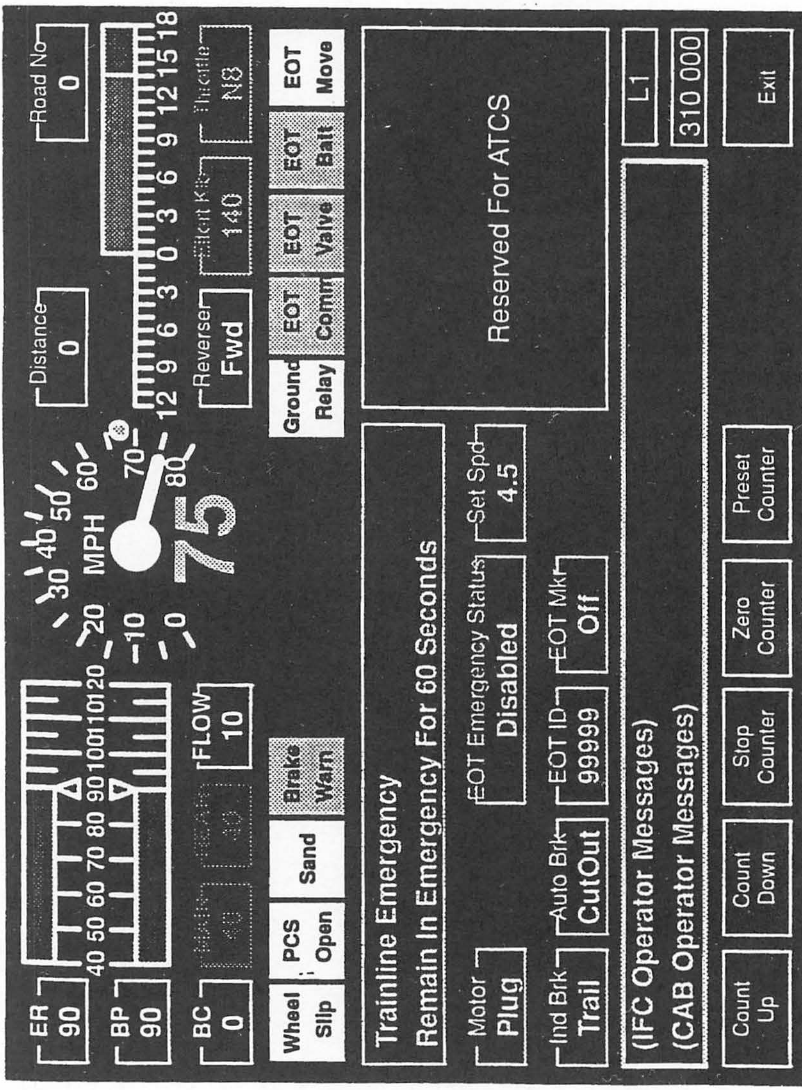


Figure 5 - GE Display Screen

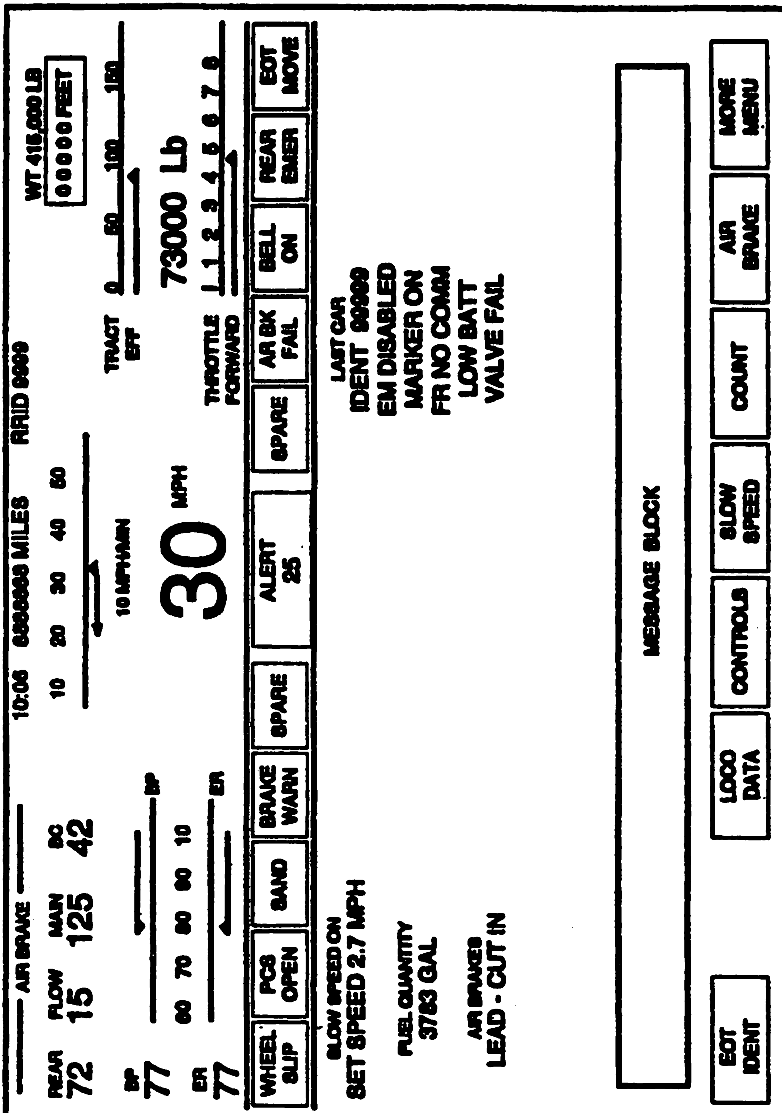


Figure 6 - EMD Display Screen

IV. ELECTRONIC GOVERNORS

Presented by
Robert J. Reynolds,
Canadian Pacific Railway

This paper will describe an electronic governor system that was retrofitted to three Canadian Pacific model GP9 locomotives. The word system has a broad meaning because this electronic governor does more than just govern the speed of the engine. This system enhances the performance and adhesion of the GP9 locomotive, adds the fuel saving feature of automatic stop/start, and controls engine cooling. We are looking to make these betterments and decided a total solution would be to have an electronic governor/control system. We went ahead with three test applications using the QEG-1000 Electronic Governor System made by Q-Tron Limited of Calgary, Alberta, Canada. The test has since been expanded to other locomotive models. This paper covers the following topics:

- Problems with existing mechanical governors
- Main features of the system
- Major components
- Diagnostics and alarm fault logging / data analysis
- Benefits of electronic governor system
- Economics of electronic governor system
- Future applications on Canadian Pacific

Problems with existing mechanical governors:

The mechanical governor that we have been using on diesel locomotives has served us well over the years. Because it is a mechanical device, it is subject to wear and requires maintenance and adjustments. It has always been difficult, even for expert mechanics, to pin down certain governor problems. Often mechanics and electricians argue over whether difficult problems are electrical or mechanical. I am sure that every railroad has needlessly changed out mechanical governors when there was nothing wrong with them. Our governor repair company complains about receiving bad order governors with no fault found. This shows there is difficulty pinpointing problems involving mechanical governors.

The proper level of governor oil is another source of problems. Operations personnel, trying to keep a locomotive running, sometimes generously add oil when governor problems are suspected, but often to the detriment of the governor. Sometimes it is not their fault because the sight glass may be difficult to observe. The electrical plug on the governor gives problems due to moisture shorting out the positive and negative pins. The mechanical governor sometimes is too slow to act on engine problems such as crankcase overpressure. Sometimes unnecessary engine shutdowns are caused due to faulty EPD or oil pressure switches. Engine protection switches that intermittently trip cause serious problems to an automatic stop/start system. We worked with the supplier to develop a new electronic governor system that would eliminate all of the old problems.

Main features of the system:

This electronic governor system consists of the following main features:

- Engine speed control
- Engine protection
- Automatic engine shut-down/start-up

- Wheel slip control
- Traction motor protection
- Dynamic brake regulation
- Engine temperature control with fan sequence control
- Fault logging and analysis

Major components of the system:

A number of components are removed when this system is applied. They are the PG governor, the temperature switches, the load regulator, the engine protection device and the wheel slip transducers. The following is a list of the major components of the system that are applied to the locomotive.

- Electronic governor actuator - replaces the mechanical PG governor, see Figure 1
- Actuator control unit - this houses the electronics for the actuator, see Figure 2
- Sensor manifold unit - this replaces the EPD assembly and other sensors, see Figure 3
- Main electronics unit - interfaces system to the locomotive electrical system
- Water and oil sensors for temperature and pressure
- Brake cylinder pressure sensor
- Ambient temperature sensor
- Battery field driver device
- Traction motor current transducers
- Battery voltage and current sensing
- Isolated main generator voltage and current monitor
- Cab display panel for viewing faults and real time data, see Figure 4

Diagnostics and alarm fault logging & software:

The system is provided with very good Windows-based data analysis software. This software is used on board the locomotive to download the alarm and statistics log. The data can be reviewed on board on in the office. Maintenance people review the data to troubleshoot faults with the locomotive. The system is self-diagnosing and logs all sensor or equipment defects. The system keeps statistics on:

- Amount of fuel and cost of fuel saved by the automatic shutdown/start up sub-system
- System information
- Throttle, fan time and generator power statistics
- Mini event recorder showing track speed, current of each traction motor, throttle position and distance all logged with real time/date. Tabular as well as graphical display of data is provided as well as a search routine to look for exceptions.
- Alarm log of locomotive/system faults

Benefits of electronic governor system:

There are many benefits of an electronic governor system; we will cover the key items. Engine speed control duplicates the control provided by the old mechanical governor but through an electric motor and solid state controls. There are no adjustments necessary or oil lines to maintain. We were able to make an interesting improvement to locomotive operation during initial testing. On that test, the locomotive engineer complained about how the GP9 locomotive always vibrates in notch 2. As you may know this is an old characteristic of the GP9. The equipment designer thought about this problem and solved it by slightly changing notch 2 engine speed. Thus, the art of electronic programming gave yet another benefit to this system.

The condition of weak batteries is annunciated on the display panel and it will not shut down a locomotive that it determines to have weak batteries. This is done by measuring cranking time and monitoring battery voltage each time the locomotive is started. The wheel slip control system greatly improves the adhesion of the locomotive. We conducted controlled tests and found a 15% improvement in adhesion compared to a basic GP9 locomotive. These locomotives are now dispatched at 21% adhesion. Figure 5 shows a test comparison of adhesion between an SD40-2 PTC locomotive and a GP9 equipped with this system. The equipment achieves this adhesion without the use of axle generators or traction motor speed probes. The system relies on traction motor current to detect wheel slips. The adhesion improvement is comparable to positive traction control, but requires a quarter of the modification and application time. Engine temperature control is performed by the system including fan sequencing. The system logs detailed engine operation. This detail such as water and oil temperatures and pressures is very important for analyzing engine or cooling problems.

Another benefit is automatic enable of low idle. Our other units have a manual enable switch that is used each spring and fall. The traction motor protection algorithm provides continuous motor current regulation based on ambient temperature, time and calculated motor temperature. Replacement and repair of overheated traction motors is a big expense to us each year. A big benefit of electronic governors is their fault logging capability that greatly helps determine the source of engine control problems.

Economics of electronic governor system:

The well regulated engine speed control provides a fuel saving estimated up to 1%. The automatic shut-down/start-up system saves us up to about $10,000 or $7200 US in fuel per locomotive per year. Automatic low idle, high idle and 2-speed DB provide additional savings. The complete application time is about 108 hours in our main shop. This work is typically done during engine overhaul or when modernizing the locomotive. It is especially advantageous when other functions such as temperature control and automatic stop/start are planned. The cost of the system from Q-Tron is about $15,000 or $11,000 US.

Future applications on Canadian Pacific:

Our plan this year is to equip 24 GP38-2 locomotives with this system. Adhesion improvements will enable the use of fewer locomotives in a consist. One SD40-2 locomotive will also be equipped to observe performance on that model.

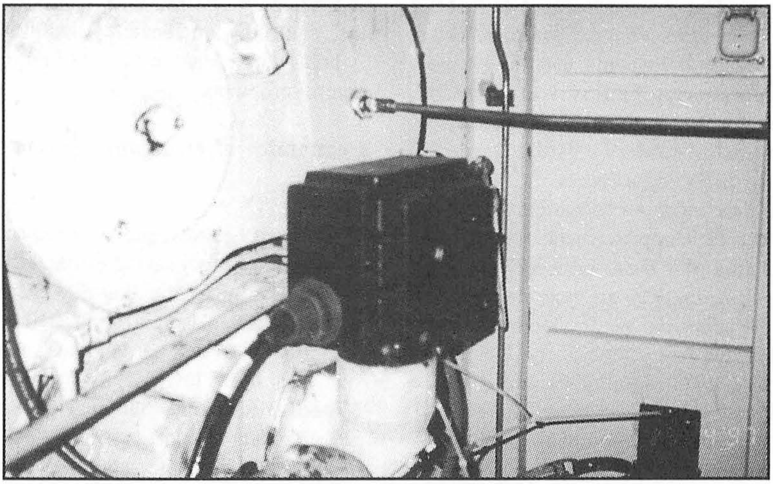


Figure 1 - Electronic governor actuator

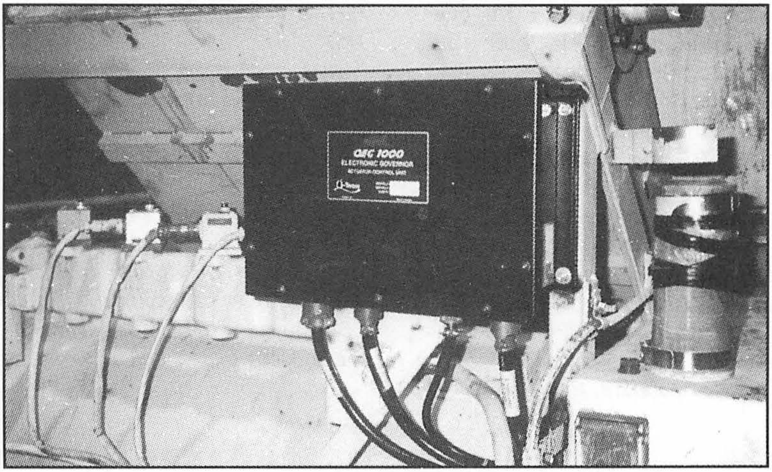


Figure 2 - Actuator control unit

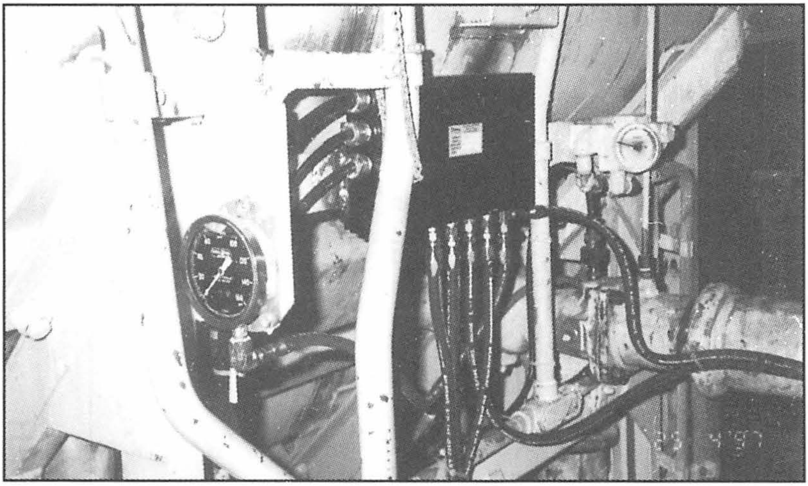


Figure 3 - Sensor manifold unit

Figure 4 - Cab display panel

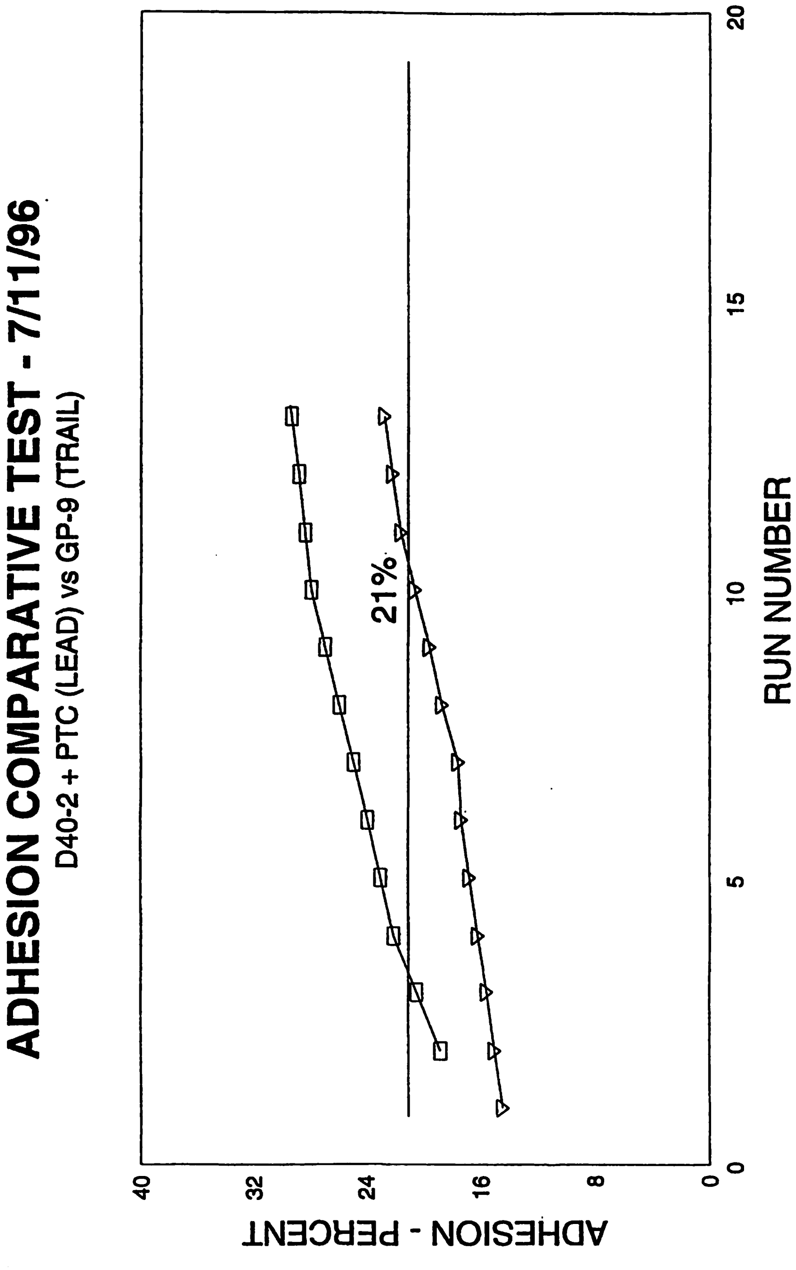


Figure 5 - Adhesion comparison

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

MONDAY, SEPTEMBER 15,1997
3:15 P.M.

Pre-Convention Presentation Boise Loco. Company

May 9, 1997 Boise, ID

T. H. VOLKMANN, Chairman
Mgr.-Loco. Facility - Engine Components
Union Pacific
North Little Rock, AR

Vice Chairman
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PERSONAL HISTORY

Tad H. Volkmann

Tad H. Volkmann, chairman of the LMOA committee on Diesel Mechanical Maintenance, was born January 31, 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.

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 in 1987, where he oversaw a period of growth that resulted in the doubling of maintenance activities and workforce.

Tad was promoted to superintendent motive power-GE locomotives in 1994, with responsibility for the maintenance and performance of CNW's fleet of General Electric locomotives.

When CNW was merged into the Union Pacific Railroad in 1995, Tad moved to Salt Lake City, Utah, as senior manager of UP's Salt Lake Diesel Facility. Tad had been most recently appointed manager locomotive facility-engine components, at Union Pacific's Jenks Locomotive Shop in North Little Rock, Arkansas. Tad is responsible for the remanufacturing and performance of diesel engines and locomotive mechanical components system wide.

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

The **Diesel Mechanical Maintenance Committee** wishes to thank Boise Locomotive Company for hosting their Pre-Convention Presentation on May 9, 1997.

OLOA
2000
Chevron
ORONITE

I. LMOA BEST PRACTICES: GE WATER LEAKS

Prepared by
Ed Burrier, NS
and
Bruce Sweeley, GE

PROBLEM: Governor shut down for low water pressure, or a 4492 fault on the DID panel.

System Description:

Proper integrity of the water system is vital to the optimum performance of the diesel engine. If the integrity of the water system is compromised by a water leak or a failed component, a drop in pressure will occur. If this condition goes uncorrected, accelerated and severe engine wear will result. To ensure that the engine water pressure does not drop, the governor and/or computer is designed to shut down the engine in the event of a low water pressure.

Inspection Procedure

Check the level of water in the water tank. If the level is low, add water in accordance with proper procedures. With the engine running, search for any visible signs of water leaks. Check the telltale hole in the water pump to ensure that no water is present at the telltale. If water is present, change the water pump.

With the engine running, check the water pressure at the governor, or sensor box. Engine water pressure at the governor / sensor in notch 8 must be above 14 PSI to ensure that the water pressure switch internal to the governor does not trip, or the computer sees less than 14 PSI from the sensor.

Check the operation of the water pump to ensure that it is capable of pumping pressure. Water pressure at the pump should be 30-40 PSI in Notch 8. Inspect the engine bonded pump drive.

Check the electrical operation of the governor or sensor by performing the following steps on Dash 8 computer equipped locomotives:

> Disconnect the governor plug and check pins G and M. Measure the voltage at pins G and M to EN wire, and ensure that pin M is 0 volts, and pin G is 64 volts.
> Short pins G to M and verify that fault 4492 is logged on the DID panel. If the fault is not logged, change the EXC controller with a known good panel. Re-connect the governor plug.

If the water pressure to the governor is sufficient, and the fault continues to be logged, replace the governor.

If water pressure is low, check for leaks by running a water pressure test.

Troubleshooting Procedure for Water Leaks on GE Locomotives

The following is a troubleshooting procedure for GE locomotives and is meant as a guide (if the unit is known to use water or is having a cooling system related problem, additional procedures should be completed to insure that the unit is properly repaired):

Unit shopped for further inspection of water problems.

Obtain lube oil sample report.

Review locomotive history for past water related problems, review the results of the lube oil sample, history, look for trend and any engineer's report.

Remove all crankcase doors, (CAUTION: Under some conditions the oil may be above the bottom of the oil crankcase doors. TAKE CARE WHEN THE CRANKCASE DOORS ARE

OPENED), valve covers, and end plates on the intake manifolds. If the intercoolers do not have the pipe plugs with the hole and cotter pin modification, remove the pipe plugs and replace with the plugs that have been modified. With all covers removed inspect for any obvious water leaks.

Fill cooling system with water (Caution: never remove fill cap if water is up in radiators).

Vent the radiators during filling to eliminate all trapped air.

Open plug or vent valve at the top of the radiators to vent trapped air.

Move exhaust valve handle to vent position and fill with water.

Air will exhaust from tube on exhaust valve. When cooling water flows from exhaust pipe and all trapped air has been vented from radiators, turn exhaust valve DOWN to operate position and proceed with pressure test.

EXHAUST VALVE TO REMAIN DOWN (OPERATION POSITION).

CAUTION: Use care when placing the fixture snugly on the fill neck so as not to damage the fill neck or fixture tangs.

Pressurize cooling system using Tesco test equipment. Close off system for at least ten minutes with 18 PSI. IMPORTANT: Do not exceed 20 PSI.

NOTE: Observe that no pressure loss occurs for the ten minutes.

Open test cocks and bar engine through two complete revolutions stopping periodically to inspect at all crankcase openings, rocker boxes, intake manifolds, for water leaks.

NOTE: Should a water leak occur on an engine with dual pipe manifold, there is a greater possibility of water from the leaking cylinder flowing into other cylinders. This has always been a concern on the intake manifold; however, with the single pipe it is unlikely to occur due to the upward branching of the exhaust elbows. Now with the dual pipe, if 1" of water accumulates in the manifold, it can run into a cylinder that has exhaust valves open. You should examine the exhaust condition of the engine by removing the end cap or last manifold section on a bank where each cylinder can easily be seen. This will also allow draining of any accumulated water.

Component Inspection: make a visual component inspection of the following:

Crankcase Inspection
Water Pump
Air Compressor
Governors
Intercoolers
Related piping
Turbo and crossover line
Radiators
Water Tank Boot
Cab Heater (Water)

Repair any defects and re-pressure test the engine. If no other leaks are indicated on the pressure test continue to next step.

Load Box: Self load or load box. Check the temperature switch, eddy current clutch, water pressure, and tripping of low water button. Mark site glass and watch for loss of water. We recommend longer load test for repeater locomotives. If there is no loss of water, check for proper water treatment and release the Locomotive.

MATERIAL REQUIRED

Cooling system test kit	P.N. T51750
Water Regulator kit	P.N. T51760
Fill Neck Pressure Fixture	P.N. T51780
Pneumatic barring over tool	
Hand tools	

II. LOCOMOTIVE UPDATE: MK1200G LNG POWERED SWITCHER

Prepared by
Dennis Nott, BLC
& Ray Plaugher, UP

In early 1992 the Boise Locomotive Co. (formerly MK Rail Corp.) perceived a need for development of a new, highly efficient, switcher locomotive as a replacement for North America's aging switching fleet. Paramount in the decision to develop a new switcher locomotive was the desire to incorporate state of the art control systems for enhanced tractive effort, economical operation and maintenance and superior environmental performance. To this end Boise Locomotive Co. formed a strategic alliance with Caterpillar, Inc., to design and produce North America's first microprocessor controlled 1,200 HP locomotive fueled entirely by liquefied natural gas (LNG), the MK1200G.

In 1993 The Boise Locomotive Co. was approached by the Union Pacific Railroad (UP) and the Atchison, Topeka & Santa Fe Railway (now part of Burlington Northern Santa Fe, BNSF) to produce two MK1200G locomotives for each company for use by each railroad as an LNG demonstration project in the Los Angeles Basin. This resulted in the delivery of locomotive UP 1298 and UP 1299 to the Union Pacific in August of 1994 and ATSF 1200 and ATSF 1201 to the Burlington Northern Santa Fe in December of 1994. The Union Pacific 1200G's went into service on September 22, 1994, and the ATSF 1200G's on December 5, 1994.

The Boise Locomotive Co. has designed several operational and safety improvements over existing switchers in the new MK1200G switchers with:

- The Caterpillar G3516 spark ignited, turbocharged - aftercooled (SITA) LNG fueled V-16 engine that produces the lowest NOx emissions of any engine of its class.
- Modern electrical rotating equipment, including electric motor drive for the air compressor, supplied by KATO Engineering, a division of Reliance Electric/Rockwell.
- A Boise Locomotive Co. designed state-of-the-art micropressor locomotive control system for superior traction and engine control.
- An advanced LNG fuel management system of cryogenic tanks, process piping, vaporizer and controls designed by Minnesota Valley Engineering (MVE).
- A modern, high visibility ergonomically designed cab.
- Excellent collision protection for the short nose end of the locomotive.
- Six-row mechanically bonded radiator cores that remove heat from separate jacket water and aftercooler circuits that are cooled by two 48-in. electrically driven cooling fans.
- Two-axle Blomberg type trucks with 40-in. wheels, G-G type journal bearings, 62:15 gear ratio, and clasp composition brakes providing superior ride, tracking and braking.

General Specification

Locomotive Type:

AAR Designation	B-B
Industry designation	0440

Nominal dimensions and capacities are as follows:

Length, coupler to coupler	56 ft. 2 in.
Length between bolster centers	31 ft. 0 in.

Weight, loaded	236,000 lbs.
Fuel capacity, LNG	1,400 gals.
Sand capacity	50 cu. ft.
Cooling water capacity	190 gals.
Lube oil capacity	219 gals.

Curve negotiation:

Minimum curve coupled to car	150 ft.
Minimum curve coupled to locomotive	274 ft.

Drive:

Traction motors	4
Type	DC, series wound, axle hung
Gear ratio	62:15
Wheels	40 in.

Performance data are as follows:

Engine RPM	1,500
Fuel	LNG
Traction HP	1,200
Maximum speed	70 MPH
Minimum continuous speed	6.2 MPH
Minimum continuous tractive effort	60,000 lbs.

Engine System

The Caterpillar G3516 SITA engine is a mature design natural gas engine used in thousands of applications throughout the world, but their primary use has been in the stationary generating plant application. The application of the G3516 SITA engine to the MK 1200G locomotive is the first time that this engine has been used in a locomotive or a variable load situation and Caterpillar took two years to enhance the design of the engine to meet the demands of this application.

The basic engine features are:
16 cylinder - 60' V configuration
Turbocharged - aftercooled
4 - stroke cycle
Spark ignited
11.1 compression ratio
1,350 BHP @ 1,500 rpm
Low firing pressures
170 mm bore and 190 mm stroke
2 - intake and 2 - exhaust valves per cylinder
Electronic ignition system (EIS)
Air/fuel ratio control
Fast transient response
Trouble shooting and maintenance capabilities.

What makes the G3516 SITA engine unique from its diesel counterparts is the low pressure LNG gas delivery system and spark ignition system. The G3516 uses low pressure (40 psi) gas flow out of the initial Acme gas regulator. The gas then flows to the Sprauge regulator that regulates the gas to the engine at 6 to 8 in. of water at idle (increases with engine speed). The gas then flows to the engine through a carburetor and is spark ignited by a spark lug within the cylinder. The 1200G runs on pure LNG and does not require diesel fuel to be mixed with the LNG as do high pressure (3,000 psi) direct injected systems that were tested in high horsepower locomotives in 1995 and 1996.

The emissions performance of the Caterpillar G3516 SITA engine are as follows:
ISO8178-1 Conditions

(Grams/BHP HR)	
Oxides of Nitrogen (NOx)	2.0
Carbon Monoxide (CO)	1.9
Hydrocarbons (HC)	2.8
Particulates	.08

Fuel System

The fuel system on the 1200G can be divided into three primary systems: the fuel tanks, process piping and valves, and the LNG vaporizer.

Because LNG is a cryogenic material

that is under low to moderate pressure when it is stored the fuel tanks of the 1200G must be cylindrical to provide the strength necessary to store the fuel. The fuel storage system on the 1200G is really three separate interconnected tanks with a total capacity of 1,400 gallons of LNG. There is one tank of 900 gal. in the middle of the tank system and the two outer tanks are 250 gal. each. Because of the cylindrical design required the space normally occupied by a conventional fuel tank on the locomotive can not be efficiently utilized resulting in the lower fuel capacity of the 1200G. Under normal operating conditions the 1,400 gallons of LNG is equivalent to about 900 gallons of diesel fuel on a diesel powered switcher.

The inner shell of each tank is fabricated from 1/4 in. thick ASTM 304 stainless steel to hold the temperature of the LNG at approximately -260 deg. F. The inner shell is blanketed with approximately 1-1/2 in. of an aerospace developed insulation material and then installed in a high strength carbon steel (ASTM A572) outer shell of 1/2 in. thick that provides the tank its structural integrity.

After the outer tank is capped and sealed the insulated space between the inner and outer tanks is vacuum pumped to improve the insulating capabilities of the system. All three tanks sit in a tank cradle that is attached to the frame of the locomotive. The dynamic load capability of the fuel tank system is 10G in all directions. In addition, the bottom of the tank cradle is protected from derailment puncture by a steel skid plate. Fuel level monitoring is accomplished with capacitance tubes in each of the LNG tanks.

Process piping on the system is simplified by the fact that the G3516 engine is a low pressure engine. When the fuel tanks are fully loaded the saturation pressure of the LNG is 70-100 psi, meaning that the pressure of the evaporated gas alone will provide enough gas pressure to run the engine without the use of pumps. The process piping and Swaglock fittings are Schedule 40 stainless steel and all valves on the tank system are all made of bronze because of the cryogenic nature of the fuel. There are three separate process piping and valve systems on the 1200G: the LNG fill and off load piping; the LNG fuel tank to engine supply piping; and the gaseous fuel and vent pipe system (discussed later under Safety). All piping and fittings at the end of the fuel tanks are protected by a steel collision plate.

The final component of the fuel system is the liquid heated vaporizer. The purpose of the vaporizer is to assist the vaporization of the liquefied LNG as the fuel supply depletes the fuel tanks. The vaporizer is a cylindrical liquid - to - liquid heat exchanger that uses engine coolant water to raise the temperature of the LNG to aid evaporation.

Rotating Electrical Systems

The main traction alternator is a KATO 8P6.5-3000 that is coupled to the engine by a flexible coupling. AC power is rectified to the rated 1,050 VDC and 4,000 amps continuous output with an intermittent capacity of 6,000 amps. The traction alternator receives excitation from the companion alternator and is ventilated by an internal, direct drive cooling system. The traction alternator is also of double bearing design to increase reliability and life.

The companion and auxiliary alternators are combined into one housing which is coupled to the engine crankshaft through a 1:1.33 gear ratio.

The companion alternator is a 130 kW, KATO series 6P2-1450 revolving field machine equipped with slip rings and brushes. AC is output at a rated 183 VAC, 100 Hz, 3-phase power at 2,000 RPM. Excitation to the main field is provided by the auxiliary alternator.

The auxiliary alternator is an 18 kW KATO series 6P2-0500, revolving field machine. 55 VAC is rectified and output is rated at 74 VDC. The exciter field is controlled by the voltage regulator by a VR 10 card.

Four D78B traction motors are connected in full parallel with no motor or alternator transition required.

Control System

The 1200G uses an MK-LOC microprocessor control system to control excitation/load control, adhesion engine control, diagnostics systems and LNG gas leak detection and control.

The excitation control system regulates the traction alternator output and is linked to the adhesion control system which optimizes available adhesion. Load control maintains horsepower in accordance with the locomotive's tractive effort characteristics.

The adhesion control system provides smooth, uniform wheel creep action to maximize adhesion for any locomotive and track condition. Wheel rotation rate signals are received from hub mounted axle generators.

The engine control system maintains accurate engine speeds of plus or minus 1%. Engine speeds are set to maximize fuel economy and avoid resonant vibrations for each throttle position. Engine control provides low idle, hot engine protection and automatic fan sequencing.

The diagnostics system monitors the locomotive performance, stores all critical information, and provides a historical fault log to service personnel for quick troubleshooting and maintenance turnaround. The system reacts to a full range of fault and trending conditions and signals critical events which require operator action. The microprocessor's command procedures and fault logs are stored in software, hardware, and nonvolatile memory. If required, service information can be displayed on the onboard computer screen, displayed on a portable interface display or off-loaded to a remote terminal.

The 1200G also has continuously powered methane detectors that provide input to the microprocessor control system that will activate engine shut down and warning systems.

Safety and Crew Comfort

The 1200G was designed with numerous features for crew safety and comfort. The cab design allows adequate room for normal crew movement within the cab as well as space for a refrigerator and steps down to the short nose should a toilet be installed there. The cab meets all AAR clean cab requirements. The under-floor mounted HVAC system also provides the crew with a clean and comfortable environment in which to work.

The cab was designed to provide the engineer and other crew members with excellent 360 degree visibility. The short nose of the locomotive is lower and slopes down so that larger windows could be installed. Another window over the long hood of the locomotive affords the crew additional visibility in that direction. The engineer's view is enhanced by the raised platform that the control stand sits on.

The cab is also sound insulated and has excellent sound characteristics of 60-75 db under normal operating conditions.

The 1200G is also built with an anticlimber and 16-in. deep I beam collision posts on the short hood end for extra crew protection in the case of collision with other railroad equipment or at railroad/highway grade crossings. All collision protection meets AAR S-580 requirements.

There are several safety features incorporated in the LNG fuel system even though that LNG is difficult to ignite because of the very narrow range of the air to fuel ratio that is required. Excess heat and fuel pressure (greater than 80 psi) are removed by an economizer regulator that draws vapor from the top of the tanks while the engine is running and passes the vapor to the engine. When the engine is shut down the road relief regulator slowly vents vapor that is produced in the tank (120 psi) through a vent at the top of the locomotive's long hood. This condition usually occurs when the locomotive has been sitting for prolonged periods without use and as a result, the fuel begins to boil off increasing vapor pressure. There are five 220 psi relief vent valves on the locomotive; three on the vent tree inside the locomotive carbody and two on the fuel tank system. The vent tree also has two 270 psi burst discs. The vaporizer has an 18 psi burst disc on the water side of the cooling system should a leak develop within the vaporizer.

The locomotive is equipped with six methane sensors for gas detection that work through the microprocessor. Methane sensors are located at each end of the fuel tanks, one below the radiators above the air compressor, one above the auxiliary generator on the expansion tank, one in the fresh air compartment below the inertial filter, and one in the cab. All of the sensors on the BNSF 1200G's are set to activate at a 10% Lower Explosive Limit (LEL) alarm level. Those on the UP 1200G's are set at a 20% LEL. The sensors on all 1200G's are set up for non-intrusive calibration. The sensors provide uninterrupted alarm capability with both audible and visual warnings. In the case of an alarm, strobe lights at each end of the locomotive (one on long hood end and one on each side of the cab) are activated and an audible sound warning is activated in the cab. There also is a normal complement of standard locomotive emergency fuel cut-off buttons on the locomotive.

Current Locomotive Operations - Union Pacific

The Union Pacific locomotives, UP 1298 and UP 1299, are currently assigned to the UP's Commerce Yard just east of downtown Los Angeles. California. Both units are assigned to general switching duties within the confines of the yard. The UP performs all maintenance and servicing functions, except fueling, to the locomotives with UP forces. Fueling is performed under contract by Northstar, Inc.

Since the maintenance is performed by the Union Pacific, Boise Locomotive Co. has a more limited access to the two locomotives. In addition, the two Union Pacific 1200G's are equipped with a GPS system that is interfaced with the 1200G's microprocessor system and, because of this, the UP does not not download the microprocessor data on a regular basis. However, the Union Pacific did download the duty cycle of UP 1299 for the period of September 4, 1996 through January 31, 1997. Officials of the Union Pacific and Boise Locomotive Co. feel that this download represents a typical duty cycle for the two Union Pacific 1200G's. Results are as follows (note: total engine stop hours for the period was 555 hours):

DUTY CYCLE UP 1299
SEPTEMBER 4, 1996, THROUGH JANUARY 31, 1997

THROTTLE POSITION	HOURS IN THROTTLE POSITION	% TIME IN THROTTLE POSITION
Idle	1,048	84.6%
Notch 1	96	7.8%
Notch 2	45	3.6%
Notch 3	24	2.0%
Notch 4	13	1.0%
Notch 5	6	0.5%
Notch 6	2	0.2%
Notch 7	1	0.1%
Notch 8	2	0.2%
Totals	**1,237**	**100.0%**

Through December 31, 1996, the UP 1298 engine had operated 7, 219 hours for an average of 8.68 hours for each day in service. For the same period the UP 1299 had 6,934 engine hours for an average of 8.33 hours for each in service day.

Current Locomotive Operations - Burlington Northern Santa Fe

The Burlington Northern Santa Fe locomotives, ATSF 1200 and ATSF 1201, are currently assigned to BNSF's Hobart just east of downtown Los Angeles, California. Both units were assigned to general switching duties within the confines of the yard until February of 1997. In February of 1997 the units were assigned to switching and local duty on the Los Angeles Junction Railway (LAJ) in Vernon, California, a subsidiary of the BNSF. All maintenance and servicing, except fueling, is performed by the Boise Locomotive Co. at the LAJ facility a short distance from Hobart Yard. The fueling is performed by Northstar, Inc., under contract to AMOCO, Boise Locomotive Co.'s fuel supplier.

The only limitations that have been noted by the Burlington Northern Santa Fe have been the fact that only 1,200 HP can be developed for traction and that the fuel tank size limits the locomotives to yard service since the units need to be operated near their fueling stations.

The BNSF is very pleased with the tractive effort capabilities of the 1200G. On August 15, 1995, a tractive effort test was conducted by the ATSF on a 2.0% grade at mile post 27.0 on the Lucerne Valley Subdivision with ATSF 1201. The test location is at approximately 4,100 feet elevation and the temperatures during the test time varied from 90 deg. F to 96 deg. F. Under those conditions the 1201 produced slightly over 1,000 HP. The test was conducted using test car ATSF 83 plus 19 loaded ballast cars with weights as shown:

Loco/Car Number	Gross Scale Weight	Loco/Car Number	Gross Scale Weight
Locomotive AtSF 1201	121.78 tons	Ballast Car ATSF 177963	128.65 tons
Test Car ATSF 83	85.00 tons	Ballast Car ATSF 177047	94.80 tons
Ballast Car ATSF 177037	94.05 tons	Ballast Car ATSF 177212	91.65 tons
Ballast Car ATSF 176926	92.65 tons	Ballast Car ATSF177893	114.45 tons
Ballast Car ATSF 177183	91.10 tons	Ballast Car ATSF 177132	92.75 tons
Ballast Car ATSF 177257	92.95 tons	Ballast Car ATSF 177829	93.80 tons
Ballast Car ATSF 176945	95.75 tons	Ballast Car ATSF 177681	92.95 tons
Ballast Car ATSF 177084	92.50 tons	Ballast Car ATSF 177116	95.55 tons
Ballast Car ATSF 177376	94.40 tons	Ballast Car ATSF 177469	94.60 tons
Ballast Car ATSF 177482	96.85 tons	Ballast Car ATSF 177917	108.65 tons
Ballast Car ATSF 177586	94.35 tons		

The results of the test are as follows:

RUN TRAIN CONSIST	BALANCE SPEED (MPH)	TRACTIVE EFFORT (LBS.)	ADHESION COEFFICIENT (u)
1 1201/10 cars	7.8	39,000	.18
2 1201/11 cars	6.6	44,400	.20
3 1201/13 cars	5.1	52,300	.23
4 1201/15 cars	3.6	61,000	.27
5 1201/17 cars	2.9	68,800	.30
6 1201/19 cars	Stalled		
7 1201/18 cars	Stalled		

Note: Adhesion coefficient "u" includes locomotive resistance.

Since the two BNSF 1200G's are normally operated MU'ed the duty cycles of each unit that were downloaded from February 14, 1996, through September 30, 1996 are virtually identical. Officials of the Burlington Northern Santa Fe and the Boise Locomotive Co. feel that this duty cycle represents a typical operation of the two 1200G's.

Results are as follows (Note: total engine stop hours for both locomotives for the period was 623 hours):

AVERAGE DUTY CYCLES ATSF 1200 & 1201
FEBRUARY 14, 1996, THROUGH SEPTEMBER 30, 1996

THROTTLE POSITION	HOURS IN THROTTLE POSITION	% TIME IN THROTTLE POSITION
Idle	5,481	85.7%
Notch 1	498	7.8%
Notch 2	203	3.2%
Notch 3	90	1.4%
Notch 4	48	0.8%
Notch 5	25	0.4%
Notch 6	11	0.2%
Notch 7	5	0.1%
Notch 8	28	0.4%
Totals	**6,389**	**100.0%**

Through December 3, 1996, the ATSF 1200 engine had operated 10,610 hours for an average of 14.53 hours for each day in service. For the same period ATSF 1201 had 10,592 engine hours for an average of 14.51 hours for each in service day.

Locomotive Fueling
- Burlington Northern Santa Fe

All fueling of the two BNSF 1200G's is done at a modular TVAC fueling station that has been installed at LAJ's locomotive service track in Vernon. This type of fueling station was chosen for its low cost of installation based on the lower volumes of LNG that the two BNSF units would be using.

The TVAC consists of cryogenic pressure vessel of nominal capacity of 5,300 gallons of LNG. The vessel is a double wall pressure vessel with vacuum insulation capable of storing LNG at low pressures for several days. The vessel has pressure relief valves and vents to release vapor pressure inside the tank. Tanks of this size will normally hold the LNG for 5-10 days before venting, depending on the tank's volume and the pressure upon delivery of the LNG. The vessel is housed in a frame conforming to the specifications for an ISO container. All fuel transfer equipment is skid mounted and placed next to the pressure vessel. Instrumentation includes both mechanical and electrical pressure gauges and level indicators. This system will deliver between 40 and 50 gpm at pressures between 120 and 150 psi.

The system at the LAJ site has been


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
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permanently installed on concrete pads with a concrete spill retaining wall built completely around the equipment to meet local codes.

Fueling of each locomotive is typically done once per week. The locomotives are spotted at the TVAC (each locomotive has a fuel fill on each side) and the fuel fill nozzle from the TVAC is attached to the fuel tank receptacle. The LNG enters each tank through a top fill spray bar and is distributed through the vapor space to immediately reduce tank pressure to the saturation pressure of the incoming liquid. This eliminates the need for venting the tank while fueling.

With the low volume pumped by the TVAC, safety checks performed on the system prior to and after fueling, and the time it takes to condition the fuel before pumping, it can take up to 40 minutes to fuel the first locomotive and 20 to 30 minutes for the second locomotive.

All fuel is delivered by truck to the TVAC.

Total fuel used from start up of fueling operations in December of 1994 through September 30, 1996, (last date of fuel reconciliation of fuel deliveries to inventory) is 291,783 gallons. This works out to an average of 217.75 gallons per day per locomotive for the period.

Locomotive Fueling - Union Pacific

All locomotive fueling for both Union Pacific 1200G switchers is done at UP's LNG fueling station located within Commerce Yard. While the system and fueling process is basically the same as with the TVAC at the LAJ, UP's was designed as permanent facility capable of dispensing LNG to large volume road locomotives and all equipment is therefore sized accordingly.

The fueling station at the UP consists of a permanent 55,000 gal. 50 psi, LNG bulk storage tank that can be filled by truck or rail car. From the main bulk storage tank the fuel is pumped to a 3,000 gal. 250 psi, LNG transfer tank where the fuel is conditioned prior to filling the locomotives. From the LNG transfer tank the fuel is pumped to the locomotives at 250 psi at a rate of approximately 100 gallons per minute. Fueling each 1200G at the UP typically takes approximately 25 minutes for the first locomotive and 15 minutes for the second locomotive.

The total fuel used from start of locomotive fueling on September 22, 1994, through september 30, 1996, (last date of reconciliation of fuel deliveries to inventory) is 239,383 gallons. This works out to an average of 161.96 gallons per day per locomotive.

Locomotive Fueling Procedure

While the fueling systems at both locations are different, the procedures for fueling the locomotives do not differ. However, the LNG fueling procedure does differ from the normal diesel fuel procedure. The LNG fueling procedure is as follows:

- Blue flag locomotive.
- Shut down locomotive engine.
- Ground locomotive by attaching ground cable from locomotive fuel tank to ground stake.
- Cool down fuel pump and fill equipment by circulating (normally aspirate) fuel. This procedure allows the liquid gas to reduce the temperature of the pumping and filling equipment so that the liquid LNG does not become vapor when it flows through warmer equipment.
- After cooling the special cryogenic fill connector on the fuel station side, it is connected to the special cryogenic fuel fill on the

locomotive.

- Before pumping fuel into the locomotive the road relief valve on the locomotive must be closed to prevent vapor pressures from spiking and damaging the regulator.
- Begin fueling and fill locomotive until the pressure gauge spikes.
- After tanks are full shut down fuel station pumping system.
- Open road relief valve on locomotive.
- Remove fueling station fill connection from locomotive.
- Remove grounding cable from locomotive.
- Start locomotive.
- Remove blue flag.

Locomotive Scheduled Maintenance

The Boise Locomotive Co. worked closely with Caterpillar to develop a scheduled maintenance program for the 1200G prior to the delivery of the units to both railroads. The 1200G is a locomotive that, for all purposes, is state-of-the-art in all respects when compared to other new DC-motored locomotives, with the only major difference being the state-of-the-art LNG engine and fuel system. Therefore, Boise Locomotive Co.'s recommended scheduled maintenance cycle for the 1200G is the same as would be recommended for any new DC-motored locomotive with the exception of the LNG differences.

The initial scheduled maintenance for the Caterpillar 3516 SITA engine and fuel system was conservative, and with experience and time most of the maintenance functions scheduled on a 92 day basis have been extended out. Functions that are over and above a typical diesel powered locomotive 92 day inspection are as follows:

Additional Inspection Requirements - 92 Day Inspection

Function	Man Hours/ Interval
Calibrate methane detectors	1.0
Calibrate ignition timing	1.0
Total additional man hours 92 day inspection	**2.0**

From experience Boise Locomotive Co. has determined that the following additional maintenance functions are required for the 1200G LNG switcher on an annual basis:

Function	Man Hours/ Interval
Change oil as required by analysis not to exceed 1 year	2.0
Drain aftercooler condensation	0.5
Clean/set spark plug gap and adjust engine valve lash	8.0
Inspect fuel system valves/ fittings and leak test	4.0
Replace gas regulator	1.0
Replace burst disks	1.0
Total additional man hours annual inspection	**16.5**

All four 1200G locomotives have now been in service for two years and there were several items planned for replacement during the annual inspection and two year inspection that have not had to be done. Boise Locomotive Co. is continually monitoring the performance of the following items to determine the optimum maintenance interval:

Replace spark plugs.
Replace oxygen sensors.
Replace engine thermostats.
Replace jacket water pump.
Replace aftercooler water pump.
Replace carburetor.
Replace starter motors.
Replace coolant.

Replace water temperature thermostats.

All scheduled maintenance is still in the evaluation process. It is Boise Locomotive Co.'s goal to extend all maintenance functions as long as possible; however, different operating conditions may dictate revisions to the scheduled maintenance work scope and schedule.

Unscheduled Maintenance

Since the units were put in service each Union Pacific 1200G has been in operation for 863 days through January 31, 1997. Each BNSF 1200G has been in service for 789 days through January 31, 1997. During the period of operation through January 31, 1997, there were a total of 114 defects reported on all four 1200G's. Failures reported are listed in ANNEX 1. An analysis of the 114 reported defects breaks down as follows:

DEFECT CATEGORY	NUMBER REPORTED	PERCENT REPORTED
Defect reported, none found	17	14.9%
Auxiliary generator problems	15	13.2%
Fuel system/fuel pressure	14	12.3%
Control system/ Microprocessor	13	11.4%
Sensors/probes	12	10.5%
Engine/Engine control module	10	8.8%
Engine no start	9	7.9%
No load	8	7.0%
Sanders	3	2.6%
Air system	3	2.6%
Cooling fans	2	1.8%
Operator caused	1	0.9%
other single events	7	6.1%
Totals	**114**	**100.0%**

The largest category of defects reported was 14.9% where defects were reported and none were found. Traditionally there will always be some defects reported with no defects found. However, the Boise Locomotive Co. feels that the large number of reports of this type on the 1200G's is due to the prototype-type nature of the locomotives. Because the 1200G's have a new engine system, fuel system and control system entirely different from any that the company has ever produced, there were probably several instances where the operator noted a problem where the operator's description, the maintainer's experience or lack of proper diagnostics from the micro lead to no defect being found. A prime example of this is the backfire problem which was reported several times but no defect was found until a later date.

The auxiliary generator defects at 13.2% of the reported defects took several months to solve and the root cause of the defect was not related to the auxiliary generator itself. It was found that air borne debris was in the carbody near the auxiliary generator. This debris was being ingested by the auxiliary generator causing the brushes, commutator and slip rings to be coated with a film of dirt. To eliminate the problem Boise Locomotive Co. installed impingement filters over the air vents on the auxiliary generator housing. Since the installation of the impingement filters there have been no auxiliary generator defects.

The fuel pressure, fuel system and some of the no load defects were for the most part due to problems with the LNG regulator (regulator plunger sticking). In fact, two of the most serious LNG leak problems occurred when the plunger on the LNG regulator failed to close when the locomotives would not start. This allowed LNG gas to flow through the intake system, through the turbochargers into the fresh air room setting off the methane detectors. To eliminate this from occurring again Boise Locomotive Co. revised the coding on the microprocessor to have the gas valve to the regulator shut off if the engine does not start. In addition, it is Boise Locomotive Co.'s recommendation that the regulator be changed out at every annual inspection since the plunger on the regulator will eventually stick even when not in an engine start mode. Since the regulators have been changed on a regular basis the fuel system problems have not occurred. A design change to the fuel regulator is being investigated at this time.

The bulk of the control system, microprocessor and some of the no load problems were attributed to digital output board #2. This board was found to have an internal defect that has been corrected by the installation of an external noise suppression circuit. No further problems have occurred since the installation of the noise suppression circuits. A new board is in development now that will eliminate the need for the noise suppression circuit.

The defects associated with methane sensors and other probes was found to be directly related to moisture in the connections. An improved sealing method as senor and probe connections has all but eliminated this problem.

The defects associated with the LNG engine are deemed to be of the infant mortality variety except for the backfire, engine control module (ECM) and no start problems. Boise Locomotive Co. believes that the last three defects above are related to an inherent operational problem related to engine design. The 3516 SITA LNG engine was originally designed as a electrical power generation engine that typically runs at full load continually. From the duty cycles shown that appeared earlier it can be seen that the 1200G application of this engine is anything but a high, constant load application. In fact, the predominant loading is in the idle position. Boise Locomotive, in conjunction with Caterpillar, has determined that when the LNG engine is running at idle or low throttle positions the turbo boost pressure is low enough to allow the downward stroke of the piston to create a vacuum in the cylinder. This vacuum in turn was drawing oil past the valve umbrella seals, down the valve guides, into the cylinders resulting in oil deposits at the bottom of the head. When the engine was operated in high load conditions these deposits would burn causing the ECM to sense an other-than-optimum engine operating condition, causing the engine to predetonate and shut down. The condition also allows deposits to form on the valve guides and valves and that may be causing cold start problems. To date only one engine valve has been burnt on the ATSF 1200. Caterpillar has developed a revised head for the LNG engine that has tighter clearance on the valve guides, an improved seal with the single lip seal replaced by a multiple lip seal (equivalent to 60 lip rings per inch) and the valves are of two angle design rather than the original single angle design. A full set of these new design heads was installed on ATSF 1200 in January, 1997, for testing. To immediately mitigate the problem Boise Locomotive Co. recommends that the 1200G's be shut down when possible to reduce idling time.

To adequately measure how the above defects have been dealt with during the service life of the 1200G's one can look at mean days between failure. From the in service date for each 1200G through the end of 1995 (1,716 in service days) a total of 84 defects (Including no defects found) were reported for a mean days between reported failure of 20.42 days. In 1996 (1,464 in service days) there were 30 defects (Including no defects found) reported for a mean days between reported defects of 48.83 days. However, of the 1996 defects reported 27 occurred in the first six months; from July 1, 1996, through January 31, 1997, (860 in service days) there have only been 3 reported defects for a mean days between reported defects of 286.67 days.

Availability of the units has not been tracked as the contracts that Boise Locomotive Co. has with the Union Pacific and the Burlington Northern Santa Fe recognize that the 1200G's are test locomotives. Each contract contains clauses that allow the Boise Locomotive Co. a limited period of time to make repairs and adjustments before an availability penalty applies. In all cases, the company has made repairs to defects before the elapsed time resulted in an availability penalty. In most cases repairs are made when the locomotives are in for fueling/servicing or during their scheduled maintenance.

Conclusion

The 1200G test program on the Union Pacific and the Burlington Northern Santa Fe has been the only successful demonstration to date of the feasibility and safety of using LNG as an alternative fuel. The 1200G's have proven that an LNG powered switcher locomotive can be operated and maintained efficiently and safely much the same as conventional diesel powered switcher locomotive.

We would like to thank the following individuals from the Boise Locomotive Co. who have contributed information and their time in the preparation of this paper:
David Brannan, Operations & Maintenance, BLC

Doug Graybeal, Service Department, BLC
Jim Larkin, Program Manager 1200G Program, BLC
John Reynolds, Service Department, BLC

We would also like to thank Mr. R. Bryan Morrison, formerly of the ATSF, for supplying the tractive effort test data performed by the ATSF.

For a more detailed technical description of the 1200G please read:

The MK1200G Switching Locomotive
Jim Larkin, 1200G Program Manager, MK Rail Corp.
Report of New Developments Committee
Locomotive Maintenance Officers Association - 1995

ANNEX 1

ATSF 1200

1/12/95	Low fuel pressure	Replaced PCV 3
1/29/95	B/O methane sensor	Replaced #6 sensor
2/6/95	B/O sander	Water in sand box removed
2/16/95	ECM shutdown	No defect found
2/19/95	Not loading	Replaced PWM board
2/22/95	Methane detection	No leak - reset breaker
2/24/95	Fuel level bouncing	No defect found
3/3/95	Would not run	Auxiliary Generator breaker down
4/10/95	Not loading	Replaced digital output board #2
4/14/95	Not loading	Replaced digital output & input board
7/29/95	Would not start	No defect - unit started
8/6/95	No load	Changed CPU board
8/24/95	High fuel pressure	Adjusted fuel regulator
8/31/95	B/O Alarm bell	Replaced DOP board #2
9/23/95	B/O Train Line Interface Panel	Replaced interface panel
12/30/95	Methane sensor going off	Regulator stuck - Sprauge regulator replaced
1/27/96	ECM Engine kill	Ran engine 45 min until fault cleared

2/9/96	Would not start	Defective output board
2/11/96	ECM Engine kill	Ran engine 45 min until fault cleared
2/27/96	ECM Engine kill	Ran engine 45 min until fault cleared
3/5/96	Would not run	No defect found
3/8/96	Would not start	Replaced timing pick-up
3/16/96	#1 Cooling fan off	Grounded - replaced fan fuses
3/25/96	Low water shut down	Replaced all gaskets head to manifold
3/27/96	Would not run	No fuel pressure - replaced PCV 3 regulator
5/20/96	Would not start	Replaced timing pick-up
5/29/96	Not loading	Micro setting wrong-micro adjusted
9/17/96	Backfire	Burnt engine valve, piston & liner replaced
11/13/96	Water leak	Defective burst disk on vaporizer replaced

ATSF 1201

1/24/95	B/O Methane sensor	Replaced sensor
2/5/95	B/O Methane sensor	Re-calibrate sensor
2/13/95	Methane strobes flashing	Ground at #1 sensor repaired
2/22/95	B/O Sander	Changed #2 sander tip
3/23/95	B/O Methane sensor	Water in sensor - water dried out
3/28/95	Auxiliary generator fault	Replaced burnt off wire lug
4/10/95	Horn button sticking	Cleaned horn button
4/24/95	B/O Compressor fuse	Replaced fuse
5/29/95	Not loading	Repaired output board
6/29/95	B/O Load meter	Replaced load meter
9/23/95	B/O Train Line Interface Panel	Replaced panel
9/27/95	B/O Timing sensor	Replaced sensor

10/6/95	#5 Methane failure	Replaced methane board
10/14/95	B/O Methanse sensor	Replaced sensor
10/15/95	Methane fault	Replaced methane monitor
12/22/95	GFC Contactor not engaging	Replaced GFC contactor
12/24/95	PWM Board not communicating	Replaced PWM board
12/26/95	No auxiliary generator	Unit started 3rd try
12/29/95	Fuel over-pressure	Replaced Cash Acme regulator
1/27/96	Engine shut down - low oil pressure	No defect found
2/18/95	No auxiliary generator	Cleaned slip rings
3/5/96	Would not run	No defect found
3/13/96	A1 Valve stuck	Cleaned and rebuilt A1 valve
5/20/96	Code on ECM	Replaced spark plug nd transformer
11/13/96	CIM Screen not functioning	Replaced CIM screen
UP 1298		
10/30/94	Stack temperature probe	Replaced switch
11/4/94	Low gas pressure	Replaced economizer valve
11/14/94	B/O #1 cooling fan	Replaced #1 cooling fan
1/21/95	Would not start	Dried water out of EIS plug
2/16/95	ECM Shutdown	No defect found
2/17/95	ECM Shutdown	No defect found
2/19/95	Would not start	Sticking STA contactor repaired
2/23/95	B/O Fuel gauge	No defect found
3/12/95	Backfire	No defect found
3/22/95	Backfire	Replaced fuel regulator
3/24/95	Backfire	No defect found
3/31/95	Backfire	No defect found

4/9/95	Fuel over-pressure	Adjusted fuel regulator
4/18/95	Dropping load	No defect found
4/19/95	No fuel pressure	Replaced PCV #2
5/7/95	Not charging	Replaced VR-10
5/23/96	Microprocessor locking up	Replaced chips in micro
6/2/95	No companion voltage	Replaced brushes
6/9/95	No auxiliary generator	No defect found
6/24/95	No companion voltage	Cleaned brushes
7/7/95	No auxiliary generator	No defect found
7/12/95	ECM shutdown	No defect found
7/14/95	Backfire	Electrical miss-wire repaired
7/29/95	No auxiliary generator	Replaced brushes & stoned commutator
8/9/95	No auxiliary generator	Cleaned brushes
8/11/95	No auxiliary generator	Cleaned brushes & commutator
8/16/95	No auxiliary generator	Replaced B/O rectifier
9/12/95	B/O Microprocessor screen	Replaced screen
9/20/95	B/O Timing Sensor	Replaced timing sensor
11/30/95	Engine shutdown-Methane danger	Replaced fuel regulator
12/11/95	No auxiliary generator	Stoned commutator
2/20/96	Methane sensor went off	No defect found-suspected water in sensor
4/17/96	Low fuel pressure	Filled fuel tank - no further problem
6/15/96	Low battery voltage	Replaced battery
UP 1299		
12/20/94	Leaking toilet	Replaced seal in toilet
1/17/95	Fuel leak	Replaced SV1
1/18/95	B/O Alarm Bell	Replaced digital output board #2

1/27/95	B/O Alarm Bell	Replaced digital output board #2
2/9/95	B/O headlight	Re-attached wire on headlight resistor
2/26/95	Fuel level 3/4 when full	No defect found
3/23/95	White smoke out stack	Replaced broken spacer plate under 1 head
4/1/95	Fuel over-pressure	Case broken Acme regulator - replaced regulator
4/4/95	B/O Alarm bell	Replaced alarm bell
4/15/95	Only loading 400 amps	No defect found
4/22/95	Not loading above notch 6	Replaced oxygen sensor
5/5/95	B/O #2 digital output board	Replaced digital output board #2
5/7/95	B/O Independent brake valve	Replaced independent brake valve
6/23/95	B/O Sander	Replaced B/O interface panel
7/25/95	B/O Microprocessor power supply	Replaced power supply
10/19/95	Reversor would not move	Repaired reversor
12/21/95	No auxiliary generator	Stoned slip rings
12/30/95	No auxiliary generator	Stoned commutator
3/5/96	No auxiliary generator	Cleaned slip rings
3/6/96	No auxiliary generator	No defect found
3/19/96	B/O Alarm bell	Replaced digital output board #2
3/23/96	Low oil fault	No defect found
3/27/96	ECM Engine kill	Ran engine 45 min until fault cleared
3/28/96	Would not start	Replaced B/O engine speed sensor
4/10/96	PCS would not reset	Replaced A1 air valve
6/3/96	Would not start	No air in fuel valve system - no defect found. Engine started when air put on unit.

III. LOCOMOTIVE ENGINE BEARING DEVELOPMENTS

Mr. John Sadler of CN Rail is gathering further technical information in order to fully develop this paper at the time of publication of the LMOA book, having been distracted from research by a small incident of flooding on the Red River in his home province of Manitoba.

Mr. Sadler will present a fully developed technical paper on locomotive engine bearing developments at the 1997 LMOA Technical Conference, where the paper will be available in handout form.

The paper will also appear in its entirety in the 1998 LMOA book.

IV. PROPER USE OF GASKETS AND SEALS

Prepared by
Jack Kuhns, Durox

The title of this paper is the proper use of gaskets and seals. Together we will share a mental picture of the physical makeup of gaskets and seals, the forces in a flanged connection, the proper preparation of flanges and how all this relates to our industry.

We'll begin with what makes a gasket a gasket and a seal a seal. Then, with that as a background, we'll put the proper use of gaskets and seals into perspective. By the end of this paper we'll all agree that proper training equals proper application and proper application equals proper results.

Gaskets and seals are the least expensive components having the greatest effect on a component's life cycle.

What Is A Gasket? (The Technical Makeup of Gaskets)

We are all aware that gaskets in one form or another are used in the assembly of just about every machine that has ever been invented. Interestingly, two industries where sealing seems to be a primary design consideration are the design and construction of submarines and space shuttles. In just about all others, including ours, the gasket is asked to compensate for what the original design did not address; in other words, stopping leaks.

A gasket is generally a composite, a combination of synthetic industrial fiber and rubber bound together in sheet form by one of two processes. The composite gasket sheet can be manufactured by either the paper style continuous roll method, called beater addition, or by the calender sheeting process called compressed. In the beater addition roll method, a slurry of water, fiber and rubber binder is mixed and continuously fed through a series of rolls which determine the thickness and density of the gasket sheet. This automated system produces a gasket sheet that is low in cost. In the compressed sheet process, a dough is created using fibers and rubber. These highly controllable batches are placed on a single machine with a single operator. All the mixing, where densification takes place is between two rollers over and over until the desired thickness and physical properties are formed. The major difference between the two processes is that the calender sheeting process is more expensive but has the advantage of producing a mix of much higher density. Higher density means better sealability and increased long term performance.

Gaskets can be best understood by thinking of them in this simple way; a gasket is really an expansion joint! A gasket must (1) react to the different thermal expansion rates of the two components it is between; (2) react to the different vibration rates of the two flanges it is between and (3) react to the clamp load placed on it by the fastening system. Now lets qualify a leak in terms of an amount. (fig. 1) Looking at the chart 5.0 Milliliters per hour equals ten drops per hour or 1 drop every 6 minutes totals 11.60 gallons per year. This being understood, a gasket can be made of just about any material as long as it conforms to the above criteria. As already mentioned, gasket sheet is made of different combinations and percentages of elastomers and fibers. This is very important as the fibers form the backbone or strength of the gasket, while the elastomer provides the resiliency and flexibility. Gasket material manufactured with long-term life and reliability in mind must also balance these requirements against cost effectiveness.

For the locomotive diesel, the most

cost effective and versatile base material is aramid fiber, such as Dupont's Kevlar tm. Aramids are very strong, durable and versatile materials; they are also more expensive in comparison to other base materials such as cellulose.

The combination of the different materials is a science. The balance between the amounts of the different materials used determines the price. The resultant performance determines the cost. Less expensive combinations can be substituted for performance and quality quite easily but can add hidden costs when problems occur. Gasketing products that meet the toughest standards of testing and have proven combinations of materials should be the only ones considered.

What Is A Gasket's Purpose?

A gasket's purpose as outlined is to
(1) provide a resilient connection between flanges that will either respond in unison to the flanges on either side or to isolate one from the other;
(2) seal the media flowing through the flanges;
(3) provide a proper dimensional thickness with enough compressibility to compensate for manufacturing tolerance variations of the assemblies or mismatch of parts during combined major overhauls;
(4) provide enough surface sealability to compensate for damaged flanges due to corrosion, rust, or poorly machined surfaces; and
(5) enhance life cycle of component

Are There Different Types of Gaskets?

As previously mentioned, different materials can be used to accomplish the gaskets' primary functions, although the combinations must be able to cover all the bases without sacrificing the joint integrity.

The factors affecting a gasket's ability to seal are fixed in nature's laws of physics. These laws determine a material's adaptability to gasketing. Therefore, gasket design engineering is just like other design engineering: it is a series of compromises dictated by various factors.

Temperature, for one, quickly determines what materials get used where. Carbon, graphite and ceramics are materials often used when the temperatures exceed 400 or 500 F. In that case the high price of these materials is justified. Price versus cost is another compromise. There are other choices such as glass fiber, rock wool (which is a mineral) or cellulose. Each of these has different properties that must also be considered and qualified.

The ratio of Kevlar or similar base material to rubber binder determines the way the gasket reacts to the applied clamp load, the thermal cycling and vibration. We will explore clamp loan in depth later.

First.....

What Is A Seal?

A seal is a deformable material that has been chosen over a flat gasket for several different reasons. The primary reason could be because the flange shape could not support the clamp load necessary for a flat gasket. Perhaps the available flange configuration required a more complex or three dimensional shape. Or, perhaps the pressures needing to be sealed are low enough that a simple face seal will do the job.

This of course, is not to imply that gaskets are for high pressure and seals are for low pressure. It only means that gaskets are easier to design when internal pressures are high and there is sufficient available flange strength to support a properly loaded flat gasket. Seals require tighter adherence to tolerances and usually do not allow much, if any, flange surface corrosion in the area of the line contact or in the surface of the seal's gland or groove.

Seals can be made of many different elastomers, although there are few materials that can provide across the board versatility and remain cost effective at the same time.

The common failure mode of seals is to get hard and brittle. This is the result of the elastomer negatively reacting to the temperature or media with which it is in contact. Most often the plasticizers will leach out or be baked out as evidence of this negative reaction.

Another common failure mode is compression set. This is a gradual loss of memory of the seal, measured as a percentage. This condition is the result of using a polymer that was pushed beyond its limits. All polymers have upper and lower temperature limits. When a service pushes these limits, the seal may work in the short term. The long term effect will be a high compression set, with a rapid loss of plasticizers. This results in the hardening or aging of the seal. The best practice is to select a polymer with a temperature cushion of about 75 deg. above and below the extremes of the intended application. Next, formulate the compound for the media to be sealed. Some materials such as Epdm have excellent resistance to water and steam and poor resistance to oils.

Other compounds such as nitriles and polychloroprenes have good oil resistance but may fall short in the upper end of the temperature range. Silicones can be compounded for a variety of specialties but often compromise desirable characteristics in the process, limiting their versatility. Specially compounded fluoroelastomers have excellent versatility when optimized for the locomotive diesel engine.

Remember, rubber compounds like gasket compounds are compromises based on cost, temperature of the application, expected service life and media to be sealed.

What Is A Seal's Purpose?

The primary purpose of a seal is similar to that of a flat gasket, to seal out, or in, whatever media is present. A seal is generally not intended to carry any load other than that which is necessary for attaining a seal. However, in the case of large compression type connections such as those on the locomotive the seal is intended to carry the vibrations, thermal cycles and weight of the hardware. Premature seal failure should not be the reason a component must be replaced.

Are There Different Types of Seals?

There are many different types of seals of course, but in this paper we will discuss in depth those that use an elastomer as the primary seal.

There are static and dynamic seals. A static seal is one that remains fixed in place and is intended to seal under the force of compression and generally with only line contact, such as an o'ring.

A dynamic seal is intended to seal against motion such as on a hydraulic cylinder shaft or on a valve guide. A rotating shaft seal is also classified as dynamic seal. Air brake valves use both static and dynamic seals.

One design of seals attempts to utilize the best properties of both gaskets and seals. It uses elastomer seals with metal carriers. The elastomer is molded to either the O.D., I.D. or both of the carrier depending on the need of the intended flange opening. This design is based on the premise that the flange surface will be in a newly machined, flat condition. Corrosion in the area of the seal beads must be minimal. This is because the seal beads must be very small in both height and width and can not protrude onto the flat surface area of the flange. This design could have good success if the flange surfaces could be machined to accept the mating seal bead and if production tolerances of individual components could be held tight enough to allow multiple piece assemblies to fit accurately together in a leak free manner.

Of course seals can be made out of materials other than an elastomer, such as a piston ring. Air is even used under pressure in areas where temperatures are too high for an elastomer or the wear rate of a metal seal would be unacceptable. ASTM standards which are used to measure different aspects of gasket and seal manufacturing can be a good reference or starting point in the evaluation of a gasket material's or seal material's suitability for a particular application.

Proper Application.

Training! Training! Training!

As mentioned in the beginning, there is no substitute for thorough training. An explanation of clamp loading will help the craftsman understand the forces involved in a flanged connection.

Understanding Clamp Loading.

The following factors are present in any flanged connection:

1. The pressure to be sealed.
2. The surface area of the gasket or seal.
3. The total available clamp force of the fastening system.

Numbers two and three combine to resist number one.

Fasteners' Contribution To Equation.
(Bolt Strength and Yield Points)

For clarity let's look at a graph of bolt sizes and strengths (fig 2). Let's say you have a flange that has four 1/2 inch grade five bolts torqued to 60 ft lbs. They each exert 7,560 psi. They combine for a total pressure of 7,560 x 4 or, 30,240 lbs of available clamp stress. These data are taken from industry fastener standards and will vary slightly from one fastener manufacturer to another, but the formula is the same. You then divide this number by the total surface area of the gasket.

From the graph, you see that our gasket has a total surface area of 10 square inches (fig 3).This places 3024 psi of clamping stress on the gasket (fig 4). It is important to remember that the individual fastener force is always more than imagined. When incorrectly tightening or overtightening a flange, the force is concentrated under the head and nut of the fastener. This can easily bend or warp a flange that is not strong enough to resist this. This is why flanges become damaged when improper procedures are allowed.

We have all either asked or been asked...did you try and tighten it first? Therefore, the importance of proper torquing in a 1/2, 2/3, full, stepped process cannot be emphasized enough. This is true for seals as well as gaskets, as flange distortion from past practices or thermal cycle aging dramatically affects the ability of a gasket or a seal to perform.

Another factor that effects clamping stress particularly, in flat gasketing, is compressibility of the gasket. Compressibility is the reaction of the gasket to the combined clamp stress. Different gaskets have different ratings for this, but most are in the 7 to 17% range of the original thickness.

This must be compensated for in the torquing process as ample time must be allowed for it to take place. Just a few moments' pause during the final stage of the torquing process allows for the gasket to react. Do not be misled though. Compression under clamping load is an important part of the sealing process.

It is at this point that the gasket is pressed or densified into the flange surface imperfections, cutting off leak paths. The two flanges and the gasket or seal now become a live expansion joint.

Surface Preparation.

This brings us to surface preparation. It may seem that we are going about this discussion backwards, as surface preparation is actually the first step. But now, with our background painted, our mental picture is ready for this first step.

Identifying nonparallel flanges can be done in a variety of different ways. The simplest method is to take a sanding block or flat file across the flange surface exposing high areas as shiny spots. You can use bluing to assist in this step. The high spots can then be machined or sanded back to parallel. The proper RMS finish can then be recreated. This should be in the 125 to 500 range for most gasket surfaces.

The use of disc grinders for flange cleanup seems to be an industry standard. An interesting parallel is, so are fluid leaks. These grinders, thought to be timesaving devices, can cause severe damage, with improper or careless use destroying RMS finishes, flange flatness, and by grinding in leakpaths. Again, the issue is price versus cost, time saved versus flange repair or replacement. For seals, the finish should be free of burrs or nicks that could cut the seal under compression.

Under this topic lubrication should be addressed. The rules of thumb are that gaskets should be applied dry and seals should be lubricated. Lubricating seals prior to installation will aid in the assembly as well as help the seal settle into the sealing gland. However, it is imperative to check with the seal supplier for a listing of approved lubricants, as some lubricants can damage some seals by attacking the rubber compound.

Additional Sealing Material - Pros and Cons.

Another highly debated topic is the use of additional sealing material. This comes in the form of paste, liquid, rtv type caulk and grease. Certain locations require the use of some form of caulk such as gasket junctions or dovetails.

The practice of greasing gaskets prior to installation stems from two reasons: One, the need to help hold the gasket in place; and two, to help in initial sealability. The answer for the first is to use a small amount of adhesive, I repeat small!, to hold the gasket in place. In this area other ideas such as component and gasket mounting pins can be used. The answer for the second is to properly prepare the surface of the flanges and to properly torque the fasteners. If a gasket requires grease to seal, then the grease is hiding some condition of the flange that the grease is filling in or being hydraulically locked into.

Now, when the component gets hot the grease liquefies and your clamp load diminishes. Very simply put, for best long term success do not put anything in the place of craftsmanship.

What about coating the gaskets with RTV? How many leak paths do you have with two flanges and a gasket? Two, one on either side of the gasket. Now coat the gasket with RTV, which, once dry is a solid layer of material. How many leak paths do you have now? Four, one on either side of each layer (fig 5).

The Importance Of Gaskets and Seals Relative To Safety and The Environment

Any discussion of leaks must mention safety. The oily running board or shop floor is one thing that can easily be identified. The effect of that oily running board or shop floor on operating personnel or the surrounding environment must be considered. That small leak when combined with rain or wash water can produce a dangerous situation or environmental threat.

Not to be overlooked are how the effects of flange load, thermal cycling, vibration and poor maintenance practices have affected the exhaust system components. They are subject to the extreme limits of all these factors. Remember, gasket sealing materials choices are limited due to the high temperatures, and this puts more emphasis on the other factors affecting gasketing performance, such as proper torquing.

Related Cleanup and Other Downstream Costs

The costs of repairing leaks go far beyond the obvious hourly shop time (labor rate). Let's look at a simple buildup of shop time and hence, costs, for a locomotive that has come to a service center for fuel and an oil leak has been discovered at the upper deck housing. It is determined the locomotive must be shopped for repairs. The lost time and cost clock starts here with the employee who had to identify and report the leak (:05 min.), to the time of the employees who had to remove the locomotive from the consist, replace it and place the problem locomotive in the shop (:30 x 2 employees = 1 hr.), to the scheduler or planner who must classify and assign the work (:05 min.), to the employees who actually do the repair and their supervisors (:45 x 2 employees = 1.5 hr.), to the material department employee who must get parts for the repair (:05), to the employees who must clean up the locomotive after the repairs are completed (:30 x 2 employees = 1 hr.). You must also include the overhead and hourly rates of the shop maintenance crew for maintaining the cleaning equipment (:30 min.). Let's not stop here: be sure to include the cost of employees maintaining the pollution or oil skimming plants (:15 min.).

Now let's put the locomotive back on the ready track in a consist, run an air test and apply a 24 hour dispatch sheet (:30 x 2 employees = 1 hr.). The total is 5-1/2 hours of unproductive locomotive revenue producing time, not including any material or parts costs. To some these numbers may seem a little pessimistic but to others very optimistic. Either way they are very real.

Proper Storage.

The proper storage of gaskets and seals should be put into perspective, not just because of their cost, but by a reminder of our opening statement: they are the least expensive item that have the greatest effect on cost. So shouldn't they be afforded the same consideration as more expensive components?

Most gasketing and sealing products have a shelf life of 3 to 5 years. This is providing the gaskets or seals are stored out of direct sunlight and are not contaminated by foreign materials. Airbrake seals and gaskets cannot be installed if over 5 years old and cannot be sold if over 3 years old.

In Conclusion

Continuous improvement in gasketing and sealing is vital to the future of our industry and our environment. Often answers come in the form of a new support component or product such as these:

Air compressor water line manifold;
An O'ring in place of a gasket on a radiator header,
Flex fuel lines in place of ball and socket sealed metal lines;
Eliminating connections where possible such as on GE water inlet manifolds;
Flex water lines to the after-cooler replacing rigid metal pipes;
Under EMD top deck cover, splash deflectors.

We have discussed the physical make up of gaskets and seals. We have discussed some of the limiting factors that affect them such as application procedures and flange design. This last point is of course most important as we pointed out in the beginning: in most cases, we must work with what is already in service as concerns as flange design. We have learned, though, that what we do have is choices. We can improve the design of gaskets and seals and the materials they are made of. We can improve training, maintenance procedures and practices. Armed with this knowledge we, together, can work towards cost effective improvements to reduce fuel, oil, water, air, and exhaust leaks.

And remember, our environment is on loan from our children!

FIGURE 1.

SEALABILITY OF GASKET MATERIALS

MILLILITERS PER HOUR	GALLONS PER YEAR
0	0
.1	0.231
.2	0.462
.3	0.693
.4	0.924
.5	1.16
.6	1.39
.7	1.62
.8	1.85
.9	2.08
1.0	2.31
2.0	4.62
3.0	6.93
4.0	9.24
5.0	11.60

One Milliliter / Hour =2.3144 Gallons / Year

One Liter =0.264172 Gallons

One Gallon =3.785412 Liters

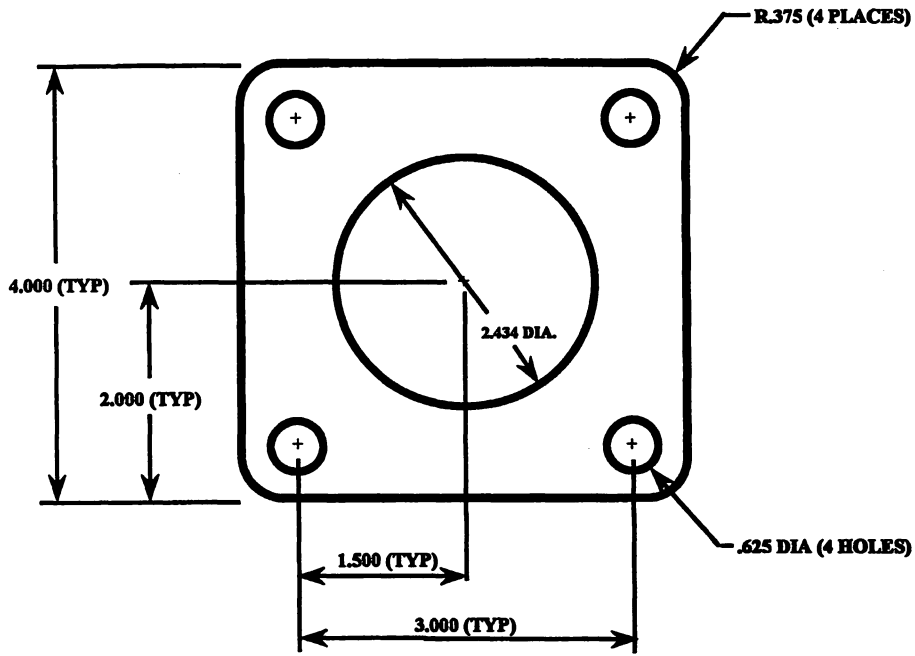
One Milliliter =2 Liquid Drops (approx)

FIGURE 2.

LOAD ON ALLOY STEEL STUD BOLTS UNDER TORQUE

Nominal Diameter of Bolt (inches)	Number of Threads Per Inch	Diameter of Root of Thread (inches)	Area at Root of Thread (in.²)	STRESS					
				30,000 psi		45,000 psi		60,000 psi	
				Torque (ft./lbs.)	Compression (lbs.)	Torque (ft./lbs.)	Compression (lbs.)	Torque (ft./lbs.)	Compression (lbs.)
1/4	20	.185	.027	4	810	6	1,215	8	1,620
5/16	18	.240	.045	8	1,350	12	2,025	16	2,700
3/8	16	.294	.068	12	2,040	18	3,060	24	4,080
7/16	14	.345	.093	20	2,790	30	4,185	40	5,580
1/2	**13**	**.400**	**.126**	**30**	**3,780**	**45**	**5,670**	**60**	**7,560**
9/16	12	.454	.162	45	4,860	68	7,290	90	9,720
5/8	11	.507	.202	60	6,060	90	9,090	120	12,120
3/4	10	.620	.302	100	9,060	150	13,590	200	18,120
7/8	9	.731	.419	160	12,570	240	18,855	320	25,140
1	8	.838	.551	245	16,530	368	24,795	490	33,060
1-1/8	8	.963	.728	355	21,840	533	32,760	710	43,680
1-1/4	8	1.088	.929	500	27,870	750	41,805	1,000	55,740
1-3/8	8	1.213	1.155	680	34,650	1,020	51,975	1,360	69,300
1-1/2	8	1.338	1.405	800	42,150	1,200	63,225	1,600	84,300
1-5/8	8	1.463	1.680	1,100	50,400	1,650	75,600	2,200	100,800
1-3/4	8	1.588	1.980	1,500	59,400	2,250	89,100	3,000	118,800
1-7/8	8	1.713	2.304	2,000	69,120	3,000	103,680	4,000	138,240
2	8	1.838	2.652	2,200	79,560	3,300	119,340	4,400	159,120
2-1/4	8	2.088	3.423	3,180	102,690	4,770	154,035	6,360	205,380
2-1/2	8	2.338	4.292	4,400	128,760	6,600	193,140	8,800	257,520
2-3/4	8	2.588	5.259	5,920	157,770	8,860	236,655	11,840	315,540
3	8	2.838	6.324	7,720	189,720	11,580	284,580	15,440	379,440

FIGURE 3.



TOTAL SURFACE AREA = 10 SQ. IN.

FIGURE 4.

CALCULATIONS

4" x 4" GASKET WITH .375 RAD. CORNERS = 15.8793 SQUARE INCHES

MINUS

(4) HOLES @ .625 DIAMETER = 1.2272 SQUARE INCHES

MINUS

(1) HOLE @ 2.434 DIAMETER = 4.6530 SQUARE INCHES

TOTAL SURFACE AREA = 10 SQUARE INCHES OF GASKET

(1/2" BOLT) 7,560 x (4) BOLTS = 30,240 TOTAL Lbs

30,240 ÷ 10 SQ. IN. = 3024 PSI OF CLAMP STRESS

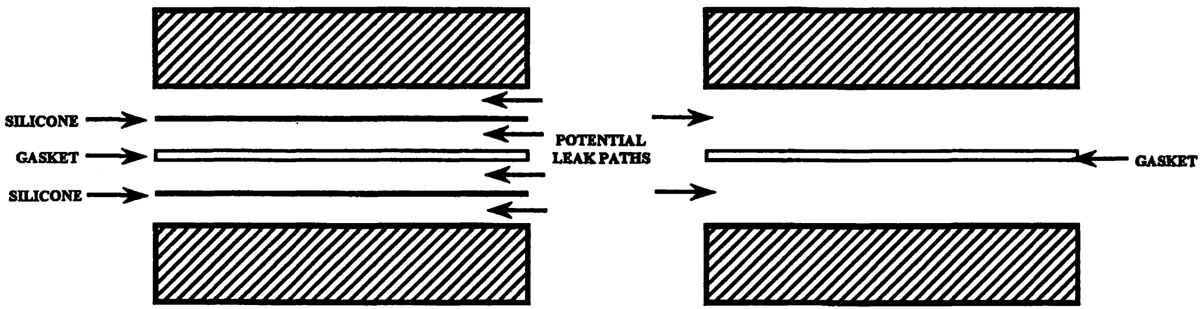
FIGURE 5.

POTENTIAL LEAK PATHS

SILICONE COATING

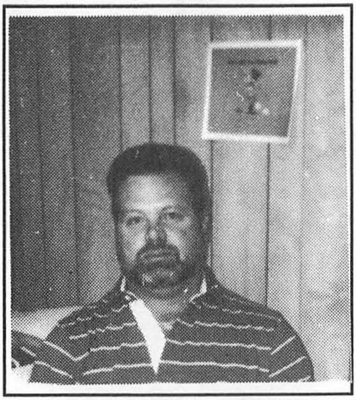
RTV tm TYPE

WITH   WITHOUT



REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

TUESDAY, SEPTEMBER 16, 1997
9:00 A.M.



WILLIAM LECHNER, Chairman
General Foreman - Air Brake Shop and Material Mgmt.
Conrail
Altoona, PA

Vice Chairman
J. BRAWLEY
Mgr.-Matl. Control
Amtrak
Beech Grove, IN

COMMITTEE MEMBERS

A. Chapman	Asst. Mgr. Inv. Cont.	CSX Trans	Waycross, GA
A. Chermak	Asst. Dir. Mat. Mgmt.	Wisconsin Central	Fond Du Lac, WI
R. Faulconbridge	Manager-Materials	CP Rail	Montreal, PQ
R. Florczyk	Mgr-Loco. Parts Sales	General Electric	Philadelphia, PA
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J. Minnie	Manager-Material	BN/SF	West Burlington, IA
D. Neu	Mgr-Supply Opns.	Union Pacific	N. Platte, NE
D. Rhyne	Matls. Analyst	Electro Motive	La Grange, Il
S. Sonke	Transit & Rail Industry Specialist	Applied Image Tech.	Midlothian, VA
R. Swenson	Managing Dir.	Genwest Rail Svcs.	Newport, NH

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, 23, and Todd William, 21, 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.

I. RAISING OUR STANDARDS FOR SAFETY

Prepared by
Alan B. Chapman,
CSXT Supply & Service Management

At the end of 1989, CSXT's FRA-reportable injuries totaled 2686. Our Supply and Services Management department reported a total of 14 injuries. Needless to say, these numbers were totally unacceptable. Far too many of our teammates were leaving the job injured.

At the end of 1996, CSXT's FRA-reportable injuries totaled 570. Our Supply and Services Management department reported a total of 2 injuries. While this is not where we want to be, our figures indicate much improvement has been made. The only acceptable goal for our company's safety record is "0", which simply indicates that all our employees return home from work injury free.

"Safety Is Priority #1 At CSXT"

The priority placed on safety by CSXT has resulted in a dramatic 82 percent reduction in the FRA reportable injury rate since 1989. The results are based on the unfailing commitment of both contract workers and management.

All Employees Are Empowered

Perhaps the most important element of the company's safety-first culture is that employees at all levels are empowered by management to follow the motto, "No job is so important...no service so urgent...that we cannot take time to perform all work safely." Put simply, if it's not safe, don't do it. This motto emphasizes both individual responsibility for safe performance and the necessary managerial support.

CSXT's focus on safety permeates the entire organization and is continually underscored by numerous programs, publications, committees and seminars.

The company's annual safety theme and quarterly safety programs provide the umbrella under which contract employees and management work together. However, the backbone of the safety program at CSXT is the structure of safety committees that reach all levels of the company. These committees are designed to be forums for communicating and problem-solving which enable employees to address their concerns. The committee structure makes sure that no safety issue remains unresolved.

All of CSXT's safety programs, training, incentive programs and managerial emphasis are focused on attaining a goal of zero injuries and accidents. The company's employees deserve the safest working environment possible.

Supply & Services Best Safety Practices

Overlapping Safety Committee System

A Safety Committee System of overlapping, integrated committees which reach all levels of the organization encourages teamwork. Employee safety committees at the local level surface any existing safety issues or problems. If they are unresolved at the local level, the issues can be channeled from the employee, through the local safety team and overlapping committee system, through the departmental directors, through the departmental vice president, through the senior vice president transportation and if necessary through to the executive vice president. At every level the ideals and concerns of the employee(s) who raised the issue are considered, reviewed and made a part of the feedback when channeled back through the overlapping process.

Supply & Services Management
Overlapping
Safety Committee Process

Executive Vice President
& Chief Operating Officer

Senior Vice President Transportation

Vice President Supply
& Services Management

Directors and General Managers

Managers Inventory Control
and Safety Committee

Employee

Safety Committees

An active safety committee is one of the best means to consistently provide a safe and positive work environment. Employee involvement is the "corner stone" of a successful injury prevention program. Experience has shown that a joint management-employee safety committee can help the company reduce accidents and cost. Safety programs with both management and empioyee groups committed to injury prevention tend to succeed most often and to the greatest degree.

Safety committees are most beneficial to the employee injury prevention program when involved in safety inspections and audits, conducting root cause analyses, participating in job safety analyses and observations, planning and implementing the team's safety strategy and getting involved in incentive programs which include reward and recognition of individual and team safe work performance.

Supply & Services Management's safety committee policy:

Selection

Safety committees for all departments will be comprised of both management and contract employees. Supply & Services management safety committee members should be elected by their peer group from a pool consisting of volunteers or candidates offered by the local chair and/or the work force. Safety Committee Chair will be selected from among the committee members. The local safety committee make-up should be a representation of the entire team.

Training

Reference "Safety Committee Member Resource Guide" as a tool. This book is intended to be a guide for committee members and contains "no absolutes." The workings of a safety committee will vary from location to location. The resource guide is intended to provide the committee with ideas and suggestions which support and respect the variety of practices which make safety committees successful.

Rotation

Supply & Service safety committee members will serve terms not to exceed two years (unless re-elected by their peers) with half of the committee replaced each year to insure consistency during transition. The local safety committee make-up should be a representation of the entire team.

Desirable qualities for Supply & Services safety committee members to exhibit:

- Commitment to keeping themselves safe and healthy on the job and at home
- Dedication to the safety of all CSXT employees
- Knowledge of company safety rules, policies and safe work practices
- Credibility with CSXT team members
- Confidence in talking with all CXST employees about safety

issues
- Ability to influence and guide team members to change unsafe behaviors into safe behaviors
- Enthusiasm for teamwork, interacting on various projects within the overlapping process, sharing challenges and "recognition" with others on the team

Supply & Service safety committee member's job responsibilities:
- Recognize and acknowledge safe work practices and urge employees to continue working safely
- "Coach and Counsel" to change unsafe work behavior into safe work behavior
- Participate in workplace assessments (JSA'a, etc.) to identify and correct hazards and exposures
- Participate in the overlapping safety committee process
- Assist with and promote safety training classes, safety meetings, safety blitzes, clean sweeps, special safety functions, incentive and recognition programs, family oriented activities and help with the selection, proper wearing and care of personal protective equipment
- Receive safety suggestions from teammates, follow up with unsafe condition report (form PI-82) and "pass-up" items
- Take the lead in ensuring the support for injured employees both at work and at home
- Participate in facility and operation safety inspections and audits, and be willing to make recommendations and develop corrective actions as a result of their findings.

Safe Job Briefings

CSXT employees are empowered to make safe decisions. In many cases, when the safe decision is not made, injuries occur. Rules and procedures cannot be written to cover everything we do on the job. Therefore, we are empowered to make safe decisions and to take actions necessary to prevent personal injuries. Where no specific rule or procedure applies, we must rely on good judgment, following the safest course available. No action should be taken until we are fully aware of the hazards involved and have a plan to avoid an injury. In short, a safe job briefing is a brief, but specific plan to safely complete the job at hand.

Job briefings will be conducted prior to work activity, and subsequently when the activity changes.

Managers and safety team leaders conduct routine observations and evaluations of safe job briefings being performed to determine the effectiveness and quality of the job briefings. Managers must observe to ensure that there is participation by all workers in the job briefing and that adequate feedback and follow-up are provided.

Observations should be made of employee work behavior to determine if:
- all hazards (obvious and not so obvious) were noted and feedback encouraged to ensure that hazards were not missed
- all equipment to be used was inspected prior to beginning the job
- the job briefing included a visual inspection of all tools and equipment
- the job briefing included a discussion of what personal protective equipment was necessary for the job
- the participants summarized/paraphrased instructions and plans for competing the job safely and questions asked
- the group discussed how follow-up would occur and what mea-

surements would be used to determine success

"A Safe Job Briefing is a brief, but specific plan on how to safely complete a job."

Pre-Shift Equipment Inspections

Pre-shift equipment inspections will be conducted prior to operating forklifts and other material handling equipment and records of inspections will be maintained. Inspection records should be monitored and equipment evaluated regularly. To ensure that all equipment is maintained in proper running condition and safe to operate, the following procedures must be followed by all operators and supervisors:

Each day before starting work, forklift operators must inspect the equipment as recommended by CSXT, Supply & Services Management and the equipment manufacturer. If any defects are found, the equipment must be tagged "out of service" and must not be used until the defect is corrected.

Safety Skills Training

A key element of a successful injury prevention and safety management program is proper safety training to equip employees with the skills necessary to perform their work safely and efficiently.

Safety skills training will be provided on the basis of essential job functions and need. Safety skills training will be provided on the basis of essential job functions and need. Safety skills training will be provided for new hires, as refresher training, for employees who are required to be trained by CSXT or government regulations and employees whose positions directly involve the action the training is to cover. Safety skills training will be provided for the managers and supervisors of such employees, and its effectiveness demonstrated by testing and regular observations. A serious accident must not occur just because of improper training or because of an employee's failure to understand. The evaluation and testing component of the training is essential for safety skills training.

Once the training has been completed the single most important issue to address is the transfer of the newly acquired skill or knowledge to the workplace. The skill is said to be transferred when the employee, who was formerly not using the skill, is observed using it on the job.

To the extent possible, any safety skills training should be presented so its meaning is clear to the employees. To do so, managers or trainers should:

- Provide overviews of the material to be learned;
- Relate, wherever possible, the new information or skills to the employees' goals, interest, or experience;
- Reinforce what the employees learned by summarizing the program's objectives and key points discussed.

In order to promote the learning of material presented by the manager or trainer, employees must be convinced of the importance and relevance of the material. Among the ways of developing motivation are:

- Explaining the goals and objectives of the training being provided
- Relating the training to the interest, skills, and experience of the employees
- Outlining the main points to be presented during the training session(s)
- Pointing out the benefits of the safety skills training.

An effective safety skills training program allows employees to participate in the training process and to practice their skills or knowledge. Employees can become involved in the training process by participating in discussions, asking questions, contributing their knowledge and expertise, learning through hands-on and "on the job" experiences.

Supply & Services Safety Skills Training Programs

Course Title	Description	Estimated Time
Forklift Training	Operators Safety Awareness	8 Hours
Mobile Crane	Operators Safety Awareness	8 Hours
Overhead Crane	Operators Safety Awareness	8 Hours
Back Injury Prevention	Pro Back & Back In Motion	8 Hours
Defensive Driving	Defensive Driving	4 Hours
Safety Certification	Safety Certification	4 Hours
Hazardous Materials	Hazardous Material Awareness	4 Hours
CHIPS	Chemical Hazards Info Program	4 Hours
Environmental	Environmental Awareness	4 Hours
SPCC	Spill Prevention Contingency	4 Hours
S&SM System	S&SM Screens and Systems	8 Hours
OMMD	Locomotive Status Screens	4 Hours
General Safety	New Employee Orientation	8 Hours
CPR/First Aid	CPR/First Aid	4 Hours
Radio	Radio Procedures and Rules	2 Hours
Strapping Hand Tools	Strapping Hand Tool Safety	2 Hours
Slips, Trips, and Falls	Slips, Trips, and Falls Prev.	8 Hours
Tank Car Unloading	AAR Securement and Unloading	4 Hours
Lifting and Rigging	Lifting & Rigging Methods	12 Hours

Incident and Accident Reporting

Regardless of severity, all incidents, accidents or near misses must be reported, investigated and a "root cause analysis" completed. The root cause analysis will be mailed to the Director-Safety, Supply & Services within 48 hours of the reported incident.

The Five W's Of Accident Reporting:

Who Reports...

Reporting the responsibility of the individual under whose supervisory jurisdiction the incident occurs.

What To Report...

Reporting is required anytime:

- An employee or non-employee is injured on company property.
- A collision, derailment, fire, explosion, or crossing accident occurs.
- An employee has an illness which a doctor states is job related.
- A "near miss" occurs which could have resulted in serious personal injury.

Where To Report...

Supply & Services Management teams should:

- Ensure that all information on the personal injury reports is complete and accurate, and the reports have appropriate signatures. The completed reports should be forwarded to Sr. Mgr. Compliance & Reporting and to Director-Safety, Supply & Services Management.

When To Report...

A verbal report should be made immediately to Director-Safety, Supply & Services Management. Reports must be input into the accident reporting system within 24 hours of the incident. A "root cause analysis" must be completed and forwarded to Director-Safety, Supply & Services Management within 48 hours of occurrence.

Why Report...

The information from the reports is used by CSXT and the Supply & Services Department to help prevent future accidents. Accident reporting is the LAW and like all laws there are penalties for failure to comply.

The Root Cause Analysis

The root cause analysis system helps teams reactively improve by reacting to problems they experience and proactively improve by identifying potential problems before incidents, accidents and other problems occur. In each case, finding the real root cause is a key to solving a team's problems. The root cause analysis will provide your incident analysis teams with a systematic tool for developing the cause of a incident or accident and what corrective action may be required.

A root cause is defined as:

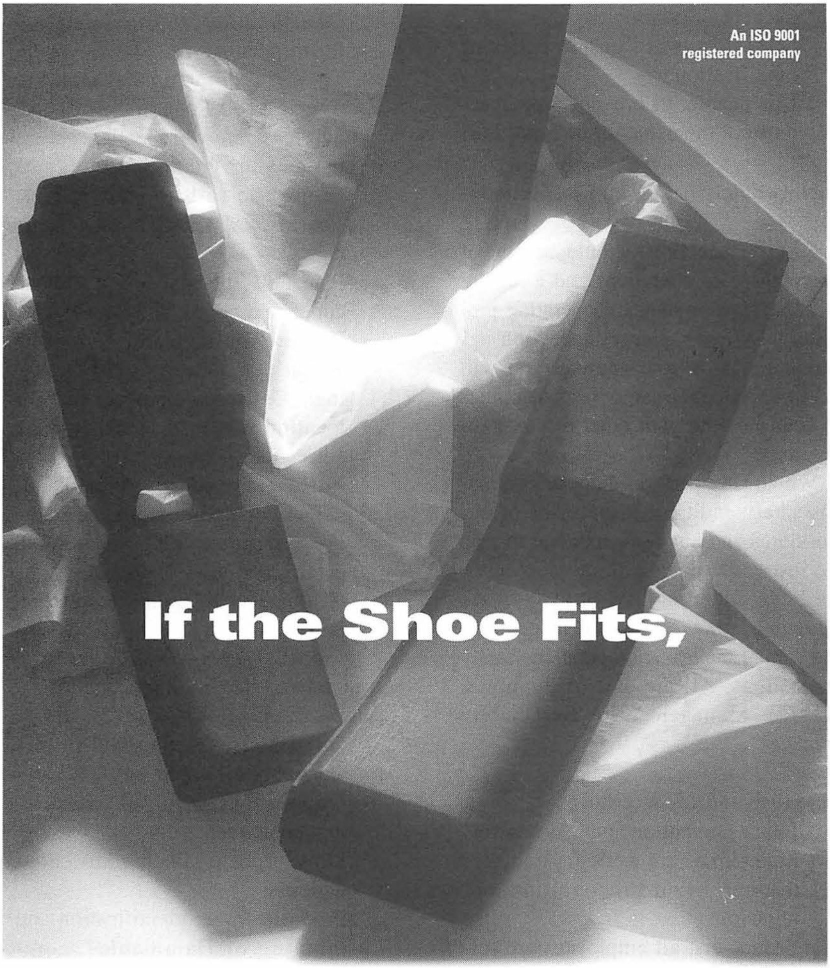
- The most basic cause(s) that can reasonably be identified and which management and the team has control to change.

Components of root cause analysis

- Determining the facts of the incident (What, When, Where and How)
- Determining the sequence of events
- Determining why the incident occurred
- Developing a root cause corrective action plan
- Evaluation and follow-up to ensure no reoccurrence.

Correction action cannot be "hit or miss". It must be:

- Formally planned, implemented and documented
- Directed toward the analyzed process
- Directed toward a specific root


An ISO 9001
registered company
If the Shoe Fits,

cause
- Directed toward the elimination of the root cause problem
- Directed toward unsafe behavior modification
- Irrevocable, to prevent a reoccurrence of the behavior or condition.

Facility Safety Audits and Inspections

Safety inspections should be part of every phase of operations and a regular element of your standard operating procedures. When a safety inspection has become part of your routine, you will have integrated the safety responsibilities of your job with your other responsibilities.

We already perform daily or continuous safety audits or inspections of our work area and environments, but to take the inspection process to the next level, we have added safety audits ("walk through"), planned general inspections and formal facility and operations safety inspections. All are part of Supply & Services Management's "Best Safety Practices".

Objectives and key successes:
- Injury prevention and loss control Maintain a safe work environment through hazard recognition and removal
- Ensure that all employees are following proper safe job procedures while working
- Determine which operations meet or exceed acceptable CSX and Supply & Services Management's safety standards
- Document and support the need for process or facility improvements
- Evaluate and measure the team's safety performance and activities
- Provide a model for a formal facility and operations inspection process.

Conducting the audits and inspections:
- Involve safety committee and other employees in conducting the inspections
- To insure that no hazards are overlooked, use a Supply & Services safety inspection checklist as your guide, but the guide should be tailored to fit your operations' specific or unique needs
- Plan how the inspection will be conducted before you start
- Review findings and corrective action plans during safety meetings. Get team members at your location involved in making the corrections
- Follow up to make sure all defects or non-compliance items are corrected and no relapse occurs
- Evaluate your team's inspection process.

At minimum a facility inspection should focus on:
- Good housekeeping and proper storage of tools and supplies
- Observations of lifting and carrying techniques
- Slips, trip and falls hazards elimination
- Proper storage, identification and labeling of flammables, combustibles and chemicals
- Proper wear, care and storage of personal protective equipment
- Safe equipment operation and work procedures in warehouses, on docks, in offices and on grounds
- Proper care of fire prevention, first aid and other emergency response equipment
- Proper inspections and maintenance and care of machinery and equipment
- Compliance with CSX and gov-

ernmental rules and policies
- Vendors and visitors are conducting their business safely, while on company property.

Job Safety Analysis

One of the best accident prevention tools supervisors possess is called a job safety analysis or "JSA". This system is used to break down any job into steps and to check each step for associated hazards. Once these hazards are indentified, a corrective action can be developed to eliminate the hazards to guard against personal injuries. Because any positive action taken can be measured using the job safety analysis, this tool can help your team to improve your safety performance record.

The job safety analysis should be conducted by the people best qualified to make the operation safe...a team made of the supervisor(s) and his skilled employees. This team will be more knowledgeable about a particular job, and can do more to spot hazards.

Set priorities for doing the JSA's by determining the jobs which have a history of previous incidents, jobs which have a high potential for disabling injury or death, and new jobs with no accident history.

Components of a job safety analysis
- Identify the sequence of the basic job steps
  - Examine a specific job by breaking it down into a series of steps and to discover potential hazards the employee may encounter.
- Record the potential hazards
  - What do you see? Do you see any slip, trip and fall hazards? Do you see any improper lifting techniques? Do you see any unnecessary lifting, pushing, pulling or twisting related to the task? Do you see potential for any body part to strike or be struck by an object?
- Recommended corrective action
  - List a corrective action for each hazard identified
  - Get employees involved in correcting the problem
- Follow up to ensure condition or behavior corrected
- Discuss finding during safety meetings.

Unsafe Condition Report

The unsafe condition report is designed to assist in reducing accidents and personal injuries sustained by CSXT employees. The local safety team's prompt handling of unsafe conditions and behaviors will provide a safe and positive work environment and help to prevent further occurrences.

To Complete the unsafe condition report
- Observance of unsafe conditions, or notification of same should be noted on the report form. The unsafe condition report can be initiated by an individual employee, a member of the local safety committee or a supervisor or manager.
- The unsafe condition should be safeguarded until the condition or defect is corrected.
- The original should be completed and delivered to the supervisor, manager or committee responsible for correction. A copy should be retained for future reference and one copy posted on the safety bulletin board.
- The individual who submitted the condition report and other employees affected by the unsafe condition must be informed of the

progress being made to correct the defect or unsafe condition.

- Every attempt should be made to correct the defect or unsafe condition in a timely manner. If for some reason the defect or unsafe condition cannot be corrected by the local team or overlapping committee, a copy of the completed form should be passed-up through the overlapping safety process to the Director-Safety, Supply & Services Management for handling. This ensures that everyone is provided feedback. It is important to note on the form what actions were being taken and by whom.

Safety Bulletin Boards and Poster Displays

Posting a variety of materials on safety bulletin boards is one of the best ways to maintain the interest of employees in injury prevention. "Interest Increased With Knowledge."

The kind of information typically found on a S&SM safety bulletin board includes:

- Unsafe condition reports and corrective actions being taken
- Company, departmental and local team injury statistics
- Company, departmental and local team safety goals & objectives
- Information about frequent causes of accidents
- Charts showing reductions in accidents
- Safety promotions and initiatives
- Minutes from company, department and local team overlapping safety meetings
- Notices about upcoming safety functions or events
- Copy of the facilities emergency response and evacuation plan
- Company, departmental and local team "alert letters"
- Results of audits, inspections and job safety analyses.

An atmosphere which promotes the health and well-being of everyone at CXST does not just happen, it requires total cooperation by both management and employees. This occurs only when all of the components of the positive safe environment exist, "when all are rewarded by being able to go home without suffering an injury or illness and when the company as a whole prospers."

II. THE RAIL INDUSTRY'S ELECTRONIC PARTS CATALOG EXCHANGE STANDARD (EPCES)

A Better Way

Prepared by
Steve Sonke,
Applied Image Technology

Background

An electronic parts catalog (EPC), as its name implies, is an electronic version of a traditional paper based maintenance library that contains assembly drawings and parts lists. An assembly drawing, commonly referred to as an exploded view, shows parts in an assembly, with callouts or bubbles associated with the parts that often show the manufacturer's part numbers. An assembly drawing is particularly important for a mechanic, because he can visually verify a part and ensure the correct part is ordered the first time. In more sophisticated EPC solutions the bubble or call-out on the drawing is "hot spotted". The mechanic communicates with the EPC by navigating to a particular assembly drawing and simply pointing at the "hotspots" and thus creates a parts requisition list.

Today, EPC's are designed to run on standard PC's in networked or stand along configurations. EPC's are specifically directed at one of the larger population segments within a rail operation - the mechanics. EPC's promise to revolutionize the shop floor in the way that PC applications have revolutionized the office with an increase in productivity and quality of work.

The purpose of the Electronic Parts Catalog Exchange Standard (EPCES) is to support the proliferation of EPC's in the rail industry. Applied Image Technology (AIT) developed EPCES under contract with the National Association of Purchasing Manager's subcommittee - the Rail Industry Forum (RIF). The RIF task team was comprised of users (railroads) and suppliers (locomotive, car and component suppliers). The Standard was published in February of 1996. The first exchange of a complete catalog was between the Electro-Motive Division of General Motors and Conrail.

EPCES Description

EPCES does not define an EPC application, but rather defines a standard for the electronic data formats used by an EPC application. EPCES understands that the components of a parts catalog are found within the following four catalog elements - text (introductory information, indices, etc.); parts data; images of drawings; and navigation information (links that maintain relationships between images and drawings and parts information). EPCES gives special treatment to each of these information elements utilizing existing international standards and defacto standards. EPCES provides a blueprint for building and assembling groups of these four catalog elements into a consistent and logical parts catalog. By utilizing existing standards, EPCES has broad vendor support and is not at variance with standards evolving in other industries. In fact, EPCES is patterned after the airline industry's ATA 2100 Standard. As ATA 2100 adopts new technology, EPCES will easily evolve in parallel.

EPCES treatment of navigation, text and data

EPCES specifies a standard generalized markup language (SGML) encoding for a parts catalog. SGML is a widely used international standard for labeling text and data in such a way that sending and receiving computer applications understand the content of the text and data. SGML labels for EPCES were defined by the RIF task team specifically for the rail industry. These labels are defined within a hierarchy providing information about relationship of the labels to each other. Thus, SGML inherently provides the navigation information necessary for an EPC application.

EPCES treatment of images and drawings

Images are bitmap renderings of drawings common in parts catalogs. EPCES utilizes the tagged image file format (TIFF) for defining images. TIFF is widely utilized today in many technologies.

Drawings (computer aided design (CAD) information is also defined by EPCES. Historically, live CAD drawings have not been available to users due to the variety and proprietary formats of CAD files. However, EPCES specifies computer graphics metafile (CGM), as it has broad industry support for 2-D graphical drawings. (The exchange between EMD and Conrail used CGM drawings exclusively.)

Why Electronic Parts Catalogs?

The rail industry is aggressively investigation and implementing EPC solutions. Intuitively most readers know that EPC's are a good investment. However, to get approval to implement EPC's that intuition must be backed up by measurable criteria and quantifiable benefits.

Justification of an EPC usually consists of a combination of hard dollar savings plus intangible benefits. (The intangible benefits often far outweight their tangible counterparts.) The tangible benefits are easy to identify and quantify. The intangible benefits often require a degree of management commitment, but they are real none the less. Almost everyone recognizes that an EPC is just a better way. The areas of justification usually include increased productivity, decreased spare parts inventory, increased fleet capacity, creating a vehicle maintenance system (VMS) database, improved safety and accuracy of repair.

Increased productivity

The task facing maintenance departments grows daily. Downsizing has hit the maintenance functions particularly hard. Maintaining more equipment with fewer personnel than several years ago seems to be the norm rather then the exception, while the locomotives and cars to be maintained become infinitely more complex. Yet the pressure to meet ever increasing equipment availability just does not go away. Simply stated, today's environment drives the requirement for improved maintenance productivity.

Mechanics today are better educated and often better qualified than their predecessors, but their administrative support has trailed the computer revolution. Study after study shows that the non-wrench time of a typical mechanic is staggering. Seldom is it ever below 40%. It is common to be as high as 50 and 60^. What's yours? A second conclusion of these studies is that over half of the non-wrench time is spent walking to a source of information, searching for information, attempting to identify parts with that information and then locating the parts needed for a repair.

Unfortunately, most of the information today is "trapped" in paper based systems and is susceptive to traditional problems - pages missing; pages ripped out by a previous user and not returned; entire manuals misfiled and not found; pages or manuals not updated; pages that are soiled and not readable; manuals in foreign languages, etc., etc. An EPC can make that information instantaneously available. Lost time searching for "trapped" information, "walk" time to a distant document library; outdated information all may be eliminated. On average a rail operation may expect to save anywhere from 30 minutes to 90 minutes per mechanic per day. The results of that productivity increase can be staggering.

Typical Example

Daily Increase Productivity (40 minutes)	.66 hours
x Number of Mechanics	100
x Work Days per Year	250
x Burden Rate	$30 / hour
= Equivalent Increase in Productivity	$495,000 per year

Decreased inventory

Inventory carrying costs are real numbers accepted by most financial managers. Decrease your inventory and you can save, in equivalent dollars, the percentage attributed to carrying costs. Carrying costs vary by organization and range from a low of just the cost of borrowing money, for example, 8% prime to a high that includes the cost of money as well as the value of space, heat, and light, obsolescence, taxes, shrinkage, damage, etc., that might be as high as 35%.

EPC's have a direct impact on inventory. Giving the mechanic the ability to visually verify a part with an image when he orders a part can reduce or eliminate the ordering of the wrong part. (Studies show that wrong parts are ordered 5% to 25% of the time.) Most parts ordered in error are never returned to the manufacturer. Instead they most often end up in a mechanic's personal safety stock or they accumulate dust in the crib.

Typical Example

Inventory - Total Value	$10,000,000
x Percentage Reduction	20%
= Dollar Reduction	$2,000,000
x Carrying Costs Percent	20%
= Savings - Carrying Costs	$400,000

Increased fleet capacity

An EPC can affect the amount of time it takes to complete a repair. Thus, if a locomotive is repaired in less time, it can be put back in service sooner. The following shows how the increase in productivity provided by an EPC can dramatically increase fleet capacity.

Typical Example
(assuming 30 minutes of increased productivity per day or 6.25%):

Annual locomotive availability	281 days
x Average downtime	10%
= days unavailable	28
x increased productivity	6.25%
= Increase in availability	1.75 days
x number of locomotives	1,000
= Total number of days of increased locomotive availability	1,750 days
	(equivalent to 6 locomotives)

EPC role in creating a better parts database

VMS is a very popular application. And rightfully so. Better management of assets by implementing a VMS can help rail operations accomplish more on smaller/decreasing budgets. A VMS is both a repository and a delivery vehicle for data. Some make the analogy that VMS is like a bucket - it can hold information as well as deliver information. If you have just purchased your bucket you have great hopes for its impact on your organization - you may think of it as a golden bucket.

Unfortunately, when you purchase it, it is empty. Most are purchased before someone asks several tough questions like where are the data going to come from; how are you going to get the data in and how are you going to get the correct manufacturer's part number associated with its corresponding internal number.

EPC's contain a complete electronic bill of material with manufacturer part numbers associated with assemblies. Using these part numbers as the foundation, rail operations can populate the VMS application with complete and accurate parts information.

For those railroads with aging VMS systems, the benefit is the same. Electronically comparing your inventory data with EPC parts data can bring to light duplicate stocked parts, obsolete parts, and highlight the "slash/dash" problems in your existing inventory database.

Increased safety accuracy

Every year, somewhere nationally, a tragic accident happens in the workplace, because someone did not follow an approved procedure. Unfortunately, too often, the worker found it too difficult or time consuming to access the appropriate safety information. Maybe it was kept in a file cabinet remote from the work site; maybe it was in an office closed on the third shift; maybe it is on a computer but the worker was never comfortable with the computer interface and forgot how to use it. Where are your lock out tag out procedures?

An EPC can provide instantaneous access to all your safety information and even make it mandatory to view it. What is the value of reducing accidents in the work place, reducing lost hours, reducing Workers Comp claims, reducing Workers Comp premiums?

An EPC may not eliminate all errors, but it can provide an extra margin of accuracy that is not available in today's paper based system. Inaccurate repairs cost money, most often coming to light when a locomotive is in service resulting in increased logistical and towing problems and their associated costs. With the latest procedure and parts information readily at hand, the mechanic's work is less likely to result in an unscheduled repair.

Why EPCES?

How does EPCES help? EPCES makes the proliferation of EPC's economical. How? First, most railroads have several suppliers. If each manufacturer provides his catalogs in a unique format, the burden is on the railroad to provide duplicate hardware, software and training, or go to the equally costly effort of integrating the variety of solutions. Secondly, some railroads, recognizing this problem, are individually investing in the research to develop their own standard. This in itself is costly to the railroad, but will become even more costly to the entire industry as suppliers pass along the costs of publishing in many formats to accommodate the requirements of their many customers. Thirdly, established industry standards supported by many vendors open the door to the benefits of increased competition and variety of solutions from third part suppliers. Finally, with a standard that provides for the visual information and the navigation elements of and EPC, the rail operation incurs no catalog processing fees.

Industry Standards VS CD-ROM Catalogs

More and more manufacturers are making their catalogs available on CD-ROM's. When viewing the CD, users are able to navigate to exploded parts views and identify parts information. Many believe that CD solutions represent an information standard, when in fact, CD's are merely a distribution medium as are floppy disks and magnetic tapes. These solutions should not be confused with EPCES which provides a standard way to define the data stored on any distribution medium (including CD's).

CD-ROM is not a standard

Anyone who has received CD's from two or more manufacturers knows that a CD is simply a medium for exchange, not an information (data) standard. Each CD may have different navigation conventions; store data in a infinite variety of formats; and if bundled with a viewer, force the railroad to train users on a variety of interfaces. If it is feasible for the railroad to extract parts information for other applications (such as purchasing and inventory), it is the railroad's problem to solve.

EPCES, on the other hand, does not define the interface or exchange medium, but rather the data itself. A rail operation using an EPCES document is able easily to access the parts information for loading into other applications as well as load the EPCES document into the EPC application of *its* choice. This makes all the catalogs used by that rail operation available to users with a single interface.

CD-ROM allows only manufacturer information

Most rail operations require the mechanic or crib attendant to identify the internal part number. A manufacturer-supplied CD does not address this most difficult task - translating the manufacturer part number into the correct internal part number. Therefore CD-ROM solutions only promise to provide a fraction of the benefit of a fully functional EPC application.

EPCES allows the railroad to choose the application that will provide the most benefit to their organization. If the rail operation chooses a fully functional EPC application, it will easily incorporate its internal parts information (part number, bin location, alternate supplier, cost, etc.) into the EPC. This enables the mechanic to immediately identify the right internal part number, determine if the item is in stock, and get it picked by the crib attendant if it is in stock, or electronically route it to purchasing if is not. Therefore the mechanic can complete the transaction without further research (lost time).

CD-ROM's cannot be modified

Most railroads modify their locomotives as they receive them. Thus, the CD is obsolete the moment you receive it because modifications cannot be added to it. Therefore the mechanic is forced to find modified information from other sources. If there are two sources of information, how does the mechanic know when to check the second source? Might not the mechanic follow the procedures in the CD-ROM and potentially reverse modifications (safety or otherwise) required by the railroad?

ECPES data are readily integrated into the railroad's existing applications. Thus the source information from the manufacturer becomes the foundation upon with a railroad builds a complete and up-to-date documentation library.

Conclusions

The deployment of an EPC application is one of the best methods for increasing productivity; reducing inventory; increasing fleet availability; and increasing safety and accuracy of repairs. The RIF task team developed EPCES to support the proliferation of EPC applications across the entire rail industry. Railroads must now adopt this technology and include EPCES documentation as a requirement in future locomotive and car purchases. This will play a major role in keeping the rail industry competitive.

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT

TUESDAY, SEPTEMBER 16, 1997
10:30 A.M.

Pre-Convention Presentation Simmons Mach. Tool Engine Systems-MPI

July 17, 1997 Holiday Inn Albany, NY

BILL PETERMAN, Chairman
Consultant
Peterman Railway Technologies
Montreal, PQ

Vice Chairman
J. MUENCH
Shop Layout Specialist
CSX Transportation
Jacksonville, FL

COMMITTEE MEMBERS

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R. Yartin	Managing Dir.- Loco. Assets	Conrail	Selkirk, NY

The Shop Equipment Committee wishes to thank Simmons Machine Tool and MPI Engine Systems for hosting their Pre-Convention Presentation in Albany, NY at the Holiday Inn on June 17, 1997.

I. WHEEL TRUING AS PREVENTIVE MAINTENANCE

Prepared by
Joe Muench, CSXT

The Code of Federal Regulations in the United States, and the National Transportation Act in Canada, have most often been used as benchmark criteria for maintaining locomotive wheel dimensions for North American railroads. Railroads generally set their wheel wear tolerances to, or just within, the government regulations. Maintenance forces then monitor and maintain wheel dimensions accordingly, primarily by truing wheels back to an optimum profile or by changing the wheels out when truing cannot be accomplished.

The optimum profile achieved at truing is somewhat short-lived, as there is an initial period of run-in wear as the wheel adapts to the profile of the rails it is traversing. Initial wear is followed by a longer period of acceptable or economical wear. Finally a point is reached when friction and interference accelerate and the wheel enters a rapid wear phase to its wear limits. It is the rapid wear phase, wear beyond that of economical wear, in which reduced locomotive efficiency and reduced economy are experienced. In addition, increased rail wear is incurred.

Two improvements in shop equipment have recently been deployed that may justify changing wheel maintenance practices to one of "preventive maintenance". They are electronic wheel measurement, which provides quick, consistent and accurate wheel gauging; and the new new generation of productive, automatic wheel truing machines that can be used to maintain wheels within economical limits before they enter the rapid wear phase. It has been calculated that by maintaining wheels within the economical wear range, an additional 20% wheel life could be achieved.

The Electronic Wheel Gauge

The electronic wheel gauge is a computerized instrument designed to take the same readings as a steel wheel gauge. The electronic gauge takes the flange thickness, flange height and rim thickness at the same time. Another measurement secures the wheel diameter at the reference groove. The electronic wheel gauge stores the readings electronically and, upon completion of the wheel measurement process, downloads the reading to a computer system for storage and evaluation.

The electronic wheel gauge is a substantially more accurate and reliable wheel profile measuring system than the finger gauge, which is not considered a precision measuring device. Controls utilized by the electronic wheel gauge virtually eliminate the possibility that the gauge will be improperly applied to the wheel.

The manufacturer projects that the greatest impact produced by its gauge will be through the improved understanding of the process of wheel wear and the impact of different wheel specification and maintenance procedures on wheel life. The experience of the Danish State Railways seems to confirm this concept. A paper on the subject was presented to the Institute of Mechanical Engineers in Birmingham, England in 1992 by the railway's senior engineer. The railway had instituted a predictive wheel maintenance program based on the electronic condition monitoring of its fleet's wheels.

The railway instituted a policy in which flanges were not allowed to reach their lowest "acceptable" thickness. This prevented cutting off large amounts of steel upon wheel reprofiling. Less metal removed from wheels requires less time, so therefore it is possible to reduce the number of reprofiling hours needed to cut the wheels. The paper documents several areas of savings. The largest contributor was the reduction in the yearly consumption of wheels by nearly 30%. The Danish railway experience has shown that it takes even more time to change the maintenance organization to achieve the optimum results than to implement the new technology. The new system was so revolutionary that maintenance forces would hardly cope with the changes.

New Generation Wheel Truer

Wheel truing machines on the market today boast wheel set production of up to 20 wheel sets per 8 hour shift. Automation has been maximized with rugged, easy to maintain CNC control systems.

The operator sets up the machine once and wheel tread and flanges on both wheels are reprofiled simultaneously and automatically in a single operation. A minimum amount of tread is removed, only enough to restore the wheel profile, thereby providing additional wheel life. In lighter duty applications, such as in a "preventive maintenance" wheel program, an even higher number of wheelsets can be profiled without cutter exchange and without losing the high quality of the tread finish. The new machines do not require axle caps or bearing box covers to be removed to access the axle centers which additionally reduces cycle time.

Railroad Requirements

- Increase locomotive availability
- Reduce fuel consumption
- Reduce chance of bearing, traction motor, etc. damage caused by wheel defects
- Reduce potential for derailments
- Reduce unscheduled repairs
- Improve scheduling, planning and utilization.

Locomotive wheels and their accessories are one of the costliest items to maintain on railway vehicles. Fast, accurate and consistent wheel profile gauging and new wheel truing machines capable of increased throughput offer the potential to better manage railroad wheel inventories. There are many variable wear factors on North American railroads - including terrain, weather and type of service - that may impact the most desirable and workable maintenance strategy.

It is prident to reduce the cost of maintaining locomotive wheels by developing a preventive maintenance strategy designed to optimize wheel service life. This can be achieved by taking advantage of new technology available and rationalizing the cost of wheel maintenance.

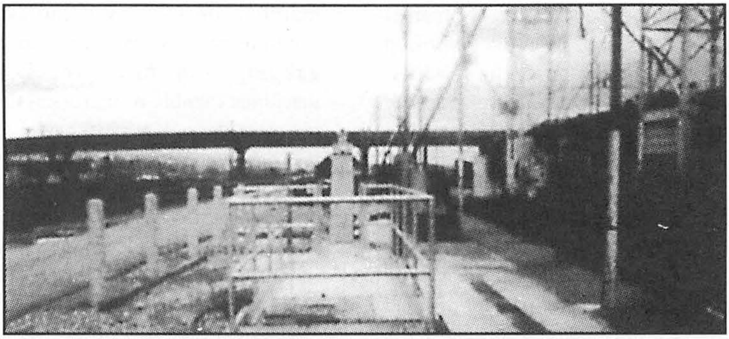
II. CONRAIL

Selkirk Diesel Terminal Wastewater Treatment Facility Recent Environmental Improvements

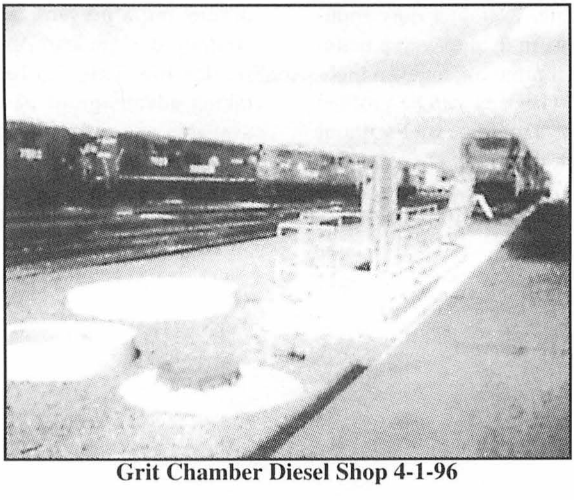
Prepared by
Ronald G. Yartin,
Managing Director Locomotive Assets, Conrail

The recent environmental improvements completed at the Selkirk Wastewater Treatment Facility (WWTF) are additions and modifications to the wastewater treatment facility in the Selkirk Yard completed in 1968, 1975, and 1984 respectively. The modifications to the facility will better enable Conrail's commitment to meet and better the levels as specified in the New York State Department of Environmental Conservation permit. These modifications consist of; a new grit screw at the fuel island and diesel shop, installation of an oil/water separator system at the fuel island, concrete oil/water separator (equalization basin) at the WWTF and the installation of a DAF system at the WWTF. These projects commenced in the fall of 1993 and were completed in the spring of 1996.

Pretreatment:

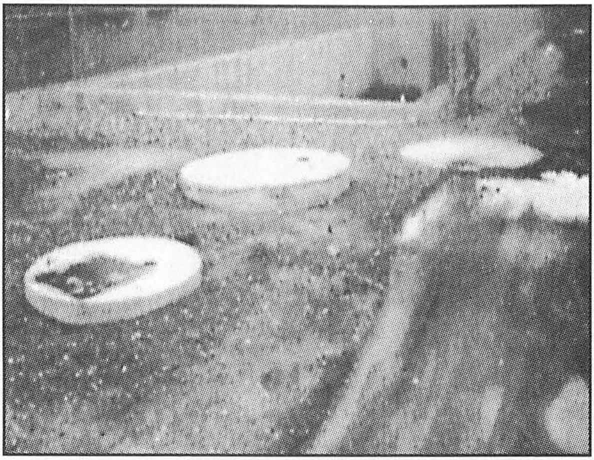


Grit Chamber Fuel Island 6-17-94

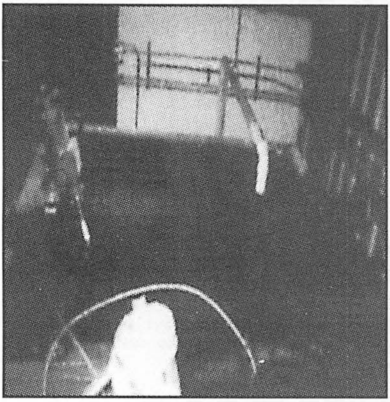


Grit Chamber Diesel Shop 4-1-96

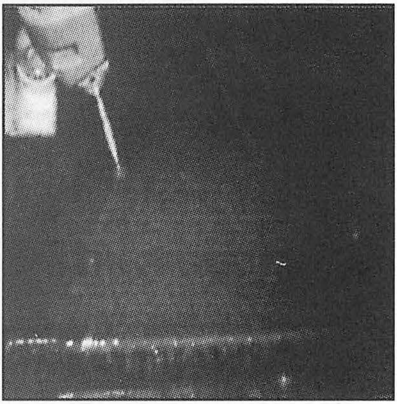
Equalization Basin 11-16-94



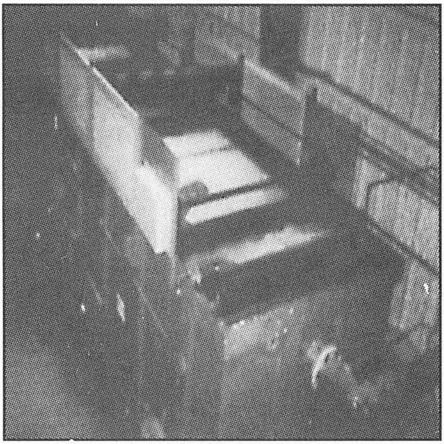
Dissolved Air Flotation System (DAF) 5-1-95



DAF Tank A

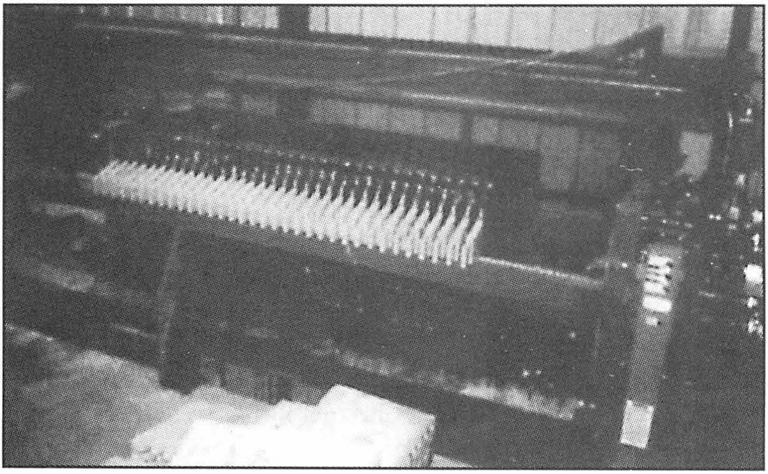


DAF Tank B

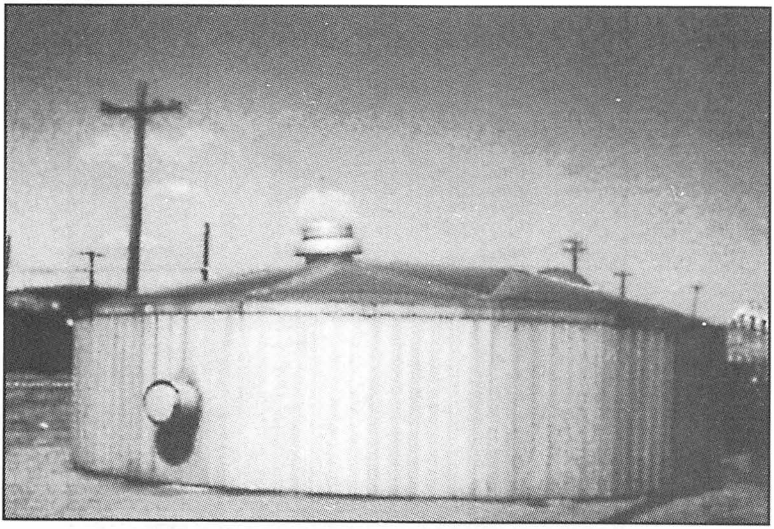


DAF Flotation Tank

Sludge Press: 9-12-95

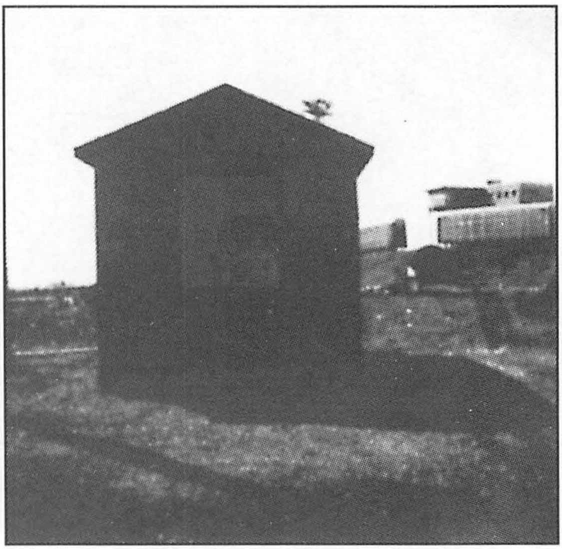


Clarifier:

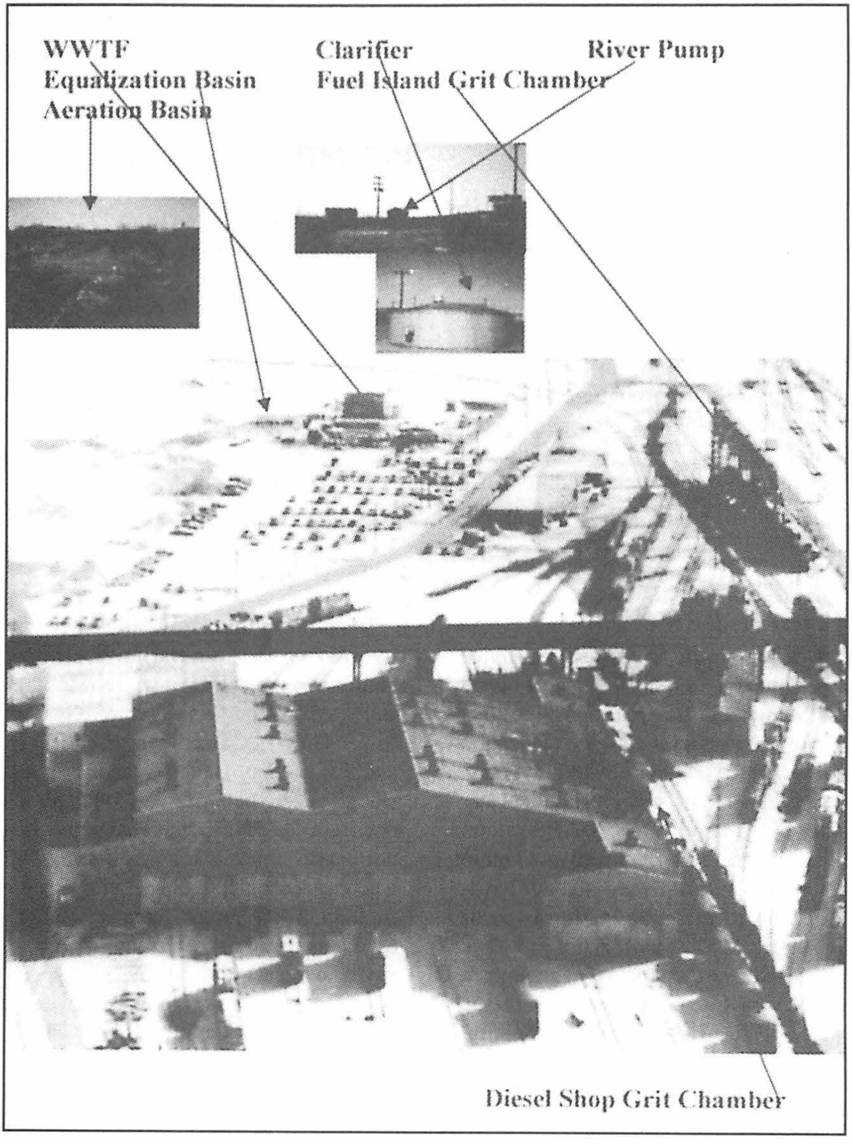


River Pump System:

River Collection Basin



River Pump Building


WWTF
Equalization Basin
Aeration Basin
Clarifier
Fuel Island Grit Chamber
River Pump
Diesel Shop Grit Chamber

Pretreatment System Diesel Shop and Fuel Island grit Chambers:

All **industrial** waste generated inside the diesel shop and wheel true building flow by gravity to a **FMC "AS"** grit screw, which is part of the current modifications. The wastewater is pumped to the manhole between tracks 5-6 on the east end of the diesel shop where it mingles with the wastewater from the fuel island and continues to the equalization basin at the WWTF by gravity. A 70 gpm submersible pump is employed to pump the wastewater into the manhole from the grit screw chamber.

The wastewater from the fuel/sand island also flows through a FMC "AS" grit screw, which is also part of the current modifications. Also new to the treatment facility is the addition of a Gnesyṡ oil/water separator at the fuel/sand island.

Equalization Basin

When the **industrial** waste generated from the fuel/sand island and diesel shop enter the transmission pipe, that waste goes directly to the equalization basin located behind the DAF building. The oil phase is removed and the water phase is treated in the DAF system. This process allows the recovered oil to be sold as reclaimed #2 fuel oil. Adjacent to the equalization basin is located a 10,000 gallon holding tank which allows the storage of recovered oil which then may be used in the waste oil furnaces currently in Selkirk. These furnaces are currently located at the M&W garage, DAF building, and wheel true building.

The equalization basin has the following specifications:

<u>Volume in Gallons</u>
251,982 gallons
<u>Normal Operation</u>
186,533 gallons

Dissolved Air Flotation Unit (DAF)

The effluent from the equalization basin is pumped via a 300 GPM duplex pumping system to the dissolved air floatation unit where the remaining oil phase which is held in the water phase is removed by floatation. Sulfuric acid 66 Be' (added to Tank A), NALCO 2224 emulsion breaker/coagulant (added to Tank A), NALCO 2225 flocculent (added to Tank B) are added to improve flocculation.

The DAF system is comprised of a three tank configuration:

Tank A is the coagulation tank with a capacity of 2,500 gallons,
Tank B is the flocculation tank with a capacity of 1,250 gallons,
DAF Tank with a capacity of 6,450 gallons.

Aeration Basin

The effluent form the DAF unit flows by gravity to the aeration basin, in addition to the **sanitary** waste from the B&B, M&W building, hump, retarder tower GYO, division office building and diesel shop. Under drains from the sludge drying bed go to a 3,000 gallon concrete holding tank located in the northeast corner of the aeration basin, where it decants into the aeration basin. In addition the return activated sludge (AS) from the clarifier is also conveyed to the aeration basin.

The aeration basin is equipped with a floating chain aeration system. There are three chains; each chain has seven floats, which contain four diffusers. The air is supplied via a 20 horsepower blower. The purpose of the floating chain system is for mixing an oxygen dissolution.

The activated sludge process is a biological contact process between waste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water rich in biodegradable organic material and concentrated microbial population in the presence of free, uncombined oxygen. The micro-organisms, using the available oxygen, oxidize the organic material and convert it to additional bio-mass. The mixture of bacterial, organic material and oxygen is kept in completely mixed condition in the Aeration Basin, and is termed **mixed liquor.**

Clarifier

The effluent from the aeration basin flows by gravity into the control structure chamber, from which it may either flow into the emergency holding basin or, is is the normal case, into the clarifier. The circular clarifier is 25 feet in diameter. It is covered to prevent it from freezing in winter weather with a fiberglass dome. When the mixed liquor is no longer kept completely mixed, biological flocculation occurs. This flocculation is caused by natural extra-cellular sheath found on the cell wall of the organisms used in the process. This sheath is sticky and forms a bond between cells sufficient to overcome the repulsion effect of similar electric charge. In specific cases, various chemicals can be used to assist the cell agglomeration. This flocculation process continues until the mass of cells is large enough to settle to the bottom of the clarifier. When this settling occurs, the particle becomes part of the concentrated microbial mass which is recycled back to the aeration basin and is termed return activated sludge (RAS).

Activated sludge is, in all cases, generated in excess of recycle requirements. This excess activated sludge must be "wasted" from the system to maintain process balance. This sludge is termed waste activated sludge (WAS).

In addition to sludge removal, the clarifier is also provided for removal of traces oil, grease or scum that may be floating on the water surface of the clarifier.

River Pump Collection Basin

The clarifier effluent overflows over scum baffles and effluent weirs around the entire circumference of the clarifier and flows by gravity to the river pump collection basin. The purpose of the collection basin is to act as a sump allowing for a quantity of water to be collected to better enable the pump station to operate. The effluent from the river pump collection basin is pumped to the Hudson river.

To better manage the operation of the WWFT's various components a computer-monitoring program has been installed to monitor the following items:

Equalization Basin

Equalization Basin Control Panel
- Monitor Level of Basin
- Monitor & alarm high level
- Monitor "On/Off" status of pumps
- Event stamps and accumulates hours

DAF Building

Environment
- Monitor building & ambient temp

Door Access
- Event stamp door activity

Reaction tank control panel
- Monitor influent flow rate
- Monitor pH
- Monitor power
- Monitor two alarms
- Monitor five (5) status's
- Monitor two (2) "On/Off" Auto switches
- Monitor three (3) Hands/Off/Auto switches
- Monitor LMI flows for Nalco

2224 & 2225
- Monitor Nalco 2224 level
- Monitor flow rate to DAF

DAF Control Panel
- Monitor power
- Monitor two alarms
- Monitor five (5) status's
- Monitor four (4) "On/Off" switches
- Monitor two (2) Hand/Off/Auto switches
- Monitor potentiometer
- Monitor pH
- Monitor oil & grease
- Monitor total suspended solids
- Monitor recycle flow rate
- Monitor recycle tank pressure
- Monitor recycle pump pressure
- Monitor sludge hopper level
- Monitor effluent flow rate

Filter press control panel
- Monitor filtrate tank ball level
- Monitor level of sludge holding tank
- Monitor filter press Allen-Bradley panel

Clarifier Building

Environment
- Monitor building temp.

Door Access
- Event stamp door activity

Clarifier Control Panel
- Monitor power
- Monitor overload trip
- Control remote reset

Clarifier Pump Pit

Environment
- Monitor building temp.
- Monitor floor water level

Pump Control Panel (Three [3])
- Monitor "On/Off" status of pumps
- Event stamp and accumulate hours

Blower Motor Control Panel
- Monitor "On/Off" status of blower
- Event stamp and accumulate hours

Flow Meter
- Monitor flow meter

River Pump Building

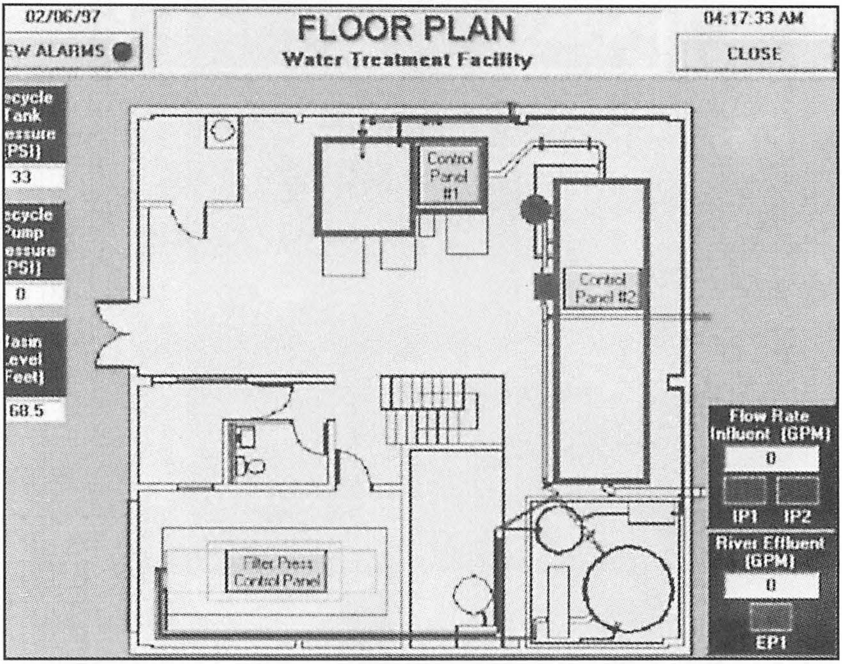
Environmental
- Monitor building temp.

Door Access
- Event stamp door activity

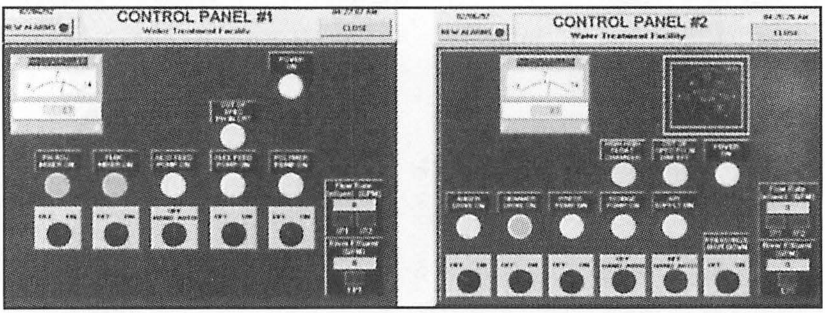
Pressure & Vacuum Devices Pump
- Monitor pressure and vacuum
- Monitor "On/Off" status of pumps
- Event stamp and accumulate hours

Volume totalizer
- Monitor & provide reports

The monitoring program has been designed to mimic the physical layout of the facility. The first screen presents a floor plan which allows a specific area to be examined.



After the screen is selected the on screen representation presents a real time view of the WWTF operation.



In addition of the monitoring program coupled with the environmental improvements has proven a valued asset to the operation of the WWTF facility and has paid for them as shown in the following table of cost savings.

Operation Item	Annual Cost Prior Improvement	Annual Cost Post Improvements	Cost Savings
Overtime	$20,000.00	$500.00	98%
2 Plant Operators			
Chemical Cost	$36,000.00	$25,000.00	31%
Sludge Removal	$75,000.00	$39,000.00	48%

REPORT OF THE COMMITTEE ON FUEL, LUBRICANTS & ENVIRONMENTAL

TUESDAY, SEPTEMBER 16, 1997
1:45 P.M.

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

Vice Chairman
G. BOWEN
Dir. Laboratory Svcs.
BN/SF
Topeka, KS

COMMITTEE MEMBERS

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Z. Bolt	Sr. Tech. Spec.	Exxon Co.	Houston, TX
D. Campbell	Tech. Engr.	Electro-Motive	LaGrange, IL
D. Carlson	Staff Engineer	Shell Development	Houston, TX
K. Davis	Mgr-Tests & Lab Svcs.	CSX Transportation	Waycross, GA
B. Dittmeir	Sr. Lab Spec.	Ethyl Petro.	Richmond, VA
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P. Purmer	Tech. Rep.	Royal Additives	San Antonio, TX
T. Pyziak	RR. Acct. Exec.	Safety-Kleen	Elk Grove Village, IL
G. Schafer	Senior Technologist	Texaco, Incorporated	Houston, TX
C. Tincher	Product Manager	Lyondell Lubricants	Winnipeg, MB

PERSONAL HISTORY

Bruce A. Kehe

Bruce Kehe received his B.S. degree in Mechanical Engineering from Valparaiso University. He joined the Elgin, Joliet & Eastern Railway in 1979, holding various positions in the Industrial Engineering and Mechanical Departments. In 1993, he was promoted to his present position of Manager-Mechanical Services.

In addition to his involvement with LMOA, he is active with the Chicago Railroad Mechanical Association and SAE Technical 9 Committee for Medium Speed Diesels. He is also a member of the National Association of Railroad and Environmental Testing, serving as its Chairman in 1994.

Bruce and his wife Barb have two children, Sarah and Brian, and reside in northwest Indiana.

The Fuel, Lube & Environmental Committee wishes to thank the AAR Transportation Technology Center (Pueblo, CO) for hosting the FL&E Committee meeting in February 1997 in Pueblo.

I. FERROGRAPHY-USED OIL ANALYSIS PROGRAM

Presented by:
Doug Holmes, Predict DLI

What are maintenance strategies?

Four maintenance strategies are used today. The most common maintenance method is *responsive maintenance.* This strategy is to fix things when they are broken. The next strategy is *preventive maintenance,* which is calendar based. Preventive maintenance will result in a cost saving of 40% to 50% over pure responsive. *Predictive maintenance* or condition based monitoring is exactly that, maintenance performed based on the condition of the equipment. Predictive maintenance will result in a 30% to 50% saving over preventive maintenance. *Proactive maintenance* is the prevention of future failures.

The benefits of using the later strategies are:
1) Reduced maintenance costs,
2) Reduced unscheduled downtime,
3) Improved OEM warranty programs,
4) Adds proactive maintenance/ Root cause analysis capabilities,
5) Improved safety

Why use ferrography along with spectrographic analysis?

Spectrographic analysis is an excellent tool for evaluating lubricant condition, but has limitations when evaluating equipment condition. The reason for this limitation is that spectrographic analysis can only detect particles approximately 8 microns and smaller, whereas ferrography can detect particles up to 300 microns.

Ferrographic Wear Particle Analysis/Instruments

Wear particle analysis is a three-step process. The first step is <u>trending.</u> The wear particle concentration is trended over time to detect the onset of abnormal war. The second step is <u>particle identification.</u> Particle identification is the microscopic and analytical evaluation of particles to determine the origin and severity of the wear. The last step is <u>interpretation.</u> This is the analysis of all data and the recommendations.

The trending process is done with an instrument called a Direct Read Ferrograph. The Direct Read Ferrograph provides the wear particle concentration (WPC). WPC indicates the relative amount of all magnetic particles present in the sample (0.1 to 300 microns in size.) This process is accomplished by running a sample down a capillary tube across a magnetic assembly. Photo detectors monitor the amount of light blocked by trapped particles in the precipitation tube. The next step is the qualitative analysis.

The FM Ferrograph is the instrument used to do qualitative analysis. The FM Ferrograph has a sample run across a substrate or ferrogram. A magnetic assembly is under the ferrogram and deposits the larger magnetic particles in the entry zone and the smaller magnetic particles at the exit. The larger nonmagnetic particles will be at the exit and loosely attached to the smaller ferrous particles.

Wear Particle Classifications

There are three types of wear particles: Ferrous, Nonferrous and Contaminants. Ferrous particles are magnetic particles (Fe, Fe_3O_4), paramagnetic or imbedded ferrous magnetic particles, non-magnetic Fe_2O_3 and

stainless. The non-ferrous particles are copper alloys, aluminum, babbitted metals, zinc, chrome, etc. Some of the contaminants are dust, dirt, external process materials, manufacturing debris, filter material, friction polymers and organic matter.

Following is a list of the particle types, generation modes and typical sizes:

Normal Rubbing: Wear particles that are continuously generated in all equipment. Sizes range from 1 to 15 microns and are typically smaller than 5 microns.

Severe Sliding: Wear particles that are generally produced from surfaces undergoing high stress. Particles are greater than 15 microns in size and are generated when gears/bearings/cylinders are operated under severe load and speed.

Cutting: Wear particles generated as a result of one surface penetrating another. Sizes can range from 5 to over 100 microns. There are two sources of these particles: misalignment of components and/or contamination.

Gears: Wear particles generated from gear tooth pitch line (laminar) and/or tip (sliding). Sizes range from 15 to over 100 microns. This type of wear is generally the result of excessive load and/or speed on the gear tooth.

Bearing: Wear particles generated as a result of fatigue in the rolling elements and races of anti-friction bearings and the sleeves of journal bearings. Journal bearings include babbitted and unbabbitted bearings. Particle sizes range up to 500 microns. Common causes of generation include contamination, excessive load and improper lubrication.

Spheres: The onset of rolling element bearing fatigue is indicated by the presence of spherical wear particles. Sizes are generally less than 5 microns. Spheres normally precede rolling element fatigue spalling or brinelling.

Black Oxides: Associated with insufficient lubrication between metal surfaces. Particles are formed under high temperatures as a result of metal-to-metal contact. Size ranges vary.

Red Oxides: Commonly termed, "rust" and associated with water contamination. Water had to be present in the lube system to some previous time for red oxides to form even though the current sample may not contain water. Particle size varies.

Corrosive Wear: Caused by the lubricant becoming acidic. Circulating metal particles in the lubricant, as well as the outer wear surfaces, become dissolved to submicron proportions. Sizes range up to 0.1 micron.

Lubricant Degradation: A high concentration of friction polymers which indicates lubricant polymerization under extreme pressure and/or temperature and over-stressing of the lubricant. No particular size range.

Sand/Dirt: Outside contamination of the lubricant. Sources can be from rebuilt units, improperly cleaned new machinery, perforated air filters and poorly functioning breathers. Particle sizes generally are under 5 microns. This type of wear is the most common cause of premature equipment failure.

Locomotive Case Study

When sampling locomotives, it is very important to take the sample from the correct location. When taking samples for spectrographic analysis, the particles that are detected are particles that are dispersed in the lubricant. The particles that are detected in ferrographic analysis are particles that are suspended in the lubricant. Therefore, when using ferrographic analysis, the sample should be taken from the dip stick hole. If the sample is taken from a sample tap, the larger particles could blow by the sample area and may not be detected.

A recent case study on locomotives from a major Eastern railroad illustrated the analytical benefits of using ferrography in conjunction with spectrographic analysis. Ferrography can be an important tool in evaluating locomotive condition and in the development of effective locomotive maintenance strategies.

II. 2000: A NEW MILLENNIUM FOR LOCOMOTIVE MAINTENANCE: EPA EXHAUST EMISSIONS REGULATORY IMPACTS

Presented by: Dick Cataldi
Association of American Railroads

On January 31, 1997, the Administrator of the federal Environmental Protection Agency (EPA) signed a Notice of Proposed Rulemaking (NPRM), proposing emission standards for locomotives and locomotive engines. The proposal is scheduled to become a final rule in December 1997 and take effect on January 1, 2000.

The proposed rule would have an immediate impact on locomotive engine manufacturers as well as almost everyone who performs heavy overhauls on locomotive engines. These engines will then have to be maintained properly throughout their lives. Proper maintenance will not necessarily be defined by the locomotive operator - a railroad - but by whoever holds the EPA certificate on the engine family.

The proposed rule would separate locomotives into four groups:

- "Tier 0" where the engine was originally manufactured from January 1, 1973 through December 31, 1999.
- "Tier I" where the engine was originally manufactured from January 1, 2000 through December 31, 2004
- "Tier II" where the engine was originally manufactured on January 1, 2005 or later
- Pre-Tier 0 engines, which are not covered by the rule unless the owner upgrades them to Tier 0 standards

The proposed gaseous and particulate matter emissions standards for Tiers 0, I, and II are given in Table 1. The weighting factors for determining the emissions level are shown in Table 2. Every locomotive must meet both the line-haul and switcher standards. Passenger locomotives would be weighted differently than freight locomotives, as shown. Smoke standards are given in Table 3. EPA developed these standards by calculating reductions in oxides of nitrogen (NOx) of 33%, 45% and 60^% respectively for Tier 0, I, and II compared to mid-1990s national fleet averages. Tiers I and II have some tightening of particulate matter, hydrocarbons, and carbon-dioxide compared to the baseline, while Tier 0 locomotives do not have to make any reductions in these emittants. The smoke standards are similar to those for truck and off-highway engines.

EPA recognized that some engine models may not make the standards without massive redesign that would be unreasonably expensive, so they proposed that manufacturers can average, bank, and trade emissions credits to meet the standards on a fleet-wise basis. This may be especially useful for Tier 0 locomotives that were never designed to meet any emissions standards and which are all over the map on their baseline emissions levels. "Banking" means that a manufacturer can earn a credit for having an engine family under the emissions limits in one year and hold those credits for up to 3 years and then offset any engine family that exceeds the limits. "Trading" allows manufacturers to give their credits to other manufacturers. Compensation is set by the marketplace and is of no concern to EPA.

Locomotives will have to be "remanufactured" (using a certified "kit") at the time that the owner performs an overhaul on the diesel engine. For Tier 0, this will go into effect on January 1,

2000. No owner is required to do these remanufacturing events any sooner than they would normally perform an overhaul. EPA expects that nearly all line-haul locomotives will be remanufactured by around 2006. Switchers will take much longer, though no one knows today how long it will take to bring all of them into compliance.

Something that will not be settled until the final rule is published in December is who is eligible or required to obtain certificates for remanufacture of locomotive engines. Under the scenario in the NPRM, it appears that any entity that wishes to may obtain a certificate. An option that EPA asked for public comment on would require railroads to obtain the certificates. This is a major issue on which the railroads have taken a strong stand with EPA. Since railroads are not technology firms, they should not be required to develop and certify remanufacturing kits. At this time, the railroads believe that they will not be required to be certificate holders.

The likely cast of certificate holders (EPA calls them "remanufacturers") will include the OEMs (General Electric, General Motors Locomotive Group, and Caterpillar); some aftermarket suppliers; some non-railroad, non-OEM locomotive engine rebuilders; and possibly one or more railroads. The certificate basically covers an engine family that the remanufacturer defines by engine specifications and that has a certified level of emissions determined through an EPA "Federal Test Procedure" or FTP. The remanufacturer defines a "kit" that is installed in the engine family by an installer at the time of a top-end overhaul. The installer may be a railroad, the remanufacturer, or a third party engine shop. While it is expected that the installer will not have to hold the EPA certificate, he must obtain the use of it for every Tier 0 and later engine he overhauls starting in 2000.

If a railroad chooses to not install certified kits in any engines covered by this EPA rule, the railroad runs the risk that a state will establish standards that must be met. The states would not necessarily copy the EPA rule; they might establish more stringent standards that would cost more to meet than the EPA standards. All states are preempted from regulating locomotive emissions as long as the railroads follow these EPA rules. An important exception: railroads with fewer than 500 employees are exempted from these rules as well as state regulations.

What will constitute a "kit" could vary quite a bit. It must include installation instructions and instructions for inspection, maintenance, and repairs for the life of the engine. Some kits may include parts, while others may include specific parts lists for the installer to buy. Other remanufacturers may take a less specific approach to the parts and leave it to the installer to select parts and components that meet performance parameters, or there may be a list of acceptable parts from different suppliers. The marketplace will determine the contents of kits. Installers can expect to pay something to remanufacturers for the license to use the certified kits. Again, the marketplace will determine the price. Remanufacturers will spend hundreds of thousands of dollars per engine family to develop and certify their kits and they will assume considerable liability for auditing installers, conducting in-use testing of the engines, and solving any in-use problems that are identified by in-use tests. So a remanufacturer will expect to recover that investment either in license fees or in the sale of parts.

EPA's NPRM includes an estimate that the incremental cost of the license, parts, and labor for Tier 0 remanufacturing will be approximately $80,000 per locomotive. This is a cost that would be incurred at the time of an engine overhaul and assumes the incremental is above and beyond what it would cost to replace all of the engine power assemblies and fuel injectors and resetting of engine timing.

EPA didn't give much documentation of how they reached the $80,000 figure, citing proprietary information obtained from the OEMs. In extreme examples, some "kits" may involve nothing more than resetting fuel injection timing at the time of a heavy overhaul while others could entail replacing mechanical engine governors and fuel injection equipment with electronically controlled equipment, rematching turbochargers; changing the design of pistons, cylinder liners, and heads; adding additional radiators; and repiping the entire cooling system. Even without a license fee, the latter kit would result in an incremental cost well over $80,000, while the former kit would cost nothing at the time of an overhaul other than the license fee.

Remanufacturers will have to conduct market research to determine what the railroads want in these kits. An option is to make a fairly advanced technology kit that does not cause any fuel penalty and that improves engine performance and reliability. Such a kit would cost more, but presumably it would have a positive rate-of-return on the investment. Another option for the same engine family might be an inexpensive kit that causes a fuel penalty and does nothing to improve performance and reliability.

At about three-quarters of what EPA calls the "useful life" of engines, the remanufacturers will be required to conduct in-use FTP emissions tests of a small sample of engines. If the engines do not exceed the emissions levels that the remanufacturer specified in his certification, the engines "pass" the test. If they exceed those levels, the remanufacturer must determine the reason for it. If the reason is because the owner or operator of the locomotive did not follow the remanufacturer's inspection, maintenance, and repairs recommendations, the remanufacturer is not liable for the results (and neither is the owner/operator, as long as he used reasonable judgement in maintaining his locomotive). If the problem is due to the design of the kit or a part or to workmanship of a part or component, the remanufacturer must develop a fix for the problem. These fixes would be agreed upon between the remanufacturer and EPA and would be provided to the railroads with the expectation that the fixes would be done during regularly scheduled maintenance. EPA has not proposed mandatory recalls with locomotives taken out of service.

Useful life was defined as 7.5 times the horsepower rating to obtain mega Watt-hours. A 4000 horsepower locomotive would then have a useful life of 30,000 mega Watt-hours. Three quarters of that would be 22,500 mega Watt-hours. For Tier 0 locomotives lacking Watt-hour meters, the useful life would be 750,000 miles.

There is an "anti-tampering" provision in the NPRM that is common to all EPA rules. If a railroad or other engine maintainer knowingly changes the emissions characteristics of the engine (through changes in engine setup, removing emissions control devices, or replacing a part with another part known to alter the emissions characteristics), he has committed a federal crime. The civil penalties were not spelled out in the rule, but will probably be the same as for other mobile sources.

The anti-tampering provision and the remanufacturer's maintenance instruc-

tions will change locomotive maintenance. These rules apply to newly manufactured locomotive engines too.

The certificate holders will provide recommended inspection and maintenance intervals and will recommend what specific parts should be replaced or requalified at these intervals. The NPRM does not say that the railroad or other engine maintainer must follow those recommendations exactly. The railroad or maintainer may use its own experienced judgement, as they do today. If you are convinced that parts and components are lasting longer than the recommended replacement period, it is acceptable to substitute your own maintenance intervals. If you are convinced that replacing a recommended part with a different part will not affect the emissions characteristics of the engine, that is also acceptable. Unacceptable maintenance is knowingly installing parts that affect the emissions level. That would include parts that might even "improve" emissions. When you modify an engine to change emissions, it is almost impossible to reduce every one of the pollutants coming out of the engine. If one or two pollutants go down, something else inevitably increases. Beware of claims pushing products that allegedly reduce emissions. If you put it on with the expectation that you are affecting the emissions in any way, you are breaking the law.

Something of great importance to railroads and other engine rebuilders is the identification of kit certifiers. There will be no such thing as a "certified part" or component, no matter what you may hear from suppliers - only certified "kits." These kits must include the package of installation, inspection and maintenance instructions for the entire engine, with proper EPA documentation of the certificate.

There will be a need for more record keeping than you may be practicing today. First, each kit "installer," whether a railroad or a contractor, should keep a record of each locomotive remanufacturing event to show that all the parts were installed and the engine set up as required by the certificate-holder. These records should probably be kept on file until the locomotive is remanufactured again in the future or scrapped.

Second, railroads are likely to end up with some locomotive models that have two or more different kits. The certificate-holders may have specified different parts and engine set ups as well as different maintenance. The locomotive owner needs to keep these locomotives straight to assure that each one receives proper maintenance and repairs.

As these rules are finalized by the EPA, LMOA should follow up and keep its membership up-to-date on any technical changes. Further, LMOA members will probably need some interpretation of these rules in the future.

TABLE 1. SUMMARY OF EPA PROPOSED LOCOMOTIVE EMISSIONS LIMITS

(Units are grams per brake horsepower-hour)

Type of Service:	Line-Haul Duty Cycle			Switcher Duty Cycle		
Year Originally Built:	1973-99	2000-04	2005-??	1973-99	2000-04	2005-??
Tier:	0	I	II	0	I	II
Hydrocarbons HC	1.0	0.55	0.3	2.1	1.2	0.6
Carbon Monoxide CO	5.0	2.2	1.5	8.0	2.5	2.4
Oxides of Nitrogen Nox	9.5	7.4	5.5	14.0	11.0	8.1
Particulate Matter PM	0.6	0.45	0.2	0.72	0.54	0.24

Notes:

1. These are the limits for engines operating on diesel fuel oil. Different limits are proposed for CO from natural gas engines. Aldehyde limits are proposed for alcohol-fueled engines.

2. EPA has proposed individual throttle position limits for each emittant in addition to the duty cycle weighted limits.

TABLE 2. EPA PROPOSED ENGINE DUTY CYCLES FOR CERTIFICATION

	Duty Cycle Weightings		
	Freight	Passenger	Switcher
Throttle Notch			
Idle	38.0	47.4	59.8
1	6.5	7.0	12.4
2	6.5	5.1	12.3
3	5.2	5.7	5.8
4	4.4	4.7	3.6
5	3.8	4.0	3.6
6	3.9	2.9	1.5
7	3.0	1.4	0.2
8	16.2	15.6	0.8
Dynamic Brake	12.5	6.2	0.0

TABLE 3. SMOKE STANDARDS[1]

(Units are % Opacity)

Number of stacks	Exhaust Diameter	Examined Plume Section	Steady-State	30-sec Peak	3-sec Peak
Single	12" or less	Total	20	35	50
	More than 12"	Each 6: Segment, or	10	15	20
		Total[2]	30	40	55
Multiple	12" or less	Any One	20	35	50
		Sum of Stacks	30	40	55
	More than 12"	Each 6" Segment, or	10	15	20
		Total for any One	30	40	55
		Sum of Stacks	40	50	60

[1] Measurement performed continuously during testing.

[2] Sum of each 6" segment or the total, whichever is lower.

III. STANDARDIZED TEST PROCEDURES

CURRENT DEVELOPMENTS

Presented by:
Ronald R. Lodowski
Consolidated Rail Corporation

Introduction

The 1990 LMOA Fuel, Lubricants, and Environmental (F, L & E) Committee paper; FIELD EXPERIENCE WITH MULTIGRADE RAILROAD LOCOMOTIVE OILS; detailed to the railroad industry the economic benefits of converting from single grade to multigrade diesel engine lubricating oils. The paper stressed that the conversion to multigrade oil resulted in longer drain intervals on two major North American railroads. What had been forgotten was the industry mindset of draining lubricants essentially on a percentage increase of viscosity. This resulted in dirty locomotives due to elevated soot and particulate loading. At the identical time, an increase in diesel engine main bearing failures were observed. A small segment of the bearings that were examined appeared to have been exposed to some degree of corrosive wear. By 1992, it had become obvious that greater significance must be placed on insolubles measurement. It was also decided that the correlation between acid and base levels of used lubricating oils and soft metal corrosion should be examined. As a result, the 1993 LMOA F, L & E Committee paper; INSOLUBLES DETERMINATION WITH THE ADVENT OF MULTI-GRADE DIESEL ENGINE OILS; developed a proven, repeatable, standardized pentane insolubles test for the railroad industry. The 1995 LMOA F, L & E Committee paper; STANDARDIZED TEST PROCEDURES: PAST, PRESENT & FUTURE DEVELOPMENTS; dealt with the past, the current, and planned future activities of an internal multi-industrial subcommittee. The 1996 LMOA F, L & E Committee paper; STANDARDIZED TEST PROCEDURES: THE ANNUAL SUBCOMMITTEE UPDATE; highlighted the current laboratory apparatus that provides the qualifications of a usable pentane insolubles screener test, and its observed correlation to the 1993 LMOA Insolubles Test Procedure (ITP). This year's paper is an update of developments that have occurred as a result of the ongoing research projects of the LMOA F, L & E subcommittee.

Suggested Pentane Insolubles Testing Procedures

To reiterate what has been stated in earlier F, L & E committee papers; pentane insolubles are approximately 85% carbon based particulate (for example soot) which are produced during diesel engine operation. Left unchecked, elevated insoluble levels can result in plugged filters, engine sludging, and premature component replacement.

The 1996 LMOA F, L & E Committee paper; STANDARDIZED TEST PROCEDURES: THE ANNUAL SUBCOMMITTEE UPDATE: suggested the use of a low cost capacitance meter to routinely screen lubricating oil test samples. Recommendations were given concerning maximum limits. In addition, procedures were suggested where the screener test could be used and still provide maximum diesel engine protection. Following these guidelines, a major western railroad has stated in 1996 that it has seen a 50% reduction in the number of 1993 LMOA ITP performed with no adverse effects on locomotive fleet performance. The same major western railroad this year, has observed that capacitance meter readings greater then 30 correspond to an 80% accuracy in predicting that the pentane insoluble level exceeds 4%. This is the current limit that is listed in the General Electric Transportation Services Group Maintenance Instruction; MI-00128. Using the capacitance meter as a screening tool has resulted in only 170 1993 LMOA ITPs run per month on a fleet of 1,800 General Electric locomotives. This equates to approximately a 91% reduction in testing; at a saving of $59,000 US, and 2,000 staff hours per year. It is recommended by this committee, that any railroad that desires to apply the capacitance meter technology, first review the coefficient of determination (r^2) prior to utilizing it as a screening tool. The same western railroad has observed that diesel engines that have 1.5 to 2.0 inches of crankcase vacuum have higher pentane insoluble levels than those that are pulling 4.0 to 4.5 inches of vacuum. It is the committee's conclusion that maintaining proper diesel engine vacuum pressure; by the reduction of blow-by gases, helps decrease needless insoluble loading.

The Correlation Between Neutralization Testing Procedures and Soft Metal Corrosion

The 1994 LMOA F, L & E Committee paper; <u>TBN - A REVIEW OF CURRENTLY ACCEPTED METHODS;</u> stated that pH was the most widely utilized procedure for determining the corrosivity of diesel lubricating oils. The pH of a fluid, normally aqueous, is the negative logarithmic concentration of hydrogen ions. This is a measurement of the acidity of a fluid. Although not recognized by the diesel engine manufacturers as a viable condemnation procedure, the railroad industry has historic *confidence in the* pH testing procedure. The 1995 LMOA F, L & E Committee paper; <u>STANDARDIZED TEST PROCEDURES: PAST, PRESENT & FUTURE DEVELOPMENTS;</u> emphasized the need for a standardized, industry accepted corrosivity test. This year's paper is an update of developments that have occurred as a result of the ongoing research project of the LMOA F, L & E subcommittee in this regard.

As has been emphasized in the past, over exposure of diesel engine bearings to an engine oil with minimal acid neutralizing capabilities will result in the accelerated corrosion of soft metal surfaces; primarily copper and lead. What is now necessary as an industry is to determine the relationship between corrosive wear in the diesel engine and base or acid numbers. The total base number (TBN) is an expression of the quantity of acid that is required to neutralize alkaline constituents in the diesel engine oil additives. The total acid number (TAN) is an expression of the quantity of base that is required to neutralize acidic constituents in the diesel engine oil.

The LMOA subcommittee has initiated an analysis of all current, accepted neutralization measurement techniques. If one is acceptable, this will eliminate the need for the development of a new testing procedure. At the current time, the subcommittee is progressing the following topics:

1) The subcommittee is in the process of obtaining coupons from a major North American main bearing manufacturer. These coupons will be constructed of the same bearing material that is currently utilized by diesel engine manufacturers. They will be used during corrosion testing procedures. In the interim, testing shall be performed using 99.9% purity lead coupons.

2) It currently appears that the Federal Test Method Standard No. 791B Method 5321.1; CORROSION OF LEAD BY LUBRICATING OILS; may correlate regarding the degradation of the oil and bearing corrosion.

3) A major eastern railroad is testing main bearings impregnated with bismuth. Bismuth will be used as an indication of bearing wear. According to the same railroad, ferrography indicates that most metallic particles found in used lubricating oil samples are from iron and copper scrapings. Occasionally, lead flaking is evidenced.

4) Since short chain organic acids seem to attack primarily lead, lead will be the determining element in the measurement of corrosion.

5) Another major eastern railroad obtained used oil from each of the then available additive systems. These oils were further degraded by heating and oxygenation. Samples were taken covering a range of degraded states. These samples will be the basis for continued experimentation by the subcommittee.

6) A major oil additive supplier is investigating an experimental electrical technique for the direct measurement of lead corrosion by used diesel engine lubricating oils.

Conclusion

Although the problem of main bearing corrosion is not evident today the project should continue since there have been corrosion problems in the past. After investigating various testing procedures, the subcommittee hopes to recommend testing guidelines that will maximize the diesel engine lubricating oil drain intervals, while minimizing component wear.

Acknowledgment

The subcommittee has determined that for the project to progress it may be necessary to meet on almost a monthly basis. This is more than the typical commitment that is given by LMOA membership. Consequentially, the author of this paper would like to acknowledge the past and current efforts of the following individuals:

- Glen W. Bowen - Director Laboratory Services (BNSF Railway)
- Robert Briggs - Technical Representative (Royal Additives - Retired)
- K. Charles Callaway - Assistant Manager Fuels & Lubricants (TSL Incorporated)
- Dennis L. Campbell - Technical Engineer (EMD)
- Robert Dittmeier - Senior Laboratory Specialist (Ethyl Petroleum Additives Inc.)
- Terry Friesen - Staff Research Engineer (Oronite Technology Division)
- Leighton Haley Jr. - Chief Chemist (Norfolk Southern Corporation)
- William Hilgenberg - District Engineer (General Motors Corporation)
- Dr. David A. Hutchison - Research Advisor (Ethyl Petroleum Additives Inc.)
- Bruce Kehe - Manager Mechanical Services (Elgin Joliet & Eastern Railway Company)
- Charles T. Kunkel - Senior Manager Research & Development (Union Pacific RR)
- Ronald R. Lodowski - Manager Oil Control Laboratories (Conrail)
- Mark R. Logan - Staff Engineer (Oronite Technology Division)
- Dennis W. McAndrew - Fuels & Lubrication Specialist (General Electric Company)
- Piet Purmer - Technical Representative (Royal Additives)
- Fredric (Ric) D. Smies - Domestic Sales Manager (Lyondell Lubricants)
- Dr. Cline A. Tincher - Product Manager (Lyondell Lubricants)

IV. INDUSTRY UPDATES & NEW DEVELOPMENTS

Presented by:
Bruce Kehe, EJ&E

In September 1996, The Fuel, Lubricants and Environmental Committee unanimously decided to present, on an annual basis, updates on past papers and highlights of other relevant studies being progressed by various technical committees. These studies include ongoing work by the SAE Tech 9 Committee for medium-speed diesels, the American Society for Testing and Materials, and the Association of American Railroads.

Fuel Oil Stability

ASTM, the American Society for Testing and Materials, Section DO2.E.2 is responsible for maintenance of the ASTM Standard Specification for Diesel Fuel Oils, D975. The Diesel Fuel Stability Task Force of Section DO2.E.2 is exploring development of a specification element pertaining to diesel fuel stability and/or expanded discussion of fuel stability within the D975 appendix. Specific questions being investigated include:

1) Does a storage stability specification best serve the needs of current and future diesel fuel customers?
2) Is ASTM procedure D-2274, with a limit of 2.5 mg particulate/100 ml, a meaningful measure of fuel stability?
3) Is a refinery release specification really meaningful?
4) Would development of a thermal stability specification better serve current and future customers?
5) Does the Du Pont F21 (90 minute, 300°F) test, and its variants, provide a reasonable measure of thermal stability?
6) Would standardization of the widely-used Du Pont F-21 test as an ASTM standard method benefit the industry?

The task force believes that long-term storage stability is not of particular concern to the majority of end users, since most fuel is consumed within a few weeks of manufacture. Supporting this theory is the underlying industry-wide push to minimize material inventories and the demand for "just-in-time" delivery. Thermal stability (a resistance to change during use) is a greater concern, given diesel fuel's function as a heat-transfer fluid. Diesel fuel thermal stability is essential for its effectiveness as a heat-transfer fluid, particularly in the severe service encountered in locomotive applications.

Recent work conducted by one member of the Diesel Fuel Stability Task Force has identified several possible causes of thermal instability. During tests conducted on diesel fuels used in the State of California, the task force member identified an unfavorable reaction between cetane improvers and sediment precursors which resulted in premature filter plugging. Also, fuels with higher nitrogen and/or sulfur content appeared more susceptible to degradation spawned by cetaine improvers. Another possible contributor to the stability problem may be the poor solvency of some fuels. Aromatics are good solvents; fuels with lower aromatic content would be expected to have poorer solvency - allowing material that would normally remain in solution to fall out and plug filters.

Past railroad experience suggests that the Du Pont F-21 test (or variants thereof) provide a very useful measure of diesel fuel thermal stability, given the test(s):

1) Have been in use over 40 years.
2) Are currently and widely used.
3) Are relatively rapid and simple to run.

The Du Pont F-21 procedure consists of filtering a 50 mL sample of fuel, heating it for 90 minutes at 300°F, and refiltering it through a standard filter paper (pad). The darkness of the pad can then be measured using a reflectometer or visually compared to a standardized chart.

Development of a consensus standard version of the test (an ASTM standard test method) would, no doubt, be of great benefit to the rail industry. The Diesel Fuel Stability Task Force has decided to pursue making the Du Pont F-21 test procedure a recognized ASTM standard. This effort will start with a thorough review and updating of the existing procedure. The task force will then initiate and complete a round robin study (of both 90 minute and three hour versions of the test) to determine the precision and bias of the stability procedure. This is the first and critical step in making the Du Pont F-21 test an accepted ASTM procedure. The plan was to review and update the procedure by the June ASTM meeting and to complete the round robin analysis in the third quarter of 1997.

Once the ASTM procedure is accepted, this will enable the stability test to either: 1) be mentioned in the appendix of the ASTM D975 specification (similar to statements on storage stability and lubricity in the current appendix); or 2) be added as a thermal stability requirement to the ASTM D975 specification.

Risk-Based Management of Diesel-Contaminated Soil

Shortly after the LMOA convention last September, the AAR's Environmental and Hazardous Materials Research Program published its Report R-897 on "Risk-Based Management of Diesel Contaminated Soil." The thrust of this paper dealt with the fact that environmental cleanup standards for total petroleum hydrocarbons (TPH) in soil are generally based on the risks posed by specific hydrocarbons, such as diesel or jet fuels. However, most TPH solid standards used by regulatory agencies are conservative and utilize arbitrarily established values derived from the characteristics of gasoline. Railroads are essentially "victimized" with costly clean-ups because the regulatory standards in place are not specific with respect to the contaminant(s) that are actually present at a given site.

The introduction of risk-based corrective action (RBCA) clean-up goals by several states offers a refreshing approach for screening contaminated sites. The AAR's Report R-897 is a detailed introduction to the use of the risk-based corrective action process, with emphasis on the specific composition and characteristics of diesel fuel and gasoline. The risk-based corrective action method is applied to derive and compare soil clean-up goals based on either diesel fuel or gasoline as the contaminants at a hypothetical fueling facility. The results of this comparison show less strigent soil clean-up levels will generally be required when diesel fuel is the contaminant. This suggests that the physical, chemical and toxicological characteristics of diesel fuel are sufficiently different from gasoline to warrant site-specific evaluations of the soil at a contaminated railroad site. Using RBCA, the less stringent soil clean-up goals that result from diesel fuel (as opposed to gasoline) contamination will help reduce the cost of managing contaminated rail sites. Depending on site specifics, active remediation could be eliminated, or substantially reduced, as a result of the increase in the acceptable concentrations of petroleum hydrocarbons (from diesel fuel) which are allowed to remain in the soil.

The American Society for Testing and Materials (ASTM) has developed a procedure for determining RBCA clean-up goals. However, the quantitative values that describe the fate, transport and toxicity of complex hydrocarbons (such as diesel fuel) are not provided in the ASTM method. Consequently, other technical groups are developing analytical techniques and evaluating toxicological data to support the application of the ASTM procedures to diesel fuel (and other petroleum hydrocarbons).

While the RBCA process will likely increase site assessment and evaluation costs, this increase will generally be more than offset by less costly required clean-up goals.

The Fuel Lubricants & Environmental Committee endorses the AAR's risk-based corrective action approach to the clean-up of diesel contaminated soils, and encourages AAR's continued research in this arena.

Locomotive Coolant (Additives): Environmental Impact

The primary function of locomotive diesel water coolant treatment chemicals is to inhibit cooling system corrosion while providing adequate heat transfer from internal engine components.

The vast majority of locomotive engine cooling system treatments do not contain glycol-based chemistry, but rather use compounds such as borate, sodium nitrite, sodium nitrate, and sodium silicate. These chemical additives typically contain brightly colored dyes to aid in the detection of internal water leaks; these dyes are usually phenolphthalein (pink or red) or fluorescein (bright green) based.

In the event of emergency engine shut-down during inclement weather, most railroads require their crews or mechanical personnel to drain the engine cooling system to prevent catastrophic freeze damage to engine components and piping. Faulty operation of thermostatically controlled drain valves can also cause the unplanned discharge of cooling water into the environment. It is the discharge of the brightly colored (red or green) cooling water that can catch the ire of environmental regulators. The discharge of treated diesel water containing fluorescein dye is often mistakenly associated with harmful chemicals commonly contained in motor vehicle anti-freeze. In some instances, state or federal regulators have prohibited railroads from the (emergency) dumping of engine cooling water. For those railroads operating in the northern tier of the United States and Canada, this prohibition can result in very costly freeze damage - likened to a locomotive popsicle.

The AAR's Report R-900, published in December, 1996, evaluated the locomotive coolant additives commonly used by North American railroads to determine their chemical content and the concentration in which they are typically used. These results were compared to US Environmental Protection Agency (USEPA) criteria for reporting a spill of a hazardous chemical. Most of the compounds in the coolant additives are not considered hazardous by USEPA. In the few cases in which they are, the amount contained in a locomotive cooling system is well below the

USEPA's reportable quantity requirements (Table 1). As can be seen from this table, only sodium nitrite and sodium hydroxide are currently regulated by the USEPA. Neither chemical is present in a reportable quantity in typical locomotive coolant applications. Although the chemical additives cause the coolant to have a relatively high pH when it is initially released, the natural buffering capacity of various soils will tend to quickly neutralize this impact.

The AAR concluded that railroads should make every attempt to avoid (emergency) coolant draining in environmentally-sensitive areas such as streams, rivers and wetlands. Although dumped coolant is unlikely to cause any significant environmental damage, aesthetic concerns regarding brightly colored dyes cannot be totally discounted. Color from coolant using phenolphthalein dye may dissipate more rapidly than color from fluorescein dye. This is due to the pH-dependent nature of phenolphthalein dye. Phenolphthalein appears pink/red in the alkaline environment of locomotive cooling systems; however, it is almost colorless at a pH of 8.0 or less. Following a release of coolant, the alkalinity of phenolphthalein-dyed coolant can be rapidly neutralized by the environment. The color of the coolant containing phenolphthalein would then change from pink/red to colorless.

The AAR recommends pursuing the use of pH sensitive dyes (such as phenolphthalein) in locomotive cooling treatments. Use of these dyes, as well as new inhibitor packages which utilize optical brightening agents, would still enable mechanical forces to identify internal water leaks, while mitigating the aesthetic impact associated with (emergency) cooling water dumping operations.

Fuel Cell Propulsion Locomotives

The basic physics and chemistry of fuel cell technology have been known for a long time. However, significant work toward commercializing this power source has only occurred in the last decade. Contributing factors to the delay in fuel cell commercialization include:

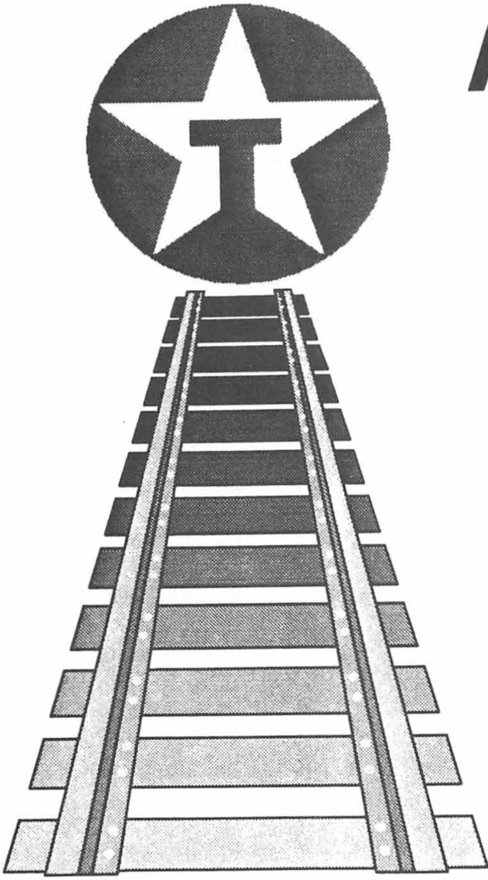
1) Initial high cost.
2) Low ratio of power output per unit volume and mass.
3) Difficulty in utilizing the low voltage DC output of the fuel cell.
4) General lack of knowledge of base materials:
   a) Overall life of key compnents
   b) Packaging

In recent years, however, our industry recognizes:

1) Increasing worldwide demand for crude oil.
2) International politics associated with the remaining crude oil supply.
3) Mandated clean air quality standards/regulated emissions.
4) Continued interest in low cost alternative fuels.
5) Availability of high power semi-conductor devices.
6) High efficiencies associated with fuel cell technology.

Today's power semiconductor devices (inverters, converters, GTO thyristors, etc.) now provide the technology to utilize the direct current fuel cell output in electrical power generation equipment. It is now technically reasonable to consider replacing the present locomotive diesel engine/generator power plant with a conditioned fuel cell system.

Significant progress has been made in increasing fuel cell power output per



unit volume and mass. High initial costs remain a problem. However, production of standard fuel cell "stacks" in higher production volume are expected to reduce procurement cost. A fuel cell "stack" is created by assembling several single cells in series or parallel to obtain a desired voltage or current. Much work is required to determine and qualify which fuel cell technology best fits a particular commercial application.

Each specific fuel cell application also requires investigation regarding the compatibility of all the components and subsystems. For example, most fuel cells require hydrogen as their fuel. The only byproducts of a hydrogren-based fuel cell are water and electricity. It should be noted that the hydrogen may be delivered to the fuel cell directly or by deriving it as a result of "reforming" a hydrocarbon base fuel. The BTU content per unit volume of the alternative hydrocarbon fuel remains a concern when designing a locomotive to have an equivalent operating range and refueling schedule as today's diesel-electric units operating on No. 2 diesel fuel. This lower BTU value may not be fully compensated for through the fuel cell's intrinsic higher efficiency.

Work accomplished to date has resulted in a request for project proposals from the U.S. Department of Energy for the design and demonstration of a fuel cell powered locomotive. The following fuel cell technologies could be evaluated for a railroad locomotive application:

PEMFC - Proton Exchange Membrane Fuel Cell
SOFC - Solid Oxide Fuel Cell
PAFC - Phosphoric Acid Fuel Cell

The U.S. Department of Energy has not awarded a contract for the fuel cell locomotive project because of budget cuts by Congress. Available funds for fuel cell development have gone to automotive electric car development.

Research and development activities toward making fuel cell powered locomotives commercially viable face numerous technical, economical and political challenges. Optimistic estimates indicate a prototype fuel-cell locomotive is at least 15 years away; however, the Fuel, Lubricants and Environmental Committee supports the continued research and development of alternatively-fueled locomotives.

Paper References

The following Fuel, Lubricants & Environmental Committee papers can provide additional information on topics covered in this paper:

- 1996: Diesel Fuel Standards and their Application to Railroad Fuel Quality Issues.
- 1993: Bioremediation.
- 1990: The Responsibility of Railroads and Facility Managers in the Handling and Disposal of Hazardous Materials.
- 1988: Overview of Environmental Requirements for the Use of Petroleum Products in the Railroad Industry.

The author wishes to acknowledge the contributions of: 1) Mr. John Bacha, Chevron Products Company, for his work and input in the ASTM DO2.E2 Section's continuing study on diesel fuel oil stability; and 2) the AAR's Environmental and Hazardous Materials Research Program regarding the "Risk-Based Management of Diesel-Contaminated Soils" and "Locomotive Cooling Water Dumping Impact" studies contained in this report. Also appreciation is given to Mr. Chuck Horton, from Electro-Motive Division of General Motors, for his insight and work in the area of fuel cell technology.

Table 1

Quantity of Additive Compounds Present in Locomotive Coolant Compared to USEPA Reportable Quantities

Compounds in Solid Additives	Maximum Percentage of Compound Present in Additive[1]	Maximum Estimated Quantity[2] in 250 Gallons[3] of Coolant (pounds)	US EPA Reportable Quantity[4] (RQ) (pounds)	Amount of Coolant Required to Exceed RQ (gallons)
Benzotriazole	5	0.59	na	na
Borate	20	2.34	na	na
Mercaptobenzothiazole	5	0.59	na	na
Sodium Metaborate	20	2.33	na	na
Sodium Nitrite	45	5.28	100	4,740
Sodium Nitrate	30	3.52	na	na
Sodium Silicate	10	1.17	na	na
Fluorescein	0.1	0.012	na	na
Phenolphthalein	0.1	0.012	na	na
Compounds in Liquid Additives				
Borate	10	4.84	na	na
Sodium Hydroxide	10	4.84	1,000	51,126
Sodium Metaborate	10	4.84	na	na
Sodium Nitrite	10	4.84	100	5,112
Sodium Nitrate	5	2.42	na	na
Sodium Silicate	5	2.42	na	na
Fluorescein	0.1	0.048	na	na
Phenolphthalein	0.1	0.048	na	na

[1] Maximum percentage of compound found in any of the additives based on Material Safety Data Sheets and information from distributors.
[2] Computed assuming the maximum percentage of the compound found in any of the additives according to their Material Safety Data Sheets and assuming a three percent solution of additive in the coolant.
[3] 250 gallons is the typical quantity of coolant in a locomotive cooling system.
[4] "na" means that the US EPA has not established a minimum RQ for this compound.

SOURCE: AAR Report No. 900 "Environmental Aspects of Railroad Locomotive Coolant Discharge," 12/96.

REPORT OF THE COMMITTEE ON NEW DEVELOPMENTS

WEDNESDAY, SEPTEMBER 17, 1997
10:00 A.M.

Pre-Convention Presentation CN/CP

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

June 11, 1997
Lombard Hotel
Winnipeg, Manitoba (Canada)

COMMITTEE MEMBERS

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R. Brewer	General Foreman	Illinois Central	Southaven, MS
T. Brunner	Gen. Mech. Supt.-Loco.	Amtrak	Philadelphia, PA
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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. 23, Cheryl 20, Steven 19, and Jennifer 16, and one grandson, Andrew, 2. They currently live in Glenmoore, Pa.

The **New Developments Committee** wishes to thank the Canadian Railroads for hosting their Pre-Convention Presentation in Winnipeg, Manitoba Canada at the Lombard Hotel on June 11, 1997.

I. AN OVERVIEW OF THE ELECTROPNEUMATIC TRAIN BRAKE

Presented by
Robert S. Runyon, P.E.
Norfolk Southern Corporation

Background

For more than 100 years, the automatic air brake has been standard as the brake system for rail cars in North America. Introduced in 1874 to replace an earlier system requiring direct pressurization of brake cylinders from the locomotive, the automatic brake derived its name from the fail-safe feature wherein compressed air was stored on each car, and admitted to the cylinders in response to a reduction of pressure in the brake pipe.

As trains became longer over the years, several enhancements were developed to minimize transmission delays and make the system, more tolerant of pressure variations due to restrictions and/or leakage in the brake pipe. Pneumatic brake systems using electrical control were tested with superior results, but failed to gain acceptance by the rail industry due to the prevailing belief that the electrical connections could not survive in the harsh railroad environment.

Therefore, despite its shortcomings, the automatic train brake has remained fully pneumatic to the present time with no significant improvement foreseeable. Even with a vent valve on every car to propagate a sudden drop in brake pipe pressure, an emergency brake application can be transmitted no faster than the speed of sound, which is about 1140 feet per second in free air and somewhat slower in the confined volume of the brake pipe. Service applications and release proceed much more slowly, and precise control of pressure in the brake cylinders is impossible due to frequent and unpredictable variations of brake pipe pressure over the length of the train.

By the early 1990's, the rail industry was beginning to reconsider the feasibility of using electrical means to control train brakes. Advances in the fields of electronics and communications had opened the way to new methods of control and more reliable hardware than previously imagined. The electric trainline with its unavoidable connectors at both ends of each car, once dismissed as preposterous, was being revisited with less skepticism, and wireless communication by means of radio was commonplace for remote control of locomotives. In short, the time had come for a bold and significant departure from the limitations of the purely pneumatic air brake.

The Electropneumatic Brake

In 1994, the Association of American Railroads (AAR) established a task force to study the issues concerning electric brake control and develop a specification defining a workable system, which has come to be called the electrically controlled pneumatic (ECP) brake. In the words of the AAR, this is "a train power braking system operated by compressed air and controlled by electrical signals originated at the locomotive for service and emergency applications." Meanwhile, a parallel effort was launched by Technical Marketing Services (TSM) to manufacture and field test their own version to which they refer simply as the electronic air brake system (EABS). By early 1997, New York Air Brake Corporation had a system developed and ready to be field tested, referred to as the EP-60. It is worth noting that much of the internal design of both systems is in keeping with the AAR specification.

The benefits of such a train brake, if the issues of reliability and implementation can be resolved, are unquestionable. Some of these are itemized as follows:

1. Immediate response to brake application and release commands throughout the train.
2. Reduction of in-train transient forces.
3. Permits graduated release of train brakes.
4. Maintains full brake pipe charging pressure during brake applications.
5. Provides a communications platform for other uses, such as distributed power.

For purposes of discussion, the ECP brake can be resolved into three fairly distinct components, aside from the existing parts such as the air reservoir and brake cylinder whose functions are unchanged. These components are the car control device, communications medium, and head end unit. Each of these will be described in turn in the following paragraphs.

Car Control Device

The car control device (CCD) is "an electronic device which replaces the function of the pneumatic service and emergency portions (of the rail car) and provides for electrically controlled service and emergency brake applications," as defined in the AAR specification. Its overriding purpose is to control brake cylinder air pressure, and in turn the resulting braking effort, in response to electrical signals from the controlling locomotive. In addition, the CCD must perform a few derivative functions to render the overall system fail-safe. One of these requires it to periodically reassure the controlling locomotive of its continuing ability to respond to brake commands, which is done in response to a status querry from the locomotive. Another function requires the CCD's isolated by a train separation or break in the communications medium to act independently to stop that portion of the train. Finally, there are functions that are secondary to the main purpose of brake control, such as a provision whereby each car can identify its position in the train.

Figure 1 shows a typical application of the conventional air brake to a rail car. In Figure 2, the service and emergency portions have been replaced by the CCD which electrically implements the functions of both and contains only such pneumatic devices as necessary to control brake cylinder pressure. Because the air reservoir can be restored to full charge while the brake is applied, a single chamber and pipe connection will suffice. The new communications medium is represented here as a generic interface with the CCD, and will be discussed later in greater detail.

Since the ECP brake is incompatible with the conventional air brake by design, an important question arises concerning how to maintain interoperability among the cars while the electronic system is being implemented. Systems that have been field tested thus far have been applied to every car in the train and confined to unit trains to keep the logistics manageable, but the question of fleetwide interoperability must be addressed eventually. To this end it has been suggested that the implementation process be carried out in several phases such as listed below:

1. Phase I would involve installation of the electronic components on each car to create a pneumatic brake with electronic overlay, as shown in Figure 3. Each system

would be fully functional and self-contained, except that both would share such resources as the air reservoir and brake cylinder, using a common interface consisting of the existing pipe bracket and a special adapter plate attached thereto. Temporary means would be required to select either of the two systems for operation. In this manner the modified cars would remain operational without any loss of function, although the benefits expected of ECP would accrue on only those trains that are 100 percent equipped.

2. Phase 2 would begin only after fleetwide completion of Phase I, to the extent that stragglers can be set aside without undue hardship pending ECP installation. As illustrated in Figure 4, the service portion would be removed and the exposed face of the adapter plate covered. The emergency portion remains intact as a "last resort" backup against system failure.
3. Phase 3 would be initiated only after the ECP system has proven itself in actual service to be no less safe and dependable than the present pneumatic system, and could overlap Phase 2 to some extent, maybe completely. Referring to Figure 5, this would entail removal of the emergency portion from the pipe bracket. There has been speculation that a vent valve might continue to be a requirement for each car, a decision that can be postponed for the time being. The existing pipe bracket and retainer will probably remain with retrofit applications as a less expensive alternative to removal, but could be omitted altogether from new cars along with the adapter plate, thereby returning to the more simplified arrangement of Figure 2.

Communications Medium

The second principal component of the ECP brake to be discussed is the communications medium. This is the means whereby brake status and control information is conveyed between the controlling locomotive and rail cars throughout the train. Three physical platforms have been considered, with only the first and last receiving serious attention:

1. Trainline Wire - A pair of insulated electrical conductors extending throughout the train, twisted and shielded to preclude external interference.
2. Fiberoptic Trainline - An optical fiber extending throughout the train, with a suitable protective cover to prevent damage.
3. Radio - This definition may be expanded to include any wireless means requiring an antenna on each locomotive and car but no physical connection. Communication to each car may be direct or relayed by intermediate cars.

A simplified variation of radio communications was suggested several years ago, in which one or more rail cars would be equipped with a repeater to receive brake commands from the locomotive and locally reduce pressure in the pneumatic trainline. This arrangement would provide some relief from the transmission delays encountered with the conventional air brake in long trains, and could be implemented gradually with immediate results. It would not, however, shorten the time required to recharge the trainline, nor would it provide any of the other benefits expected of the ECP system. Additionally, there would be the logistical problem of placing repeater-equipped cars in the train at locations where they would be useful.

Just as important as the physical medium is the selection of access method, or means by which a communicating device (node) attached to the network can transmit a message without interfering with another simultaneous transmission. Several methods are in common use, such as the following:

1. Token Passing - A "token" is the authority held by a node to transmit a message. At any given instant, only a single node can possess the token and send messages if collisions are to be avoided. When it has nothing else to transmit, the node "passes the token" in the form of a specific message addressed to the next node in a designated sequence. A problem with this method is that a critical situation can develop on any car in the train at any time, possibly just after the token was passed on, which could result in unacceptable delay before the next opportunity to transmit. Another problem develops in the event of a break in the communications trainline (if used) not involving a train separation. Continued use of the network would require that a duplicate token be created for the isolated section, which opens the door to larger difficulties.
2. Polling Arrangement - By this method a single intelligent node (probably the controlling locomotive) is designated to manage the network, and sequentially polls the remaining nodes which must "speak only when spoken to." The prospect of delaying an important message is the same as with the token passing method, and for the same reason. Also, the cars situated to the rear of a trainline break are left mute for lack of a network manager.
3. Carrier Sense, Multiple Access (CSMA) - Under this arrangement any node can transmit a message as soon as the network is clear (carrier absent). Provided that sufficient capacity remains in the network to avoid saturation, access delays will be minimal. Further, after a break in the communications line, cars in the isolated but otherwise intact part of the train can still send messages to each other. These enable each car to determine the failure to be the result of a system fault and take action to stop the train, which would be inappropriate in case of a local failure on that car only.

For the reasons given above, the CSMA method was selected by the AAR as the only one suitable for the intended application. Further, it was recognized that the selected network protocol should be widely accepted and implemented in hardware with availability from several sources. The LonWorks (R) protocol by Echelon was the only one found that met these requirements, and was therefore specified by the AAR as the standard for the ECP brake.

Before leaving the present subject, we should explore the issue of a power source for the car control devices, the selection of which is very much intertwined with the choice of a communications medium. Two possibilities are under consideration: a single head end power supply on the locomotive, and individual low-power units installed on each car. The head end power source requires a wired trainline with conductors sufficiently large to prevent excessive voltage drop in the longer trains, which can be the same conductors used as the communications medium. The AAR task force has estimated the average power consumption at ten watts per car, and recommends AWG 8 wire with a 230-volt DC power source. Precautions would be required to eliminate the hazard of electric shock, such as a low-voltage test for trainline continuity prior to application of full power from the head end, and there is some ongoing debate regarding the sufficiency of the suggested precautions.

The on board power source would generate power locally on each car. Both axle-driven and vibration types have been considered, and some have been constructed as prototypes for testing. None of these is known to be in production as of the date this report is submitted for publication. A local source of power for each car is completely versatile with respect to the choice of communications medium, and its eventual success will depend on other practical considerations.

As a final note on the subject, both approaches will require a local battery on each car for initial setup and switching moves, and for any other periods of time while generated or head end power is not available.

Head End Unit

The last principal component of the ECP brake system is the head end unit (HEU), defined by the AAR as a "brake system control device used by the locomotive engineer to control the electric (train) brake system." Some of its intended functions are listed below:

1. Provide operator interface to control ECP brake system.
2. Provide data display for the operator
3. Maintain an accurate record of train consist.
4. Monitor the end-of train (EOT) beacon.
5. Supply trainline power (if used) for car control devices.
6. Provide "switching mode" for limited operation without trainline power or EOT function.
7. Provide means to conduct initial terminal brake test.

One of the functions assigned to the HEU is to maintain an accurate record of the train consist, which is essential for the detection of any car that fails to respond to commands. While the failure of a single car is not necessarily critical, multiple failures in excess of a predefined number will require an immediate brake application to stop the train while there are sufficient operational cars to do so. An initialization process must be performed in order to load the indentification of all cars into a data base in the HEU before a train can be safely moved, with means to update whenever cars are set off or picked up enroute. Methods have been proposed whereby initialization may be done automatically, which would be preferred by the railroads if feasible.

Two general arrangements of the head end unit come to mind: overlay and integrated. The overlay arrangement uses a dedicated display and controls for the train brake, leaving the existing locomotive brake system unchanged. Its application is largely non-intrusive, requiring only physical space for the electronic units and a source of power. To date, all systems undergoing field test are using the overlay HEU. Purchase and application costs have been minimized by equipping a group of locomotives with a trainline wire and mounting brackets, and placing the electronic units as needed for service. It is not implied that this would be a palatable long-term practice.

The integrated arrangement would employ a single set of controls and display for brakes on both the locomotive and train, which requires the locomotive brake to be electronic. Presumably the latter would require an enhancement in the form of an interface to communicate with the ECP head end controls, but this arrangement avoids the need for duplicate controls and display on the locomotive. Locomotives with LSI-compliant cab electronics would require head end equipment designed to be compatible therewith.

Figures 6 through 9 are generic representations of HEU applications, showing typical overlay and integrated arrangements both with wired and wireless communications media, and including a head end power source with the wired option. The illustrations are not intended to be representative of any particular manufacturer; some designs may be packaged as a different number of physical units and/or referred to by somewhat different names. For example, the controls for train brake application and ECP display, shown for the overlay system as a combined operator interface, might more easily be constructed and installed as two separate units. The dashed line shown with the two overlay arrangements represents a few incidental connections between the locomotive and train brake systems, such as for PCS operation.

Interoperability Issues

The foregoing has described an electropneumatic train brake having a number of required functions, any of which could be implemented by one of several alternatives. Conceivably, many combinations of these alternative approaches could work together as a viable system. However, for each function that requires compatibility throughout the train, in particular those involving communications, the rail industry must select and adhere to a specific approach to achieve fleetwide interoperability. Following is a list of the principal areas of concern:

1. Specific performance criteria must be established for functional levels that encompass more than a single vehicle. For example, for each command to be issued from a locomotive, there must be a defined and predictable response from every car in the train.
2. The choice of a communications medium will be a definite issue which, as discussed earlier, may in turn restrict the choice of a power source.
3. A workable protocol for message transmission will be required, using the CSMA method for network access unless a better scheme is found. On a more detailed level, a specific format for the data in each type of message is equally necessary.
4. If a trainline is selected for communications, it must be joined between adjacent cars with identical mating connectors, so that any locomotive or car may be positioned in either direction. Connectors submitted for evaluation include Connomac, Tri-Star, Amp, Amphenol, and BIW. The first two of these are stand-alone electrical connectors; the others are each part of an assembly which includes a connection for the air hoses.
5. A modulated carrier is essential for communication by radio, and this approach is also preferred with trainline communications for noise

immunity and other considerations. In either case a carrier frequency and modulation method must be selected, which must obviously be identical for all locomotives and cars.

Some of the above choices can be made and later modified with minor equipment or software changes, but the communications medium can be changed only through a nearly complete replacement of the ECP brake system. It follows that as the number of ECP installations grows, the choice of media already made becomes an irreversible decision, with grave consequences if not carefully made in the beginning. The factors relating to media selection, already discussed individually, are summarized in Figure 10.

In April of this year, the AAR released its most recent version of the ECP brake specifications, after it had been adopted by the Brake Systems Committee. Along with a comprehensive set of performance requirements, the specifications provide for an electric trainline with a head end power source, although the way has been left open for the radio option with on board power if such equipment becomes available in the future. Also specified is the LonWorks (R) protocol by Echelon, with a detailed coding description for the message set.

On June 11, at a meeting of the Brake Systems Committee, the stand-alone connector submitted by Tri-Star was selected as the preferred inter-car connector to be used with an electric trainline. For a quick disconnect interface between the inter-car cable and the end of the car or locomotive, the group expressed approval for a smaller connector from BIW, of which the mating parts are not and need not be identical.

Concluding Remarks

To date, several trains are fully equipped and operating in revenue service with the TSM system, which provides an electric trainline and overlay head end unit with power source. New York Air Brake Corporation is ready to field test its EP-60 system which is of a design similar to but not fully compatible with the TSM design. GE Harris has proposed an ECP brake system using a low--power radio transmitter on each car, whose messages would be relayed by other cars in succession, and Westinghouse Air Brake Company is said to have a system undergoing design. Time will tell which of the above systems, if any, becomes accepted as an industry standard. Although one of these has a definite lead in the race to market, it is well to remember that a race is not won in the first lap, but the last.

Acknowledgements

The author gratefully appreciates the contributions of time and expertise by the present and potential suppliers of electronic brake components, to provide a better understanding of the many related issues that required discussion in this report. Further appreciation is extended to those suppliers who furnished slide photographs of their equipment for use in the presentation of this paper.

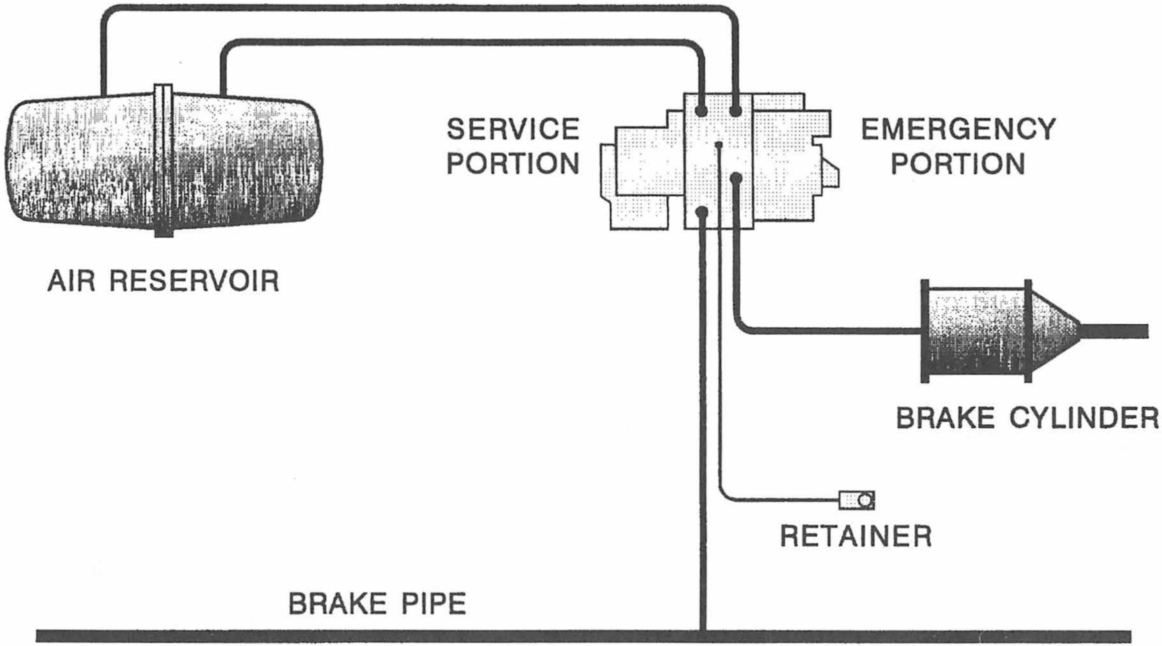

Figure 1. Pneumatic Brake for Rail Car

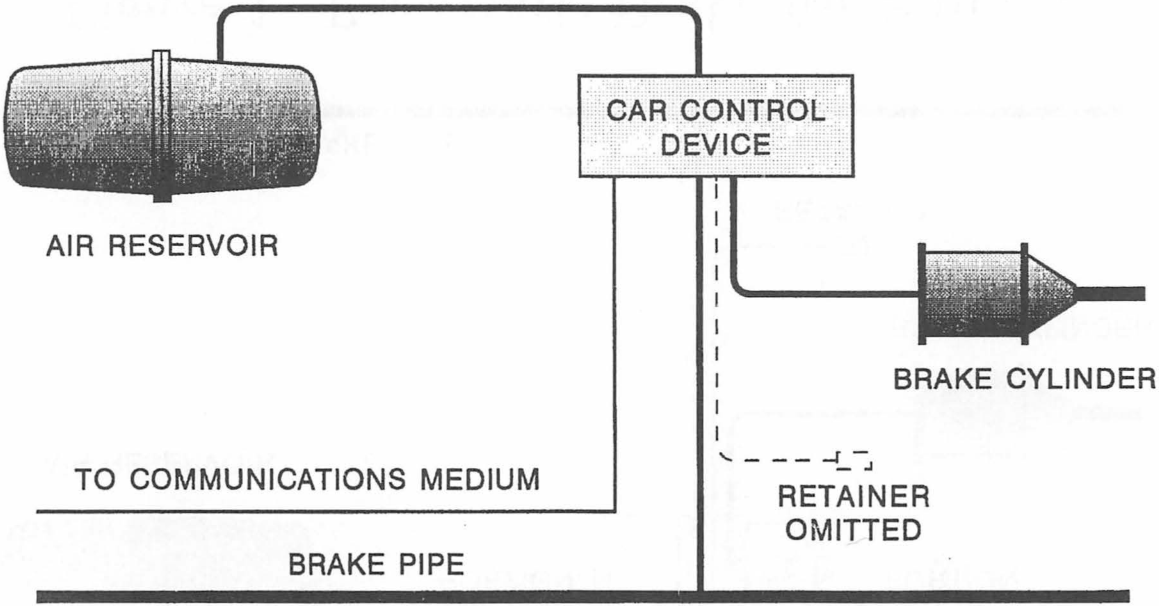

Figure 2. ECP Brake for Rail Car

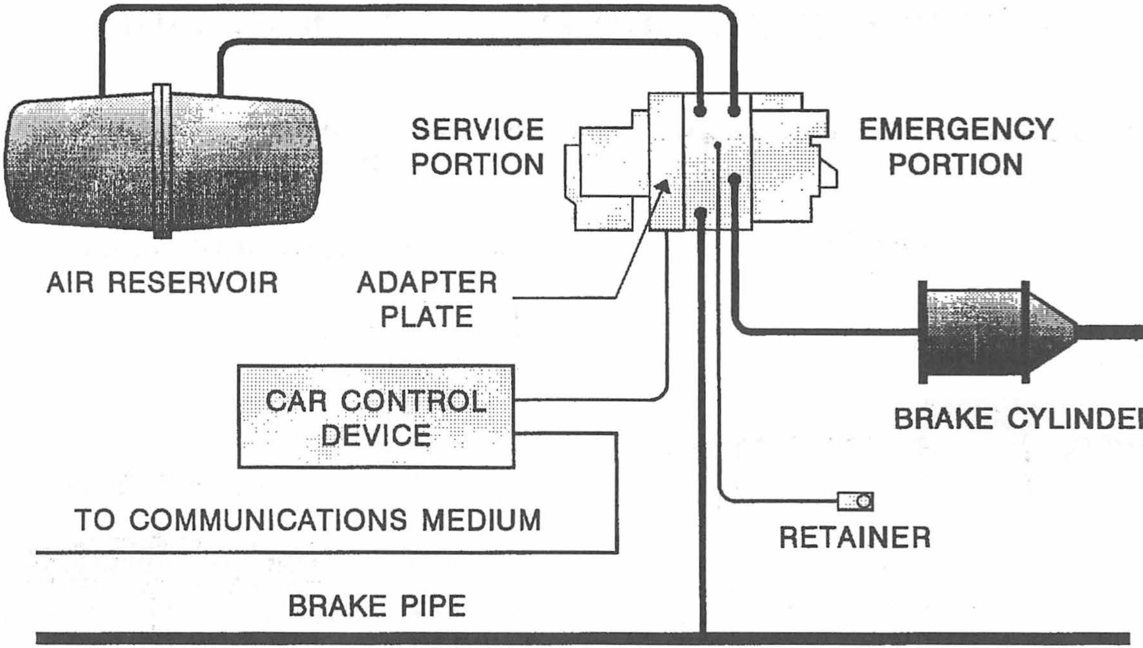

Figure 3. ECP Application: Phase 1

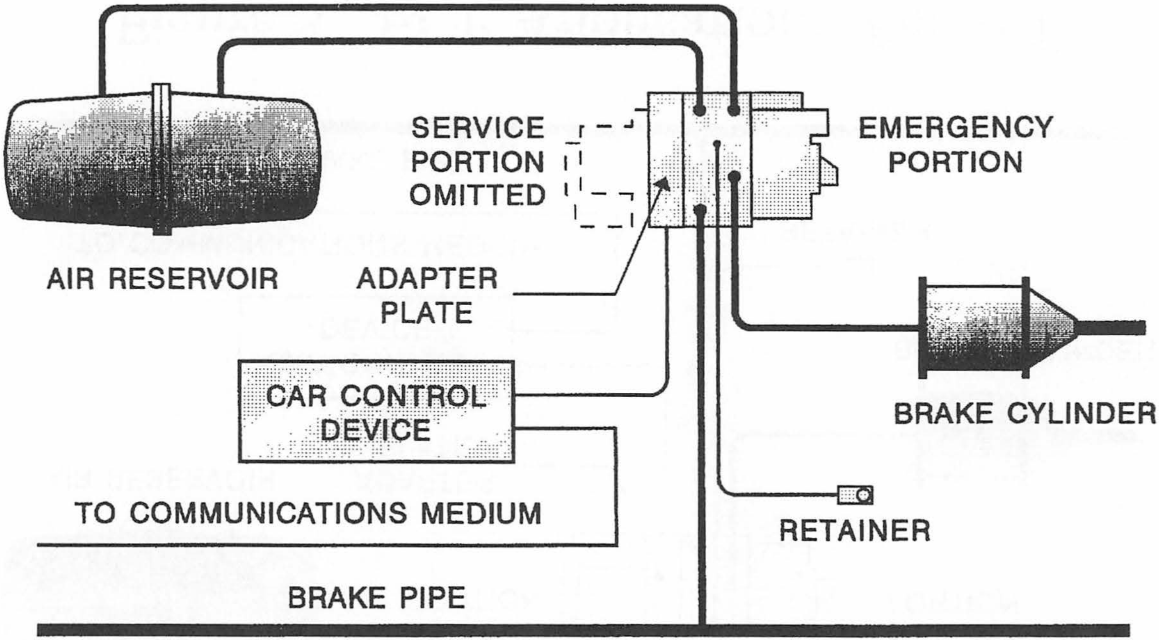

Figure 4. ECP Application: Phase 2

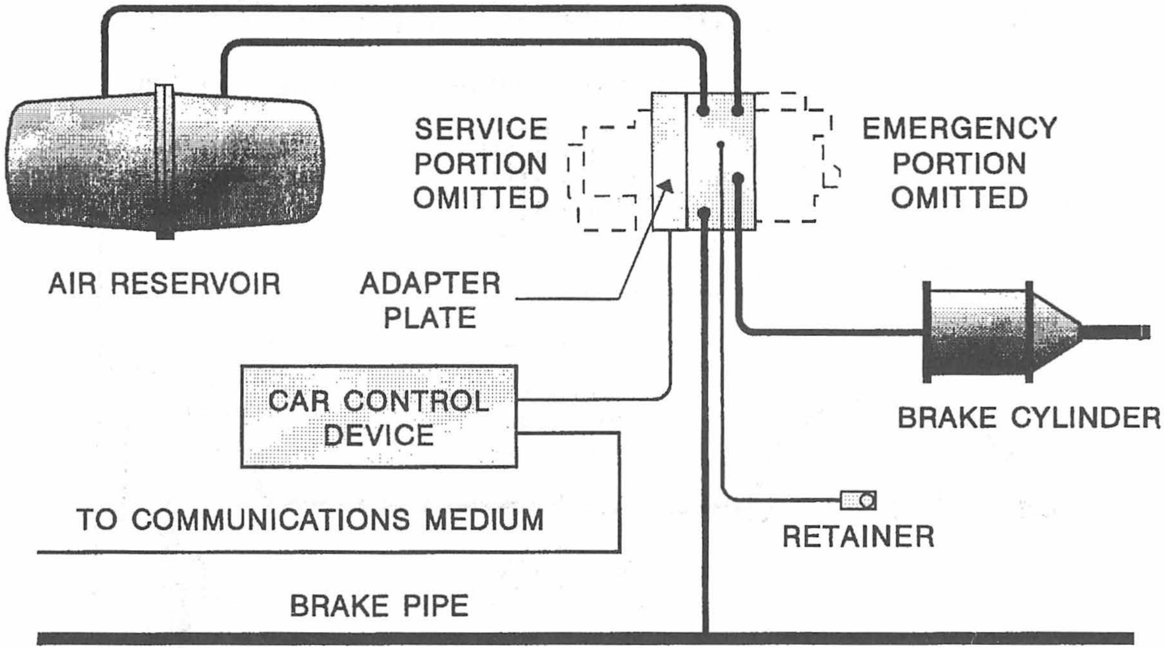

Figure 5. ECP Application: Phase 3

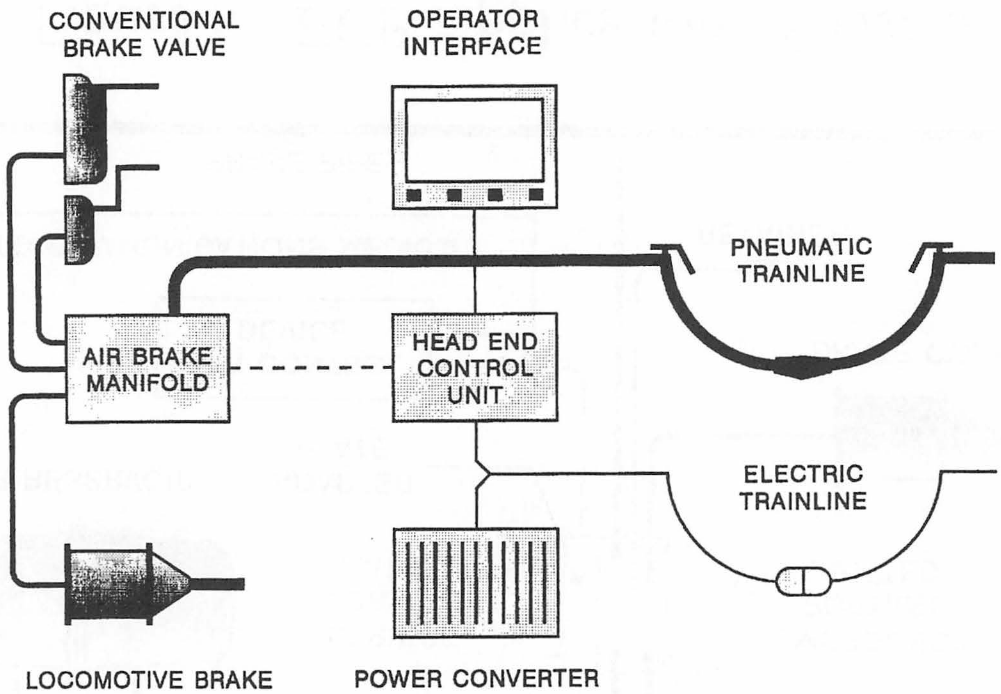

Figure 6. HEU Overlay with Trainline Wire

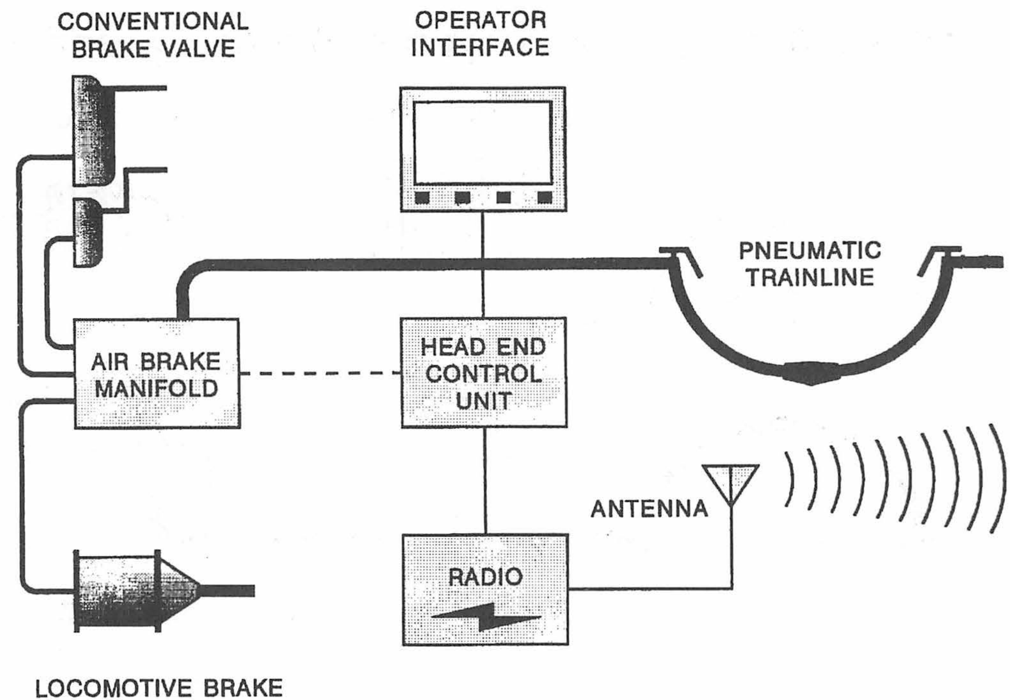

Figure 7. HEU Overlay with Radio

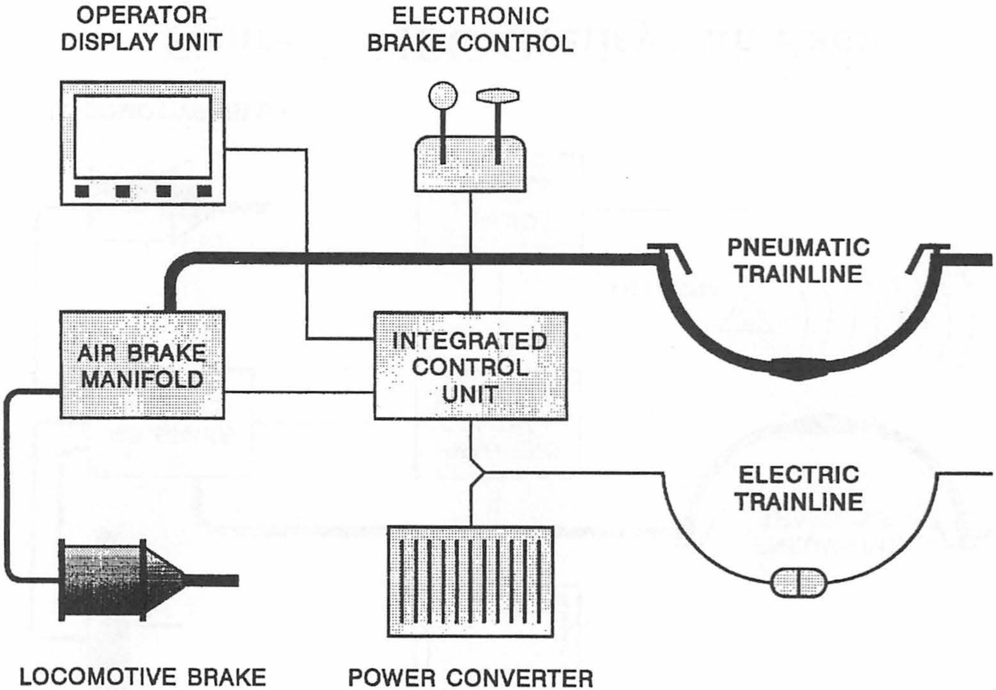

Figure 8. Integrated HEU with Trainline Wire

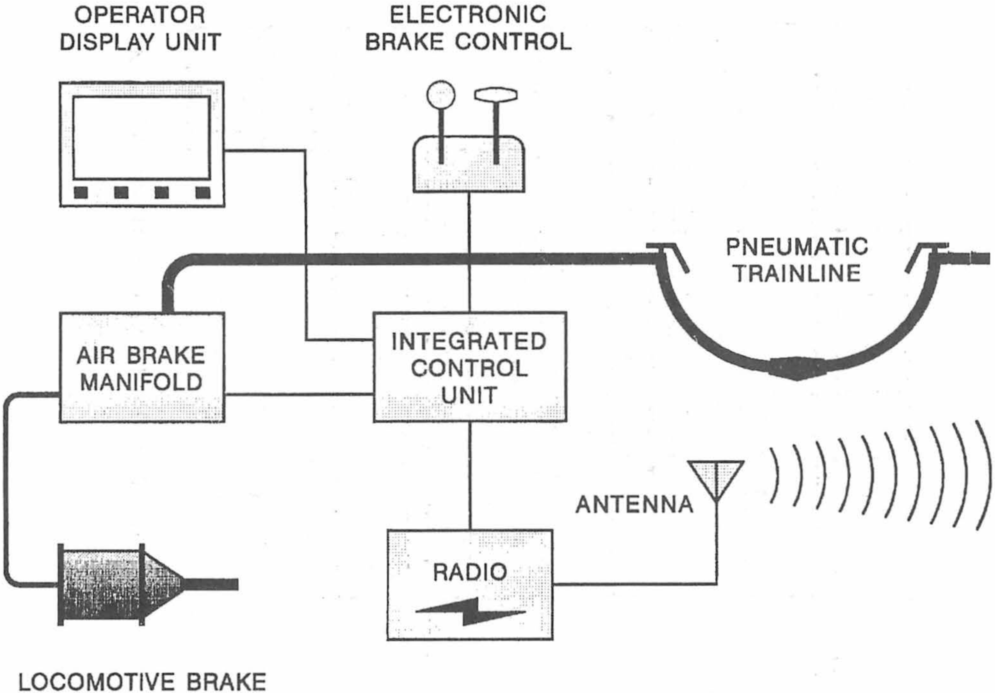

Figure 9. Integrated HEU with Radio

<table>
<tr><td>COMMUNICATIONS MEDIUM</td><td colspan="2">TRAINLINE WIRE</td><td>FIBEROPTIC</td><td colspan="2">RADIO</td></tr>
<tr><td>POWER SOURCE</td><td>Head end</td><td>On board</td><td colspan="3">On board required</td></tr>
<tr><td>IMPLEMENTATION</td><td colspan="3">Entire train must be equipped to realize any benefits</td><td>Full train</td><td>Repeaters only</td></tr>
<tr><td rowspan="4">BENEFITS</td><td colspan="5">Reduction of in-train transient forces</td></tr>
<tr><td colspan="4">Fastest possible response to brake application commands</td><td>Improved response</td></tr>
<tr><td colspan="4">Maintains full pressure in brake pipe during brake applications</td><td rowspan="2"></td></tr>
<tr><td colspan="4">Permits graduated release of brakes</td></tr>
<tr><td rowspan="3">CONCERNS</td><td colspan="3">Dirt and/or ice accumulation</td><td colspan="2">External interference</td></tr>
<tr><td colspan="2">Corrosion of contacts</td><td colspan="2"></td><td>Marginal reception</td></tr>
<tr><td>Shock hazard</td><td colspan="3"></td><td>Complex logistics</td></tr>
</table>

Figure 10. Comparison of Alternative Media

II. LOCOMOTIVE 6724, WHERE ARE YOU? GPS, Mobile Telemetry, and GIS technologies in a Railroad Environment

Presented by
Jim Harris, Conrail

Abstract

Conrail manages a locomotive fleet of approximately 2,100 units, half of which are in long-haul service, operating both on Conrail owned trackage and off property. A Locomotive Condition Monitoring System (LCMS) was developed to monitor this $2 billion of assets, by providing near real-time location and operating characteristics.

Systems currently in use at Conrail do not provide timely and accurate data; and commercially available locomotive health monitoring systems are typically of a limited, closed architecture. Preliminary specifications and a prototype were developed based on an open system philosophy consistent with the company's information technology architecture. ArcView, Conrail's desktop GIS, was used as the front end to this highly dynamic and versatile data collection, management, and analysis stem. Prototype architecture and capabilities for the on-board computer (OBC), communications subsystem, and host/server modules are discussed. Integration of locomotive originated data and existing data sets, and proposed enhancements are discussed.

Introduction

Competition is the driving force in corporate America. Until the 1980s, measuring the success of a railroad involved comparison to other railroads. While this still holds true, comparative measurements today include competition posed by trucking. Though volume of freight continues to increase, the overall picture is one of eroding market share for the railroads. Consequently, the individual railroads are now examining the technologies and business practices of successful companies throughout the entire transportation industry.

The face of railroading has been and is changing throughout North America. Currently, there are two dominant railroads in the west and three in the eastern part of the United States. This is about to change. Conrail, the largest freight railroad in the northeastern U.S. has been in the middle of a merger/takeover battle that will result in two major railroads having access to all ports and markets east of the Mississippi river. Conrail operates approximately 11,000 miles of track in the northeastern and midwestern United States and the province of Quebec. Primary routes run between Chicago and E. St. Louis in Illinois, to Newark (northern NJ)/New York and Boston, Massachusetts.

The essentials of freight railroad operation are commodities to ship, trackage to transport these goods, the personnel to accomplish delivery, and reliable power (locomotives) to convey the shipment. Conrail's Locomotive Assets group, within the Operating Assets department, is responsible for the availability and optimal performance of Conrail's locomotive fleet, which consists of approximately 2100 units. Half of this fleet constitutes long-haul road service critical to serving Conrail's customers. While Conrail jurisdiction has a defined geographic area a significant segment of its locomotive fleet is free ranging throughout North America. Regardless of the location, fleet performance status and utilization statistics are critical to overall operations: scheduling, optimal fleet size, and off-property charges. En route failures of the road fleet manifest themselves after the fact and contribute to bottleneck conditions on our key routes. The logistics of diagnosing, servicing unscheduled shoppings, allocating new power, and returning the locomotive to service are resource intensive. The ability to predict incipient failures and suggest a most likely cause would greatly reduce cycle time and increase on-time performance.

Given the dynamics of freight transportation - interchange delays, disposition of power, matching horsepower to the train consist, weather, and breakdowns - locomotive fleet sizing has never been an exact science. Historically, possessing and maintaining a fleet in excess of demand addressed any potential shortages of locomotive power. It costs approximately $1.3 million to replace a locomotive and an additional $88,000 in annual maintenance. The average age of Conrail's locomotive fleet is 17 years - on par with US Airways - with a life expectancy of 30 years. Conservatively this translates into roughly $100 million annually in fleet turnover costs. With these significant numbers, is it necessary to maintain the current fleet size? A given in the past, this conflicts with another corporate goal of "improved asset utilization" - getting more out of less. Tighter control and a clearer understanding of how and when the company's assets are being utilized is necessary. What are the spatial and temporal patterns of "trains without power" to "locomotives without trains"? How much time does a locomotive spend waiting for a train to pull (utilization)? Can the disparities be reduced such that locomotive dwell time and "light engine moves" are reduced to the point that we can reduce the locomotive inventory?

Answers to these and other associated questions require improved data collection and processing tools. Tools, such as real-time GPS tracking (Locomotive 6724, Where Are You?) and GIS (Where is the nearest facility?), are available at relatively low cost and have been employed with reported success by the competition. Real time location information, for example, would allow scheduling personnel to analyze power (locomotive) distribution and power deficit (assembled trains without locomotives) disparities.

Objectives

Typical measurements undertaken to assess fleet performance include mean-time-between-failures (MTBF), mean-time-to-repair (MTTR), availability, utilization, and en route failures. The Operating department targeted goals for improvement of the fleet:

- MTBV to exceed scheduled maintenance cycle
- 50% reduction in MTTR
- 20% increase in utilization
- 4% increase in availability
- 50% reduction of en route failures, eliminating unnecessary shoppings.

Additionally, maintenance should migrate from periodic or "run to failure" mode to "on condition" or usage-based repair - from reactive to proactive.

Technology is available to raise current fleet utilization and lower maintenance costs, leading to modified maintenance policies and decreasing overall operating expenses. Advances in sensor, communications, and micro processor technology enable us to monitor, predict and react to adverse locomotive conditions in real time facilitating rapid and effective repairs while reducing inventory, and material handling costs. Increased availability translates into a lower number of maintained units and a smaller capital investment. Graphic presentation of the fleet's location and performance provides a "big picture" view to operations' personnel not currently available.

Benefits

Collecting useable, pristine data on board a locomotive and relaying it, in real time, to a central site for immediate presentation and analysis is requisite to obtaining these goals. Monitoring every device on board that can potentially impact operating performance is not feasible. Decisions regarding proper sensor selection are necessary for effectively diagnosing a subsystem failure. Additional sensors may be required in the event a self-diagnosis can not be made. All information collected may need to be interpreted by a qualified locomotive specialist in order to correctly troubleshoot the problem. Utilization of GIS capabilities for display and network analysis will clearly expedite the process. The development of an accurate, timely, comprehensive locomotive location and condition database to store and disseminate these data ensures expeditious repair while also providing a foundation for other corporate-wide users and applications, such as power distribution and train scheduling applications.

Aside from collecting and processing locomotive condition monitoring data, the selection of an appropriate on board computing architecture would enable other users to develop potential applications requiring access to information resident to a locomotive in transit. The underlying communications infrastructure necessary to support message and data transfer between a locomotive and a central server can also provide a company-wide solution for extending its information network into the mobile environment. The combination of a multitasking computing environment aboard a locomotive, coupled with a reliable communications framework, would enable a variety of applications to be developed that require real time train information.

Background

Conrail personnel conducted a 15-month study through 1994 and 1995 collecting and collating historical data on locomotive utilization, failures, and repairs. The study covered over 6,000 locomotive incidents - anomalies that required shopping or dispatch of field service personnel. Analysis of these data yielded MTTR, number of en route failures, failure classification, average transit time to repair figures, resulting in actual utilization and availability statistics. A subsequent report cited deficiencies in the following areas:

- Current locomotive defect reporting mechanism
- Timeliness and accuracy of data regarding failures
- Excessive transit time to repair
- Inordinate percentage (44%) of shoppings resulting in "No Defects Found".

Among the recommendations cited was the need for an intelligent on board monitoring system with a near real-time delivery mechanism and central repository. Visualization of location and status information would enhance decision making processes regarding the disposition of the locomotive fleet.

Current Systems

Locomotive Assets currently monitors and reports Conrail's' locomotive performance and availability, using data reported through the Locomotive Information System (LIS) and the Locomotive Distribution System (LDS) - both of which are mainframe-based. In all instances, knowledge of locomotive failure is after the fact. These systems derive information from a variety of manual data collection processes at system and local levels. The primary function of the LIS system is to report locomotive failures and repairs. As the locomotive data become available, a subset is downloaded into a Windows-based relational database for measuring productivity.

Locomotive productivity measures developed from LIS data outline several disturbing facts. In the reporting of locomotive failures, the number one identified symptom is the category "dead". This does not provide sufficient information to maintenance facilities to adequately identify the cause of the failure. Secondly, a large percentage of the reported failures, over 40% in one analysis, were non-existent - no defects found upon a subsequent shop inspection. In either case, repair policy dictates a comprehensive check-up - a waste of time and money. This combination of inadequate information about a reported failure with no defect identified, coupled with no information prior to the failure clearly indicates the need for pre-failure locomotive operating conditions to assist in identifying the underlying cause of failures. Present systems rely highly on oral exchange of information, manual data entry, and faxing of reports. The information may pass through several hands and reporting mechanisms prior to reaching shop personnel and is susceptible to errors, loss of information, and high data latency. These and other trends have led us to identify the need to perform centralized, remote monitoring of the location, operational status, and physical condition of each of locomotives in the fleet.

Conrail formed a cross-departmental team to formalize the technical specifications necessary for implementing a condition monitoring system across the Conrail locomotive fleet. The team, representing various backgrounds and expertise, consisted of:

Steve Agostini, Asset Optimization Department
Dick Blanchard, Locomotive Assets Department
Todd Crane, Corporate Strategy - GIS Department
Jeff Eilenberg, Communications and Signals Assets Department
Bill Everett, Information Systems Department
Jim Harris, Locomotive Assets Department
John Huzinec, Locomotive Assets Department
Rick Ogden, Locomotive Assets Department.

What are other Railroads doing?

The team's early activities included establishing other railroads' use and interest in locomotive condition monitoring systems, as well as scrutinizing commercially available systems. On the whole, other Class I railroads are utilizing these systems, and relying on other entities for integration of disparate systems. The team questioned this approach due to the unfactored costs associated with integration, let alone learning and maintaining different systems.

Currently Available Health Monitoring Systems

More then 15 potential providers and system integrators proposed solutions. The result of this effort revealed inherent design and compatibility flaws in these condition monitoring systems:

- closed architecture - available systems not compatible across locomotive builder classes
- proprietary communications protocols or single network provider
- restricted scalability - Conrail cannot enhance system to monitor additional subsystems
- limited configuration ability - manufacturer defined functionality
- fixed outbound messaging - manufacturer defined fault monitoring and reporting
- one-way communications - non-interactive and predetermined.

The most prominent drawback of all systems reviewed is their inability to be deployed across the entire fleet. Conrail's locomotive fleet consists of a variety of makes and models, from different manufacturers. Some locomotives (e.g., EMD's SD80MAC) come equipped with sensors and processors to collect certain types of locomotive statistics. Additional money is required to move these data off board. Older models, such as the EMD SD50 utilized in the test pilot, are not instrumented and therefore need to be retrofitted with an entire LCMS system, from sensors, to on-board computer, to communication transceivers.

These deficiencies reinforced the LCMS team's recommendation that Conrail design and specify a locomotive condition monitoring system compatible to both present and future locomotive fleets. The team was chartered to field test a prototype and draft system specifications. Subsequent to testing and approval, the specification would be circulated to potential Locomotive Condition Monitoring System builders for construction of the on-board system. Conrail would then be able to test their products in a real-time, working environment with the prototype functioning as a control.

Design Strategy and Approach

Conrail's intention is to incrementally equip the road service locomotive fleet with a health and welfare monitoring system based upon open architecture/open systems principles. The system will incorporate the monitoring of significant locomotive subsystem parameters; convey that information to a central site, and display that information in a manner expediting troubleshooting by qualified Locomotive Assets personnel. There should be continuous performance monitoring of:

- Geographic location (global coordinates and rail line referencing system)
- Diesel engine and its support systems (combustion air, fuel, lubrication, cooling)
- Electric controls, including propulsion system
- Excitation system (speed, horsepower, braking).

Communications with the locomotives will be bi-directional in near real-time. Continuous railroad-wide data communications will be necessary for routine message and data reports, and immediate anomaly reports.

Periodic data requests will be initiated by Locomotive Assets personnel at the central site. A database server at the central site will function as a data storage mechanism, providing a feed to the LCMS display module and other client applications. Examples of client applications include existing mainframe applications such as Locomotive Information System (LIS) and Location Distribution System (LDS) as well as potential applications for shop facilities and service dispatch. This extended functionality will permit "closing the loop" on locomotive status, availability, and repair history.

Because of the magnitude of information collected and stored in the database, the system must have an easy-to-navigate interface. Since the data are primarily spatial in nature, a geographically based interface is appropriate. For temporal trending and identification of recurring problems, the collected data need to be integrated with other data sources - another task well suited for GIS. Operator-selectable displays must be available to analyze and sort through all routing messages and anomaly reports. The system must support links to expert systems and other modeling tools.

The Association of the American Railroads (AAR) establishes recommendations for the industry, which members often codify into standards and scope specifications. Applicable AAR specifications include Locomotive System Integration (LSI and Advanced Train Control Specifications (ATCS), the predecessor of Positive Train Separation (PTS). The former encompasses environmental criteria, interoperability and communications between devices, component and subassembly MTBF, and test parameters. The latter defines vehicle movement authority and enforcement, with heavy emphasis on communications protocol and messaging. Cognizant of these industry recommendations, the team deliberated over full versus selective compliance. Of greatest concern were the environmental aspects of the LSI specification. As to the ATCS specification, messaging regarding locomotive condition monitoring was incomplete.

By following Conrail's defined computing and technology guidelines and maximizing the use of commercial off-the-shelf components, subsystems, and software, the team was able to leverage in-house expertise and, in turn, speed the development process. ArcView, for example, has been certified by the Information Systems department as the corporate desktop GIS and was utilized by the LCMS team as an integration mechanism and data visualization tool. Incorporating these GIS resources not only aided rapid prototype development, but provided immediate access to data in the corporate spatial database. General reference information (political boundaries, streets), railroad industry (ownership), and Conrail-specific data (route structure, facilities) are all available to the LCMS operator. By knowing the locomotive's location in real time and the specific condition prior to dispatching repair personnel, the LCMS can improve the efficiency of locomotive repair. With the assistance of GIS tools, the operator will be able to determine the closest equipped facility or crew to the ailing locomotive.

Since the final end-to-end system consists of many complicated subsystems, the team planned to implement a modular proof-of-concept system in order to evaluate performance of all components, both individually and collectively. Three major benefits of a well-constructed modular architecture are that it provides expandability, avoids obsolescence, and prevents high costs associated with major code rewrites. Conrail plans to install components, both hardware and software, of various manufacturers so as to reduce the company's dependence on any one supplier or manufacturer, including communication network providers. Aside from the obvious reason of not being "locked" into purchasing equipment from any one supplier, it is important to keep up with an ever changing computing environment. As technology, and more importantly, our needs change, Conrail staff should be able to take advantage of a competitive marketplace for improving the

Locomotive Condition Monitoring System.

The design approach adopted also called for phased development of the total system. This would let the team focus first on the construction of the "core" technology and infrastructure necessary for collecting on-board data, and communicating messages with a central server. Further system development would allow for an increase in the number of sensors, additional on-board decision making capabilities, choice of alternative communication methods, and a variety of data presentation mechanisms.

Prototype Design and Process

There are three functional subsystems within the LCMS prototype: the On-Board Computer (OBC), the Trouble Desk, and the Communication Subsystem.

The **On-Board Computer (OBC)** collects information about locomotive condition and location, stores the data, reports the status at predetermined intervals, detects and forwards anomaly conditions and supporting information, and responds to Trouble Desk initiated requests. Under existing processes, locomotive failures are manually classified by a symptom code and description after the fact. Within the LCMS OBC, the association between sensor values and corresponding symptom code is calculated on board as the readings are taking place. This "self-diagnosis" is accomplished by determining which sensors are required to evaluate the status of a particular subsystem, and by having decision-making capability on board the locomotive. Physical components include the locomotive subsystem sensors (both analog and digital), a GPS receiver, an on-board processor, and communications transceivers.

The **Trouble Desk** can be further broken down into two components: a data storage, management, and distribution subsystem and a presentation and analysis subsystem. The data management subsystem receives messages from the locomotives (via the communication subsystem) or the Trouble Desk operator, logs them in a relational database, and notifies either the presentation subsystem or the locomotive that a new message has arrived. The presentation subsystem serves as the primary interface to the Trouble Desk operator. This is a map-based interface that displays requested information in a "railroad-centric" perspective, such as "What route, track, and milepost marks the location of this locomotive?" or "Where is the closest shop or facility equipped with a fuel pad?" When an incoming message is received by the presentation subsystem, the locomotive's position is updated on the map. If the message contains an anomaly, the Trouble Desk operator is notified by a change of the locomotive symbol on the map, and a dialog box containing the locomotive unit number, a symptom code, and an English language description of the problem.

The underlying data values used by the OBC to generate the symptom code are also available for immediate viewing, should the operator need to confirm the diagnosis or explore other conditions. This method makes troubleshooting much faster and provides an immediate entry point into the log files instead of having an expert pour through multiple (hundreds?) rows of data in order, hopefully, to arrive at the same conclusion.

The **Communications Subsystem** provides the interface between the OBC and the Trouble Desk. It receives a message from the OBC processor or the Trouble Desk subsystem, establishes and maintains the communication link, and transmits the packets to the target subsystem to parse and process.Since continuous coverage is required to ensure timely delivery of messages between the locomotive and OBC, multiple communication channels are needed. While a satellite communication link provides ubiquitous coverage, it is not well-suited to large file transfers and is also an expensive transport mechanism. Cellular technology and packet data radio are cheaper and allow larger and faster message throughput than a satellite link, but tend to cover only local service areas. Our solution was to isolate the communication links from the OBC and Trouble Desk subsystems and adopt an application programming interface (API) between these modules. This API would allow the OBC and Trouble Desk to write out a message without concern of which communication link it traverses. It is the job of the communications subsystem to prepare the messages for transport over the desired link and to ensure they are delivered in their entirety.

With the architecture divided into separate processing subsystems, messaging formats had to be defined for requesting and delivering data between them. As previously stated, the Trouble Desk operator can always review any information used to generate any OBC generated message. There are occasions, however, when a user would like to review a subset of parameters over varying degrees of time. For example, would a set of values representing one reading satisfy the question? Or is a ten-minute history of all subsystem sensors required? To handle this disparity, the team established different types of messages. A *snapshot request* - sent by the Trouble Desk to the OBC - would return one reading for all selected subsystem parameters. The *snapshot response* from the locomotive would represent the latest values recorded by the OBC. In contrast, when the OBC received a *buffer request,* it would return to the Trouble Desk all values recorded for a ten-minute period prior to an anomaly report with the last values representing the triggering event. *Status* messages are sent by the OBC at periodic intervals to the Trouble Desk. The frequency of status messages sent is a user-defined parameter and can vary between locomotives. Anomalies manifest themselves as *Alert* and *Alarm* messages. An *Alert* is a reading out of specification, with with no immediate failure pending. An example of this could be elevated engine temperature while the locomotive is pulling up a steep grade - while the value is out of range, it can be expected to return to normal once even grade is reached. An *Alarm* is a value out of range, with imminent failure. This may require shopping the locomotive or dispatching a repair crew immediately.

Findings and Conclusions

The LCMS prototype has been functional since April 1996. Since its installation, the system has logged thousands of messages - some have been alarms. Last June, we began to notice a failure report for one of the digital sensors associated with fan controller #2. (The fan controllers start fans to help regulate engine temperature.) Throughout the next few weeks, similar alarm messages were generated, but not continuously. Since the condition was not persistent, immediate action was not taken after the first reading, but a review of the location, time, and activity associated with each anomaly report revealed that Locomotive 6724's fans may not be firing properly. In each instance, Locomotive 6724 was pulling a heavy consist, some times up hill, and was therefore required to work harder - and hotter. All fans are needed to regulate engine temperature in these situations. The LCMS intimated that fan controller #2 had stopped working. The locomotive was inspected at the next shopping and, as it turns out, the fuse for fan controller #2 was blown. Success! While not a show stopper, if unknown, this condition would contribute to unnecessary engine stress and decreased life expectancy. Further, possessing this information beforehand precluded an en route failure.

With the successful performance of the prototype, and a functional specification completed, the team is ready to test and evaluate systems. Next steps include:

- Equipping more of the fleet with Locomotive Condition Monitoring Systems
- Increasing the number of available channels/sensors for on-board processing
- Implementing dynamic parameter configuration
- Enhancing on-board decision making capabilities
- Supporting additional communications links with priority messaging
- Modification of structure to accommodate additional message types - System maintenance utilities Application-specific messages (OBC/TD running multiple applications)
- Remote system troubleshooting
- OBC software upgrades.

The complexity imposed on the present system by these enhancements extends the functionality of, and reliance on, middleware and APIs. The isolation of application software from transport mechanisms and supporting infrastructure is critical. The logistics of capturing a 100+ ton moving target to tweak software or switch communication networks are diametrically opposed to the goals of increased efficiency and asset utilization.

Obviously, as the number of outfitted locomotives and sensors increases, there will be a dramatic increase in the amount of data collected and reported back to the central site. Further data modeling, data warehousing, and data "mining" techniques must be employed to guarantee fast and easy access to these data. Automated trending tools will assist users in correlating anomalies and suggest previously unforseen relationships within classes of locomotives and/or across the fleet. The use of ESRI's Spatial Database Engine (SDE) would ensure immediate access to comprehensive geographic datasets while on Oracle-based Locomotive Maintenance Database would provide a flexible repository and delivery mechanism capable of satisfying many different users. Future expansions, based on a full-scale production LCMS platform, include establishing terminal and shop diagnostic workstations, interfacing with train inspection devices, performing train consist reconciliation, and assisting power and train scheduling.

No longer an isolated technology reserved for "closet" or "behind-the-scenes" mapping, GIS is coming into its own supporting mission critical operations. Recent advances in GIS and related technologies, coupled with wider political acceptance, has promoted utilization of GIS throughout multiple application domains. Whether for asset or shipment racking, commodity flow, crew dispatch, or vehicle/locomotive repair, GIS and GPS technologies are playing an increasing role throughout the transportation industry.

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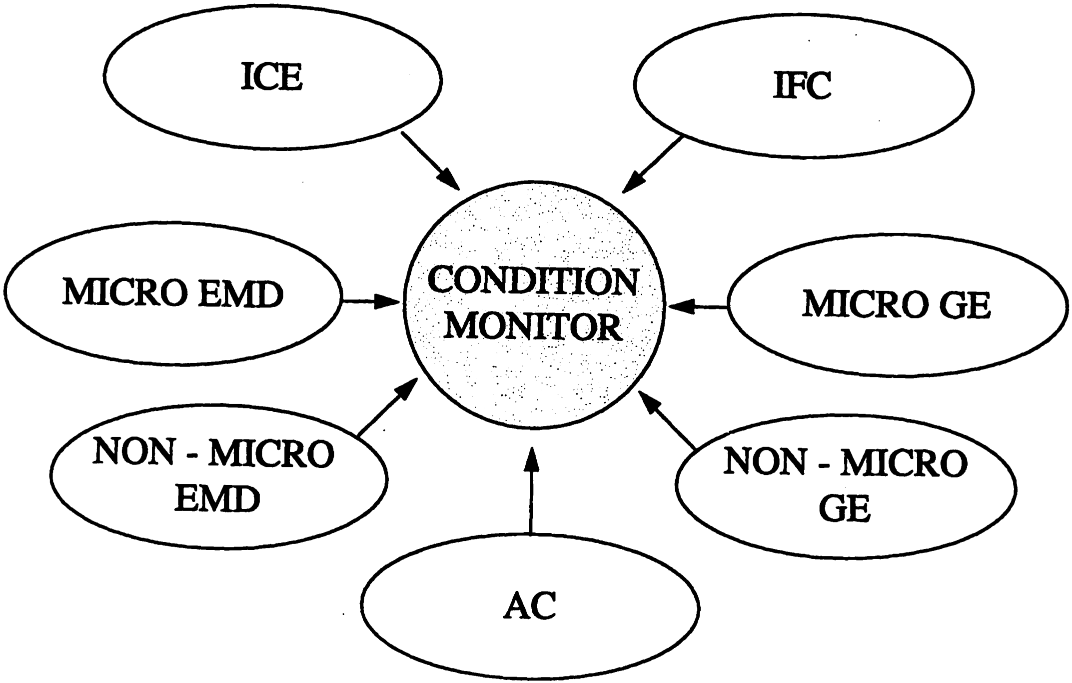
"Locomotive 6724, Where are You? Integration of GPS, Mobile Telemetry, and GIS Technologies in a Railroad Environment" will be published in the Proceedings of the 1997 Environmental Systems Research Institute (ESRI) Users Conference, San Diego, CA 1997. Check it out on the WEB at www.esri.com; Search for the 1997 User Conference Proceedings.

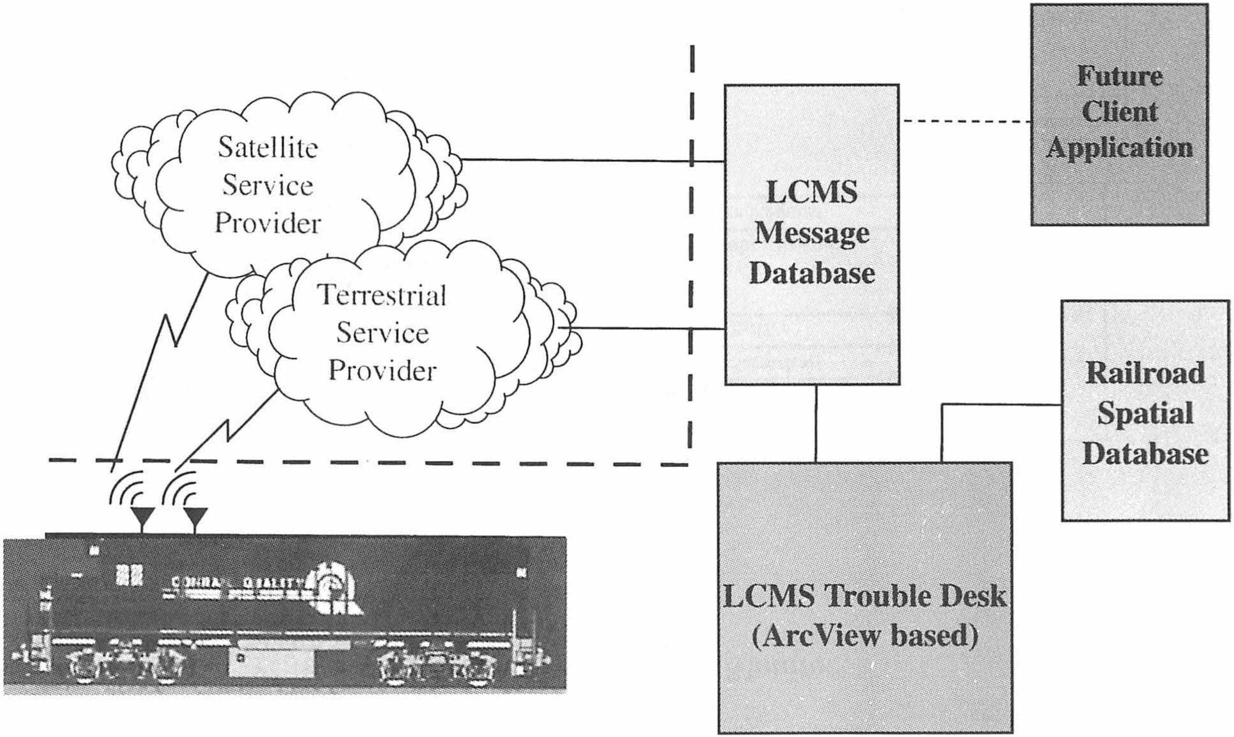
Locomotive 6724, Where Are You?

Integration of GPS, Mobile Telemetry, and GIS Technologies in a Railroad Environment

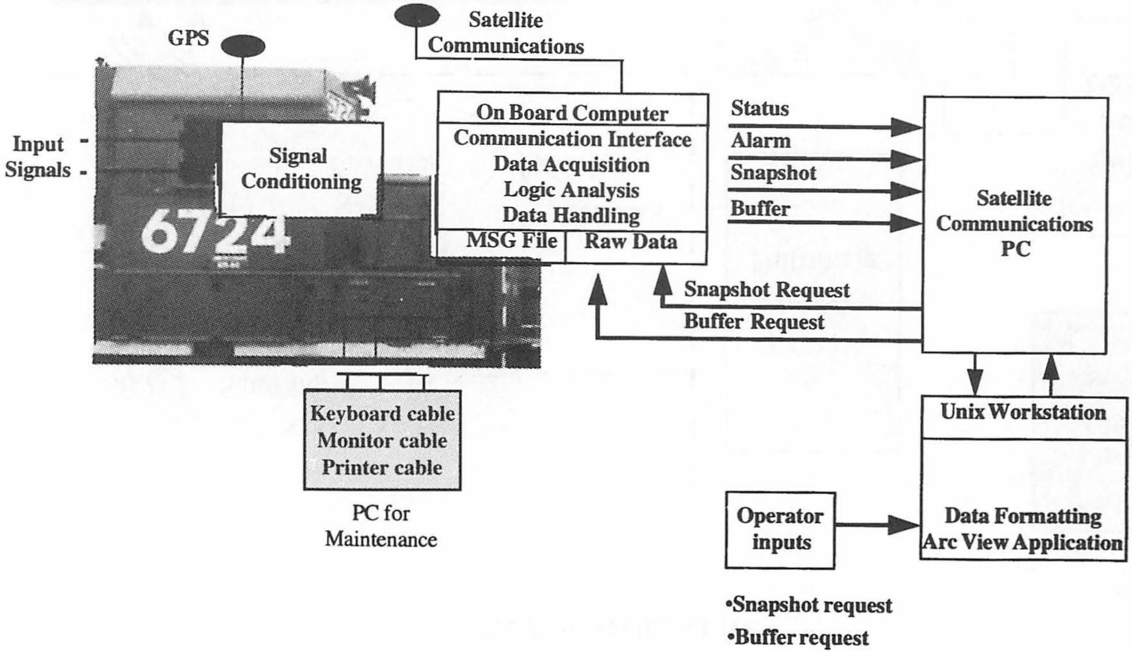
System Configurations

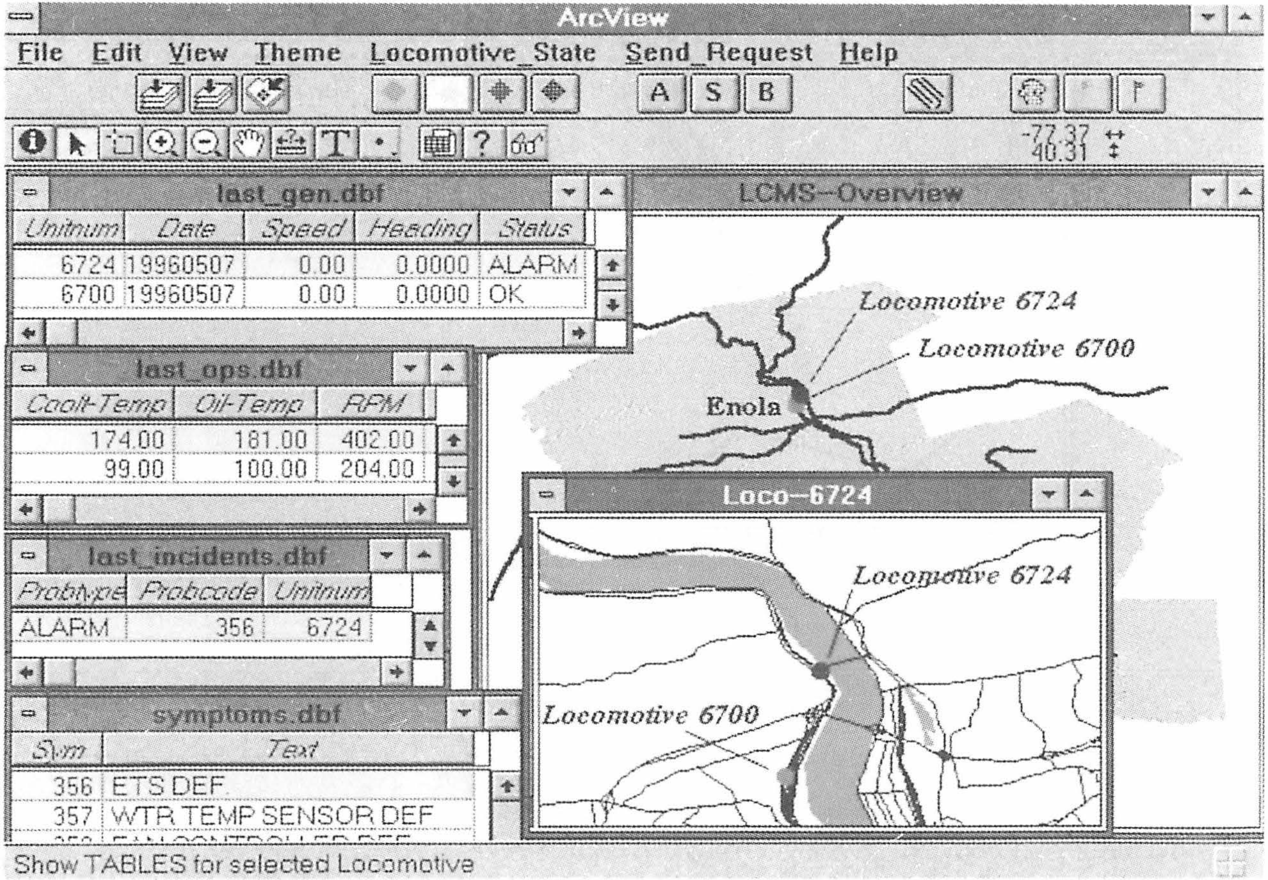


LCMS Architecture



Locomotive Condition Monitor Architecture

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Enola
Loco--6724
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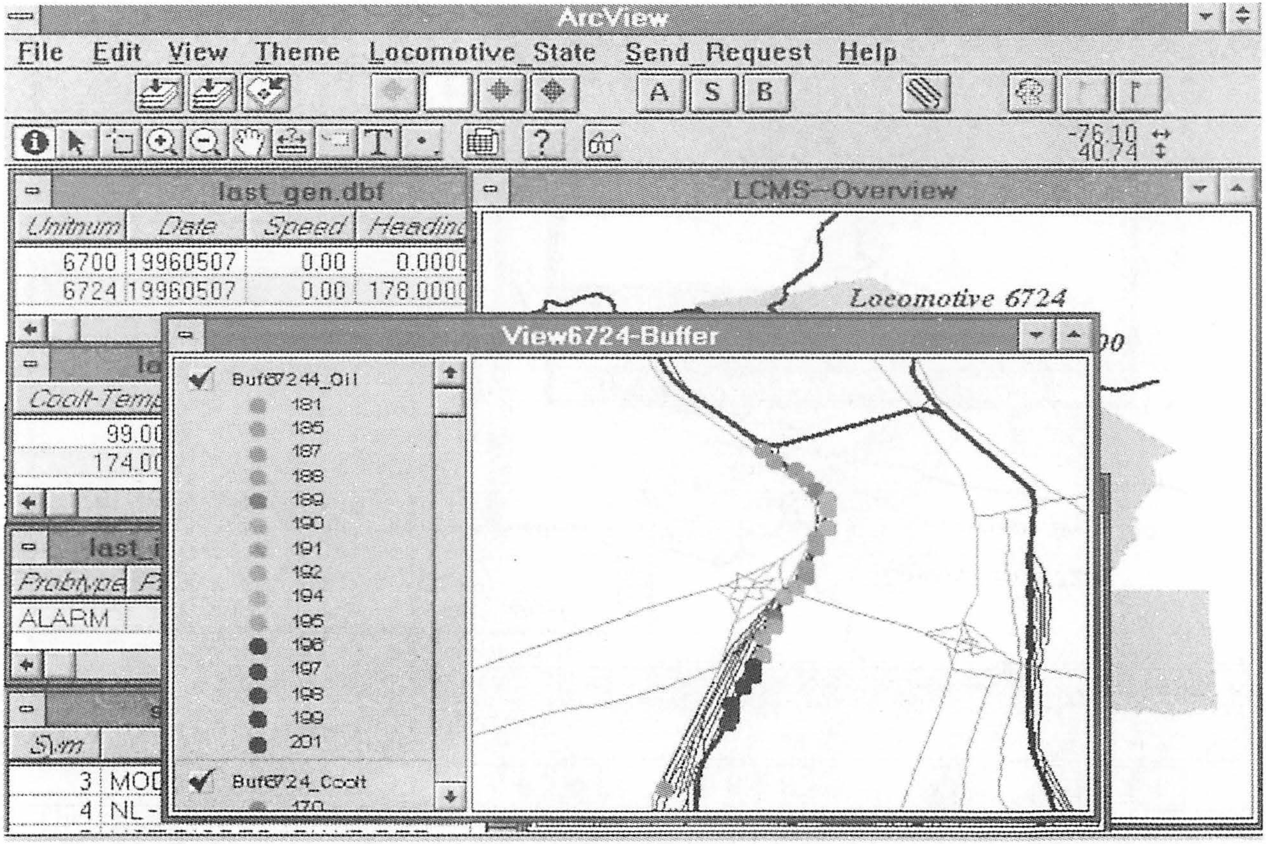
Locomotive 6700
Show TABLES for selected Locomotive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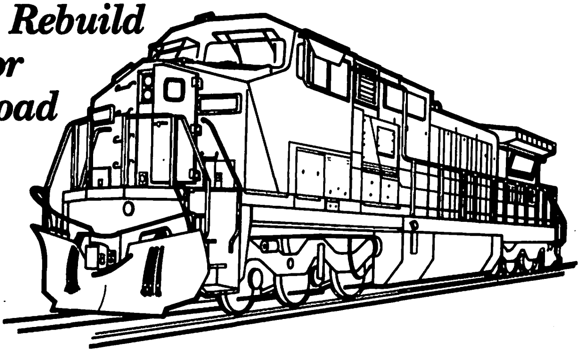

III. RUNOUT MEASUREMENT USING NON-CONTACT SENSOR TECHNOLOGY

Presented by
Keith Challenger,
National Electric Carbon

It will come as no surprise to most readers that the number of employees in the Railroad industry has decreased by over 30 percent in the last ten years.

Nowhere is the absence of skilled labor more noticeable than in the electrical and mechanical maintenance areas where there are fewer people to maintain increasingly sophisticated locomotive drive and control systems.

It should therefore also come as no surprise that there is a surge of interest in condition monitoring and data collection equipment designed to monitor and report on the condition of critical pieces of plant. Locomotive manufacturers have led the way with a significant increase in the number of on-board gauges and displays which alert the operating staff to conditions from fluid levels and pressures, to bearing temperatures and vibration levels.

Of course, on-board instrumentation is not by any means a new concept; but the need for longer periods between maintenance intervals, coupled with the reduced number of skilled personnel to perform this maintenance, has created a new line of thinking in locomotive maintenance.

Twenty-five years ago, planned maintenance procedures were in common use by most major railroads. Planned maintenance involved removing major plant from service at regular intervals during which vital components would be replaced before they ever had the chance to fail. This kept availability high and unplanned outages to a reasonable minimum. Costs were less of a factor and skilled labor was relatively plentiful.

Fifteen years ago, planned maintenance was being replaced by preventive maintenance, using a slightly different approach. Major downtime could be kept low and the cost of this extra availability could be reduced by increasing maintenance intervals on less critical items, while still performing regular inspections on the large, costlier items. The idea behind preventive maintenance was to perform regular, perfunctory inspections in the hope of identifying a potential component failure before it happened. The component would hopefully be repaired or replaced before failing, but *not* before the end of its useful life, which was a drawback of planned maintenance where items were replaced at certain times whether it was necessary or not.

In today's economically-charged business environment, we are all expected to be more commercially aware and prepared to embrace technology when time and/or money can be saved. This is very much the case in the railroad environment, where locomotive maintenance costs industry-wide have increased from $1.78 billion in 1978 to over $2.38 billion in 1995 (Figure 1)

There has also been a sharp increase in demand for more horsepower in recent years, from 49.5 million aggregate horsepower in 1992 to 55.1 million aggregate horsepower in 1995. This must be satisfied either by larger consists, or more technologically-advanced traction systems, both of which place even more demands on the maintenance function. With these factors in mind, it is no real surprise that a new form of maintenance procedure has begun to be accepted by the major railroads. Although a locomotive must still be recalled to a service facility every 90 days for statutory safety checks, it is becoming more common to find on-board monitoring equipment.

A new maintenance trend is beginning to emerge. Unlike its forerunners in the field of maintenance methodology, *predictive* maintenance makes no allowances for periodic inspections of "healthy" equipment and instead concentrates on the most likely failure modes. Here is how predictive maintenance works:

Failure mode analysis

- A piece of critical equipment is analyzed by the manufacturer who determines the failures which are most likely to occur.
- After defining the most likely modes of failure, the manufacturer decides which is the best way to monitor the condition of the equipment so that a defect can be detected before it causes a failure.

Condition monitoring

- Sensors are designed and installed to watch for these "symptoms" to occur.
- When any of the monitored conditions begins to change state, a record is made (usually automatically) and the frequency of monitoring may be increased.

Failure prediction

- By accurately tracing historical data for the equipment, it becomes possible to predict when a failure will occur, thus allowing the equipment to be serviced or repaired at the nearest regular outage.

The theory behind predictive maintenance requires that some reasonable amount of time elapse between the onset of the symptoms and the actual failure. However, not all failures give adequate warning. Consider two possible failure modes in a turbocharger for instance. Bearing wear might be considered a long-term event where gradual wear over an extended period of time causes incremental changes in vibration and an increase in temperature at the bearing housing. Foreign object damage on the other hand, would typically be a short-term event and would probably not be predictable because imbalance at high turbine speeds usually causes very rapid failure with little warning. Predictive maintenance is clearly not suited to all failure modes, but those which result in longer term deterioration of a component are certainly candidates for condition monitoring and failure prediction.

When executed correctly, predictive maintenance can not only prevent unscheduled loss of locomotive availability, but also reduce inventory costs since replacement parts can be ordered ahead of time if the maintenance planner knows exactly when the parts will be needed.

The cost of developing the sensors and monitoring equipment required for predictive maintenance can usually be justified in terms of increased plant availability, improved mission reliability, reduced manpower requirements and as mentioned, reduced inventory costs. Major locomotive manufacturers are now equipping their products with a wide variety of sensor equipment, and much is also available in the retrofit marketplace. This increased need for remote sensing of equipment conditions has prompted a number of suppliers to concentrate on the monitoring of rotating members such as shafts, bearings, commutators, slip rings and even wheels.

In non-rotating mechanical equipment, the most common candidates for remote monitoring are temperature, vibration and certain acoustic signatures. An increase in any of these parameters can be the first sign of an impending problem. In the case of stationary electrical equipment such as cables, connectors, contacts and the like, the best early clues to likely failure are voltage, current and resistance to ground. However, once the element of physical rotation becomes a factor (particularly at high speeds), condition monitoring becomes far more challenging and solutions become harder to find.

Rotating elements such as shafts and slip rings have a relatively smooth surface, possibly interrupted by helical grooving or a keyway. There are many different methods of measuring the distance from a fixed sensor to a predominantly smooth surface. This in itself does not present a major challenge. However, one of the most important electrical components on a dc locomotive is the commutator of the traction motor, which presents a rather unique set of circumstances. The surface is not smooth, it is non-ferrous (eliminating most types of magnetic sensors), and it does not have uniform reflective properties, making optical sensing difficult.

Two factors are of major importance on rotating elements. One is roundness, usually expressed as Total Indicated Runout (TIR), and the other is surface wear. Total Indicated Runout does not necessarily refer to the rotating element itself, but rather the way in which it rotates. For instance, a commutator may be perfectly circular (low TIR), but if it is used with a worn bearing, it could be rotating in an eccentric manner (high TIR). Measuring surface wear and TIR have some similarities, but it is generally considered that TIR is the more useful and less subjective measurement. Therefore, the emphasis of this paper is the measurement and recording of TIR for rotating elements of railroad equipment.

There are several methods presently used for TIR measurements. The simplest and most basic is the mechanical dial indicator (Figure 2) which consists of a solidly-mounted instrument with a protruding arm. The tip of the arm is placed in contact with the circumfrential surface of the member to be measured and as the arm is deflected, it causes a proportional radial movement of an indicator. A similar mechanical device called a Feinproof Recorder was introduced in Europe some time ago, and used a pin to record the deflection of a sensor head on a strip of waxed paper. Before long, an electronic version, called a "Pundicator" was developed, and this in turn became the forerunner of the commutator profiler. This instrument, made by a New Zealand company, was specifically designed to detect the TIR of a commutator as well as the maximum bar-to-bar height of adjacent commutator segments. Several versions of the profiler have followed, each with more sophisticated capabilities than its predecessor, but with the same major drawback of all these devices. In order to take a TIR measurement, a probe of some sort must be in contact with the surface being measured. This has the following disadvantages:

- The rotating member must be turned very slowly by hand to allow for the mechanical displacement of the indicator device.
- In the case of a commutator, centrifugal force can cause movement of individual bars which would affect TIR but would not be detected at slow measurement speeds.
- Resonance will cause high levels of mechanical disruption at a certain point in the speed range. This cannot be detected at very slow hand-turning speeds.
- Many rotating members such as shafts and wheels cannot be

turned manually unless they are disengaged from their respective drive system. In these cases, TIR can only be checked after the equipment has been disassembled when of course it is too late to discover that the TIR is good.

- In the case of commutators and slip rings, the rotating element is also an electrical conductor. For safety reasons it is not wise to turn the commutator or slip ring under its own motive power while a mechanical displacement sensor is touching a live component.
- A device which remains in physical contact with the surface being measured would not usually be considered suitable for permanent installation. Set-up and dismantling of such a device requires operator training and takes valuable maintenance time.

All these factors point to the need for a non-contact sensor which can be permanently mounted if desired, and which is capable of obtaining data while the rotating member operates throughout its speed range. The output from such a device could be incorporated into the on-board condition-monitoring systems so that such critical items as commutator or slip ring roundness could be gauged automatically, with human intervention required only when a fault condition was detected. It is currently common practice at some Class I railroad locomotive maintenance shops, to do visual inspections of commutators and brushgear whenever a wheelset is changed. Other locomotive maintenance facilities do not check the commutator roundness, but simply turn it in a lathe whenever the motor is taken out of service for other work to be done. A similar story is true of wheel and shaft turning which is done as a matter of procedure, rather than objective measurement.

It would be unrealistic to expect that every major rotating member on a locomotive could be monitored in a cost-effective manner, but there is an argument for a certain amount of monitoring when it would help in predictive maintenance practices, or for datalogging on suspect components over short periods of intense investigation. One of the reasons that non-contact roundness sensors are not as readily available as sensors such as thermocouples or accelerometers, is that there are some significant obstacles which the designer of such a monitoring system must overcome. For instance, stable mounting is fundamental to accurate roundness measurement, but is very difficult to accomplish. To install a roundness sensor on a locomotive where stable working surfaces simply do not exist, a form of mounting or fixture will need to be developed so that the distance between the sensing element and the surface of the rotating member either remains constant, or variations can be easily measured and filtered out of the instrumented data. Also, most sensors have a point of measurement which is relatively small. A basic capacitance probe for instance, might have a tip (measuring surface) of only 0.025 to 0.050 inches in diameter. Any variations across the diameter are usually averaged during signal processing. On a 12-inch diameter shaft rotating at 1200 RPM, a typical sampling rate might be 12-15,000 samples per second or one sample very 12-15 milliseconds.

A sensor for use in the arduous locomotive environment would need to be packaged in an enclosure capable of withstanding vibration, heat, dirt and possibly liquid contaminants. However, it must also be capable of maintaining precise measurement capabilities. And of course, a non-contact roundness sensor must be capable of being installed at a cost which allows relatively short-term payback in terms of maintenance cost savings and increased equipment availability.

Despite some obvious difficulties with reflective properties of the object surface, one technology under consideration is single-point optical sensing where a beam of laser light is reflected from a surface at a very precise angle (Figure 3). Differences in the distance between the light source and the reflective surface cause a difference in the way that the reflected light is received by the sensor. This change can be measured and interpreted as a difference in surface roundness. The advantages of this technology are its relatively low cost, its accuracy and the fact that it is a proven technology in various applications. However, it requires a surface with fairly uniform reflective properties, and can become unstable in a dirty environment where particles of dirt and dust obscure the lens and interfere with the reflected beam. Some manufacturers offer optical sensors with an air screen designed to keep the lens and light path free of contamination, but experience with these devices is limited and installation is complex.

A variation on the optical sensor idea is the optical array which uses a number of sensors grouped in a linear configuration tangentially to the rotating member (Figure 4). These sensors receive light output from a group of lasers mounted such that a curtain of light beams is partially broken by the rotating member. The sensors are able to detect the exact position of the interrupting surface, hence the roundness measurement becomes a simple function of the amount of light received by the sensors. This is somewhat more promising than the single-point optical sensor because it does not rely on a reflective surface and can contain some redundancy to reduce problems caused by airborne contamination. Unfortunately, it is more costly to use an array, and mounting accuracy can be even more critical, particularly in an environment where vibration is inherent.

Generally, optical sensors, whether used singularly or in an array, have some distinct advantages, but the difficulty associated with mounting and cleanliness of the light path make them less attractive in the locomotive environment.

When a non-magnetic, electrically conductive object is placed in the magnetic field of a coil, the effective inductance of the coil is decreased and its resistance is increased. This happens because the field sets up eddy currents in the object which circulate so as to oppose the field which created them. Moving the coil closer to the object increases the effect. Thus the coil characteristics are a function of the space between the coil and the object (Figure 5). This relationship is the basis of the so-called eddy current proximity sensor which may have some applications in runout measurement of shafts, wheels and other non-electrical components. It is probably not suited to a commutator or slip ring measurements because these components operate in close proximity to very strong magnetic fields which at best would distort, and at worse would completely cancel out the signal from the small coil in the sensor itself. There is also some question about the capability of this type of sensor to accurately provide suitable resolution for runout measurements.

The base technology for many types of proximity devices is capacitive sensing. This has an advantage over its optical counterpart because no line-of-sight is required so dust, dirt and other airborne contaminants are not a limiting factor. Certain types of capacitive sensors have been refined to allow the very accurate measurement that would


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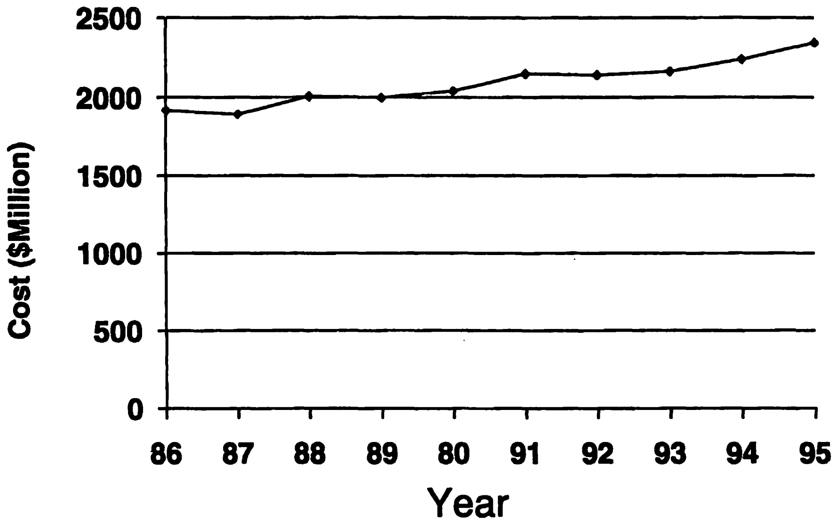
be required for surface roundness, but these tend to be more costly than optical sensors of the same accuracy. Once again, the stability of the mounting hardware is critical. A major factor in measurements on electrical components such as commutators is the presence of high frequency electrical "noise" which can cause signal disturbance. Tuning the capacitive signal frequency and the use of shielded signal wires can help to eliminate this problem, although this adds further to the cost of the system.

A non-contact roundness sensor would be mounted adjacent to the surface to be measured on a rotating member. The output from this sensor or group of sensors would be subjected to signal conditioning which would probably include analog to digital conversion. The resultant stream of digital data would then become the input for a computerized condition-monitoring system. Such systems are already installed on modern locomotives and several retrofit models are available for older units. The use of existing OEM-designed and installed on-board systems would enable this sensor to form an essential part of the much larger predictive maintenance package. Roundness measurements in isolation are unlikely to be very useful to maintenance engineers, but combined with data such as speed, temperature, vibration (plus current and voltage of electric motor armatures where applicable), would provide a complete monitoring package for a piece of critical equipment. In this example, the roundness sensor would provide a piece of the puzzle which is presently not available. As emerging technologies deliver the capability to build different types of sensor, remote monitoring of equipment will allow the flexibility for even more changes in railroad maintenance philosophy, with consequent safety improvements and cost savings to this vital industry.

Figure 1



LOCOMOTIVE MAINTENANCE COSTS

Source: Association of American Railroads

<u>Figure 2</u>

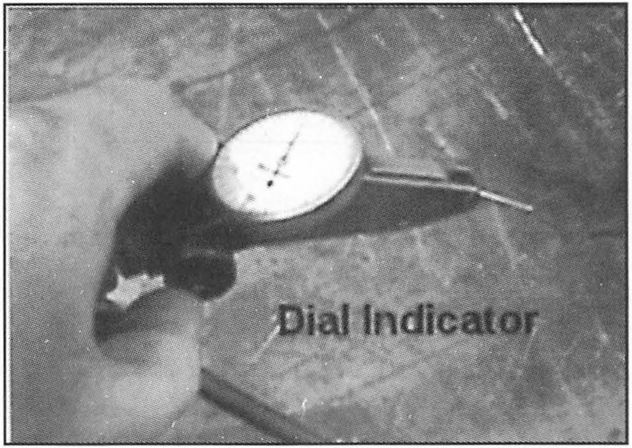
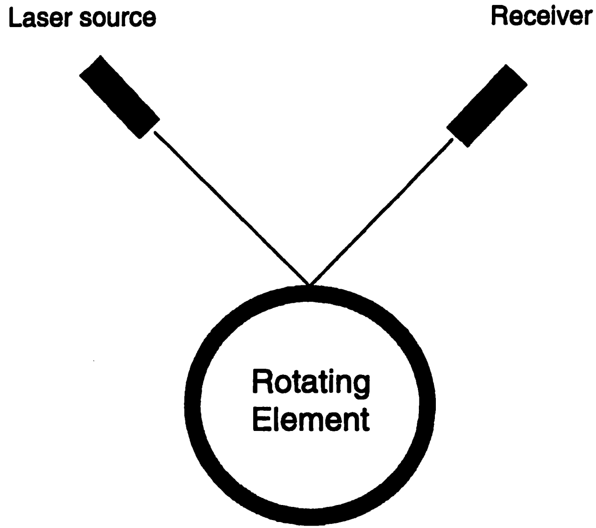
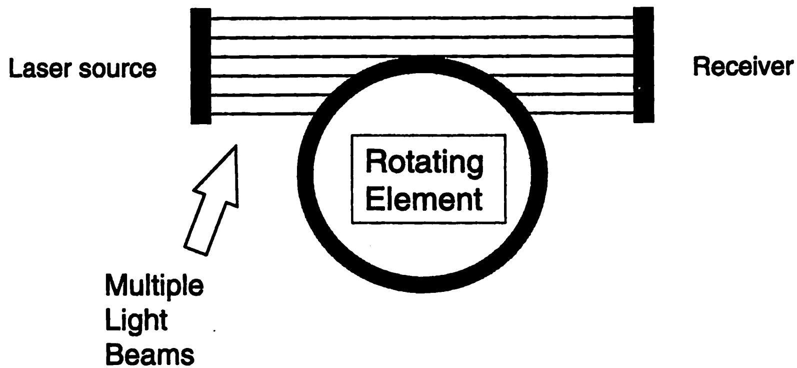


Figure 3



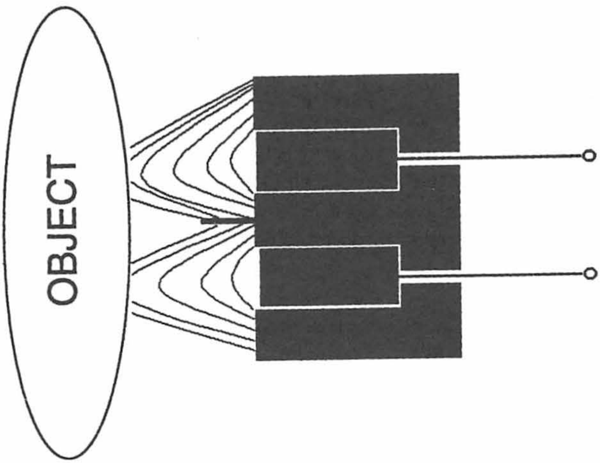
SINGLE-POINT OPTICAL SENSOR

Figure 4



OPTICAL ARRAY

Figure 5



EDDY CURRENT SENSOR

IV. COMMON RAIL FUEL INJECTION

Prepared by
Timothy A. Frederick, Conrail

Common rail fuel injection for EMD and GE diesel locomotives, once thought to be unattainable is now becoming a reality. Common rail fuel injection will enable the railroads to modify existing diesel engines to comply with EPA regulations for emissions output and attain maximum fuel efficiency.

System Description

The prototype Common rail fuel injection system is designed and manufactured as a modular system by Haynes Quantum Inc. a Florida company. It primarily consists of the following components, Fig 1:

Electronically controlled high pressure supply pump
Electronically controlled injectors
High pressure common rail
Electronic control module
Various engine system sensors

In a Common rail fuel injection system, the fuel volume between the high pressure pump and the injectors acts as an accumulator. Therefore the pressure in the common rail is almost constant during the injection process with only a small oscillation of the pressure in the common rail existing. This oscillation is due to the pulsating delivery from the high pressure pump and the injection of fuel to the cylinders.

Principle of Operation

The new prototype common rail fuel injection system achieves high pressure injection, 30,000 PSI with unlimited degrees of variability. Within certain limits the injection pressure can be selected independent of engine speed and injected fuel quantity.

Pilot injection and rate shaping or changing the shape of the injection profile with respect to engine speed allows for reduced emissions of particulates and hydrocarbons while at the same time reducing fuel consumption. To achieve this, the injector is activated or energized twice in the injection cycle (Fig 2).

The System

The prototype system utilizes an electromagnetically actuated fuel pump (Fig. 3) in which four pumping elements, equally spaced around a camshaft are mounted such that a pair of opposing pumping elements alternate to deliver pressure to a high pressure common rail. The construction of the pump with two opposing pairs of pumping elements (Fig 4), eliminates the bending stresses on the camshaft (major pressure limiting factor for all existing fuel injection systems) providing the system with unlimited pressure capabilities. The fuel pump is driven by a ten splined coupling from the EMD left bank camshaft stubshaft (Figs. 5 and 6). The fuel pump is mounted off the overspeed housing and supported from the accessory housing (Fig 7).

The high pressure common rail is adapted to reduce surges of the fuel pressure from the pump by using central and side chambers connected with crossdrilled orifices. (Fig 8). The pressure in the common rail is monitored by the electronic control module through a pressure sensor mounted on the common rail. The electronic control module will maintain the required pressure in the rail by adjusting accordingly the signal to the solenoid valve assemblies. The common rail has a relief valve for safety protection. It prevents the pressure in the rail from exceeding the maximum preset pressure. The electronic fuel injection (Fig 9) has a pressure balanced control valve to control fuel flow to the nozzle and has a pressure assistance mechanism at the end of injection to obtain a sharp end of injection. This design prevents the needle valve from being subjected to the high injection pressure.

Subsystem Design

The electronic fuel injector under the control of the engine electronic control module, will control the shape of the fuel injection profile. Such a control is achieved by varying the magnitude of the control current applied to the injector. The control current in turn varies the bias force applied to the needle valve in the injector nozzle, thereby changing the shape of the injection event profile in proportion to the amount of control current applied.

Electronic Control

The electronic control for the high pressure common rail fuel injection system consists of three basic parts; 1) The ECM, electronic control module. The electronic control module is the heart of the system and will integrate all information from the engine and to the injectors as well as the high pressure pump. 2) The SIP, sensor interface panel. The sensor interface panel will integrate all I/O from the engine and present these data to the ECM as serial data. 3) The ICM, injector control module. The injector control module will actually control the firing of the injectors based on signals received from the ECM. (Fig 10).

Electronic Control Module

At the heart of the electronic control module is a 32 bit microprocessor that will control both the high pressure pump and the injectors. The control module will ensure that the correct amount of fuel pressure is delivered to the common rail based upon engine speed and ambient conditions. Additionally the control module will insure that all injectors are fired in the correct sequence and at the correct time based upon the operating system and all external parameters. The electronic control module has attached various internal and external memory to hold both working parameters as well as the setup data for various locomotive types and fault logs for troubleshooting purposes. Critical inputs to the system, i.e. inputs that would force the electronic control module to stop operation, such as requested engine speeds (throttle valves), engine rotation and top dead center information, are routed directly to the electronic control module. Therefore if the sensor interface panel malfunctions or is otherwise inoperative, the locomotive can still be operated in a derated mode.

Sensor Interface Panel (SIP)

The sensor interface panel receives signals from the various analog and digital reference points on the locomotive. The sensor interface panel conditions the signals from the various sensors and then transfers this information to the electronic control module on a periodic basis. The sampling rate for each sensor can be modified based on the relative frequency that the sensor might change a significant amount. For example engine temperatures change rather slowly as compared to common rail fuel pressure which could change very rapidly.

Injector Control Module

The injector control module is the interface between the electronic control module and the equipment that controls the injectors, the high pressure pump of the common rail system, and will modify the excitation for the propulsion system of the diesel electric locomotive. This module has been segregated since it will be the control electronics and will be controlling either high voltage or current. It is advisable to keep this type of control equipment segregated from the microprocessor to avoid any possibility of feedback from the high voltage affecting the microprocessor logic.

The injector control module can be thought of as an amplifer, taking very small control signals from the electronic control module and controlling the high pressure pump and the injector process. The injector control module uses either high voltage or current, or both, to actuate the injectors or high pressure pump circuitry.

The common rail high pressure pump employs specialized stators, that are similar to magnet valves, to control the pumping events. These stators operate the low pressure fuel control to the high pressure pump, closing off the low pressure inlet line and allowing the high pressure pump cylinder to pump the fuel to a high pressure.

To reduce stresses on the camshaft that is pumping the fuel, the high pressure pumping sections opposite each other in the pump configuration are controlled together. Therefore each of the opposing pumping sections pump together. This eliminates all twisting, or torque, stresses in the camshaft. In order to accomplish this, the opposing stators are fired together.

The injectors use a piezo ceramic actuator to control the injection process. Piezo ceramic actuators are made by aligning many hundreds of piezo ceramic plates together in a row. When electricity is impressed on this assembly, each plate assembly bends very slightly, allowing for linear motion each time the assembly is energized. By using successively more plate assemblies, a linear actuator can be developed. To keep the size of the assembly manageable, the piezo ceramic actuator operates a mechanical amplifier that ultimately controls the injection event.

Because we can minutely control the amount of linear motion from this assembly, this technology allows the system to control not only the amount of fuel that is injected, but also gives it the ability to control the timing of the injection process as well as the "shape" of the injection event. This is important for several reasons.

First, the amount of fuel injected is critical to maintaining the requested engine speed. Since a diesel electric engine is a constant speed device, the primary mission of the control logic is to maintain the engine speed that has been requested by the throttle circuitry. By being able to control the timing of the injection event we can very precisely control engine speed. Secondly, we can control the "shape" of the injection event, irrespective of camshaft position. Under mechanical injection systems, this is forced as an optimization of camshaft lobe construction, so that under all speeds the injection process will work moderately well. However, a camshaft lobe is not a very satisfactory compromise between efficiency and effectiveness. When we are able to separate the injection timing from the actual pumping of the fuel we can minutely optimize the injection process to be precise for all engine speeds and under all conditions. By doing this we are able to precisely control both the requested speed as well as optimizing

the fuel burn and therefore the emissions of the engine.

Should it become necessary to maintain requested engine speed by reducing horsepower to the main generator, the control logic of the control module will modulate the excitatior to the main generator to allow for the requested engine speed. Additionally, should external conditions, such as ambient temperature, barometric pressure, manifold air pressure, or other internal engine parameters not allow for full horsepower at the requested engine speed, the control module will modulate the excitation signal accordingly.

Currently a prototype system is being manufactured for the EMD 645 series diesel engine. A GE 7FDL series engine version is being developed for application in six months.

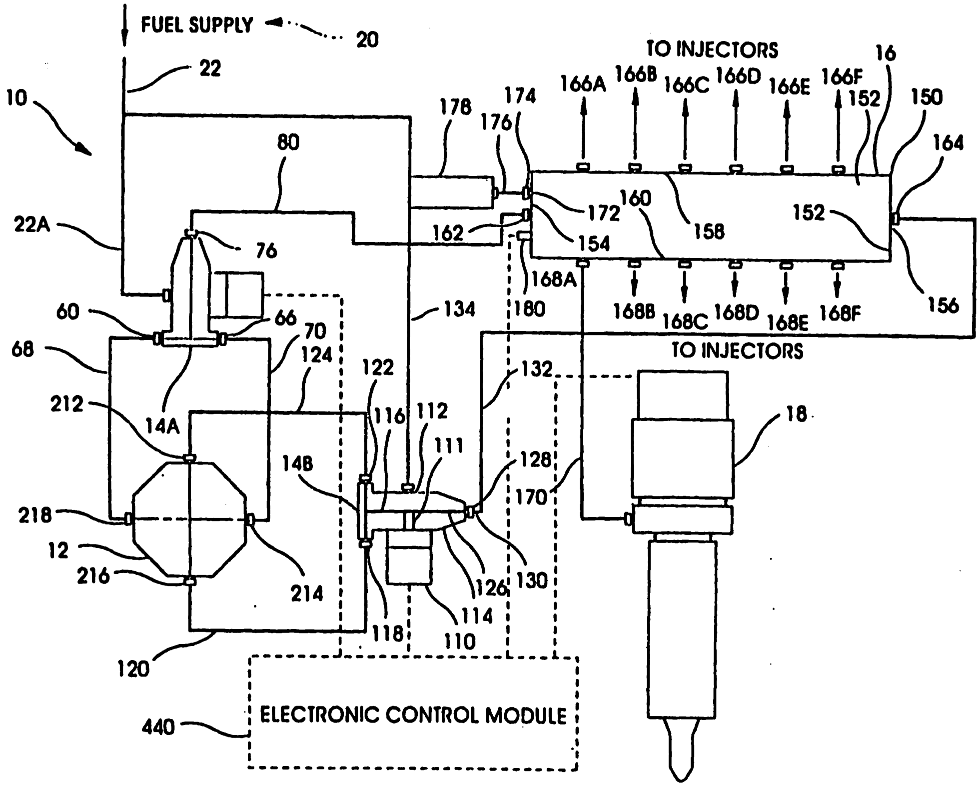

FUEL SUPPLY
20
22
10
22A
80
76
60
66
68
70
124
212
14A
122
116
112
111
14B
218
12
216
214
120
118
110
114
126
130
128
132
134
178
176
174
172
162
154
180
168A
160
158
152
156
164
150
16
TO INJECTORS
166A
166B
166C
166D
166E
166F
168B
168C
168D
168E
168F
170
18
440
ELECTRONIC CONTROL MODULE

Fig 1.

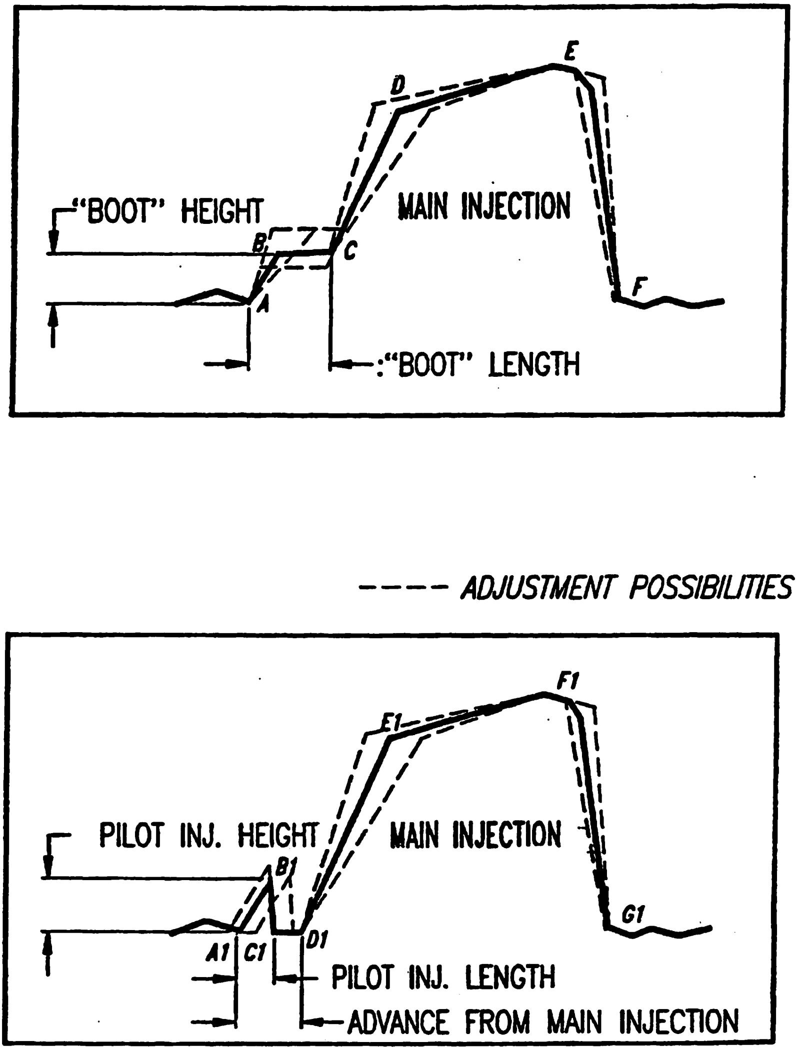

E
D
"BOOT" HEIGHT
MAIN INJECTION
B
C
A
F
:"BOOT" LENGTH
---- ADJUSTMENT POSSIBILITIES
F1
E1
PILOT INJ. HEIGHT
MAIN INJECTION
B1
A1
C1
D1
G1
PILOT INJ. LENGTH
ADVANCE FROM MAIN INJECTION

Fig 2.

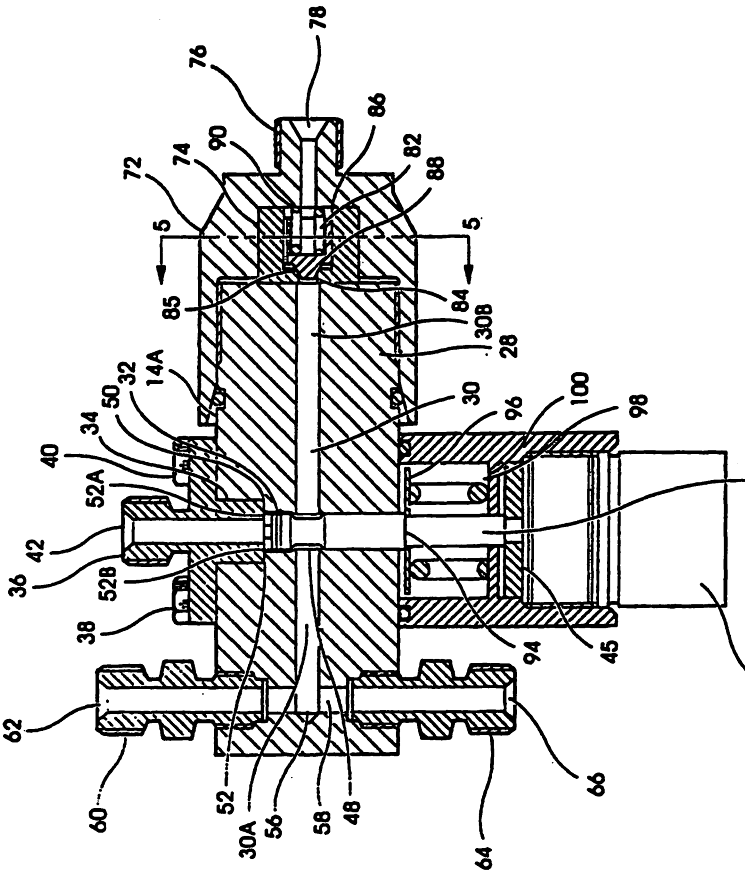

60
62
36
42
52B
52A
40
34
50
32
38
14A
85
5
72
74
90
76
78
86
82
88
84
30B
28
30
96
100
98
46
94
45
44
52
30A
56
58
48
64
66

Fig 3.

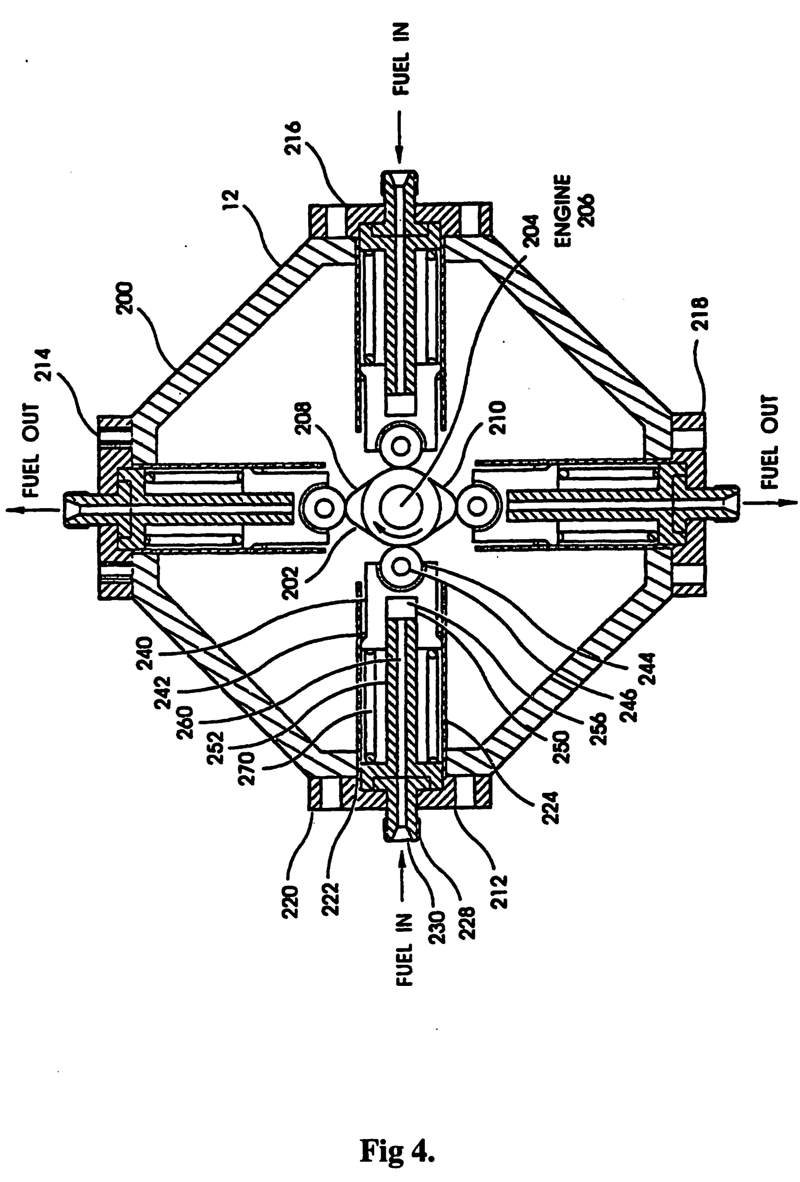

FUEL OUT
214
200
12
216
FUEL IN
ENGINE 206
204
218
FUEL OUT
208
210
202
240
242
260
252
270
244
246
256
250
224
220
222
FUEL IN
230
228
212

Fig 4.

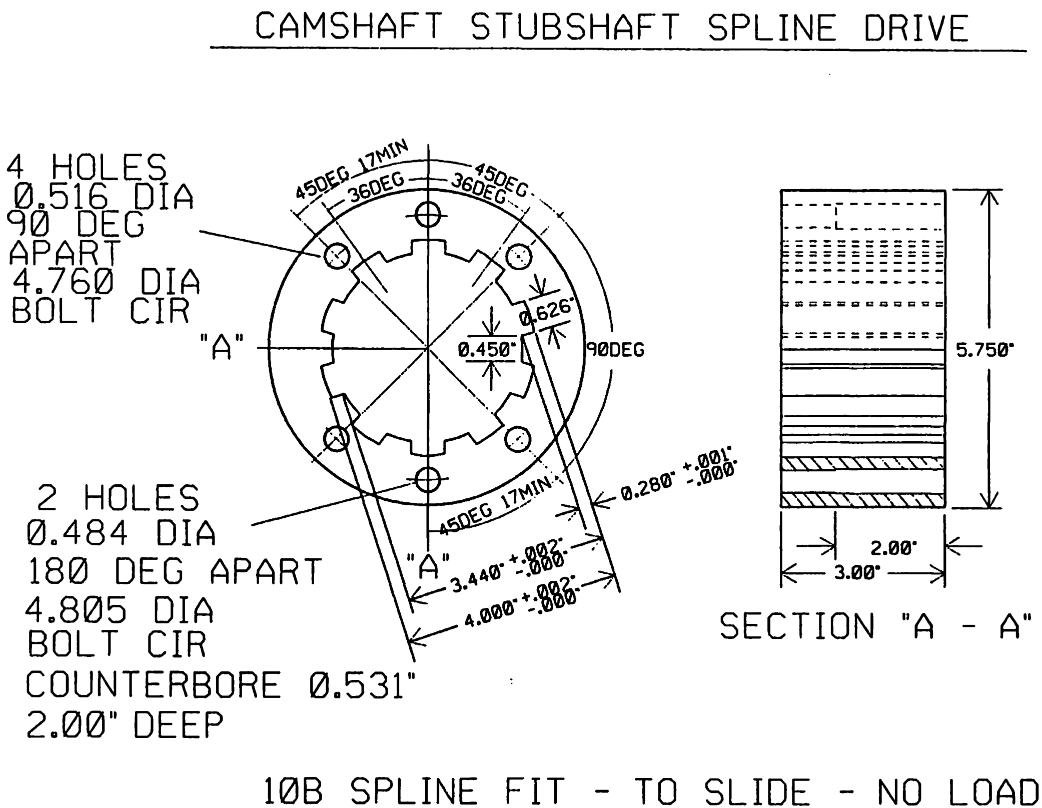

CAMSHAFT STUBSHAFT SPLINE DRIVE
4 HOLES
Ø.516 DIA
90 DEG
APART
4.760 DIA
BOLT CIR
45DEG 17MIN
36DEG
36DEG
45DEG
"A"
0.450"
0.626"
90DEG
0.280" +.001" -.000"
45DEG 17MIN
2 HOLES
Ø.484 DIA
180 DEG APART
4.805 DIA
BOLT CIR
COUNTERBORE Ø.531"
2.00" DEEP
"A"
3.440" +.002" -.000"
4.000" +.002" -.000"
5.750"
2.00"
3.00"
SECTION "A - A"
10B SPLINE FIT - TO SLIDE - NO LOAD

Fig 5.

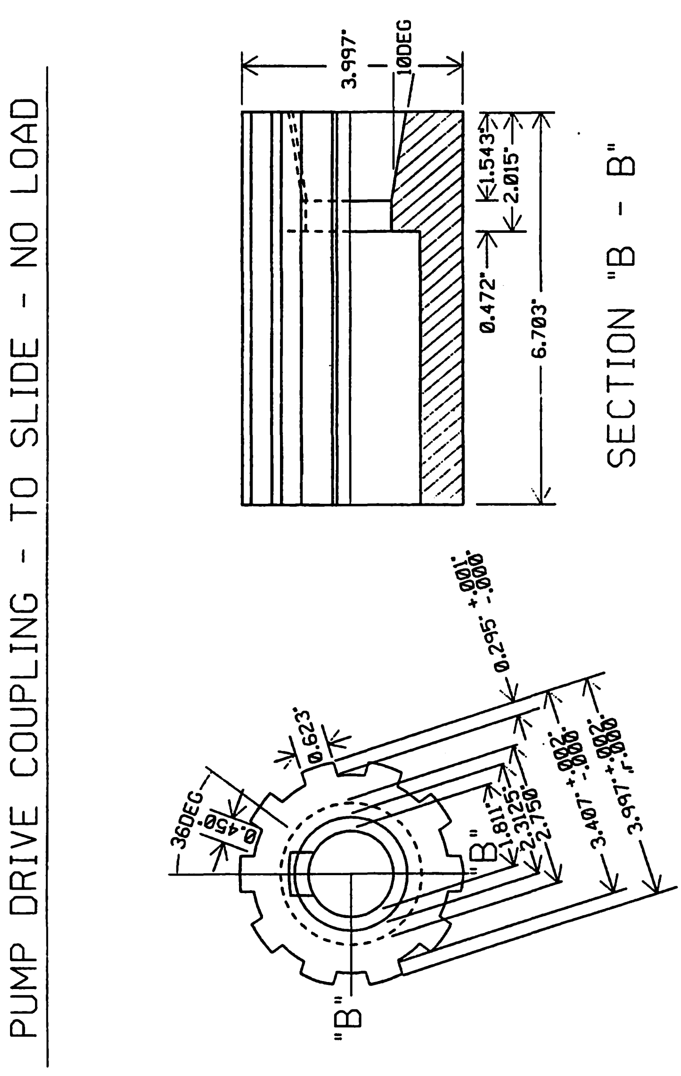

PUMP DRIVE COUPLING - TO SLIDE - NO LOAD
3.997"
10DEG
1.543"
2.015"
0.472"
6.703"
SECTION "B - B"
0.295" +.001" -.000"
0.623"
36DEG
0.450"
"B"
1.811"
2.3125"
2.750"
3.407" +.002" -.000"
3.997" +.002" -.000"
"B"
10B SPLINE FIT - TO SLIDE - NO LOAD

Fig 6.

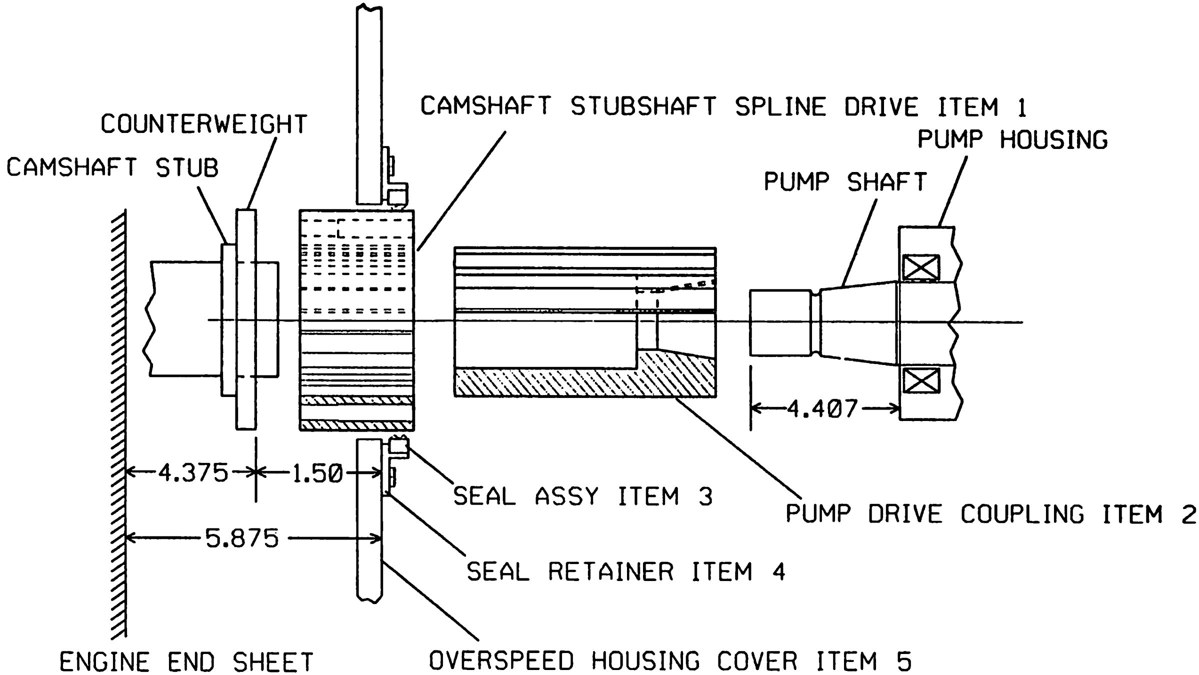

CAMSHAFT STUBSHAFT SPLINE DRIVE ITEM 1
COUNTERWEIGHT
PUMP HOUSING
CAMSHAFT STUB
PUMP SHAFT
4.407
4.375
1.50
SEAL ASSY ITEM 3
PUMP DRIVE COUPLING ITEM 2
5.875
SEAL RETAINER ITEM 4
ENGINE END SHEET
OVERSPEED HOUSING COVER ITEM 5

Fig 7.

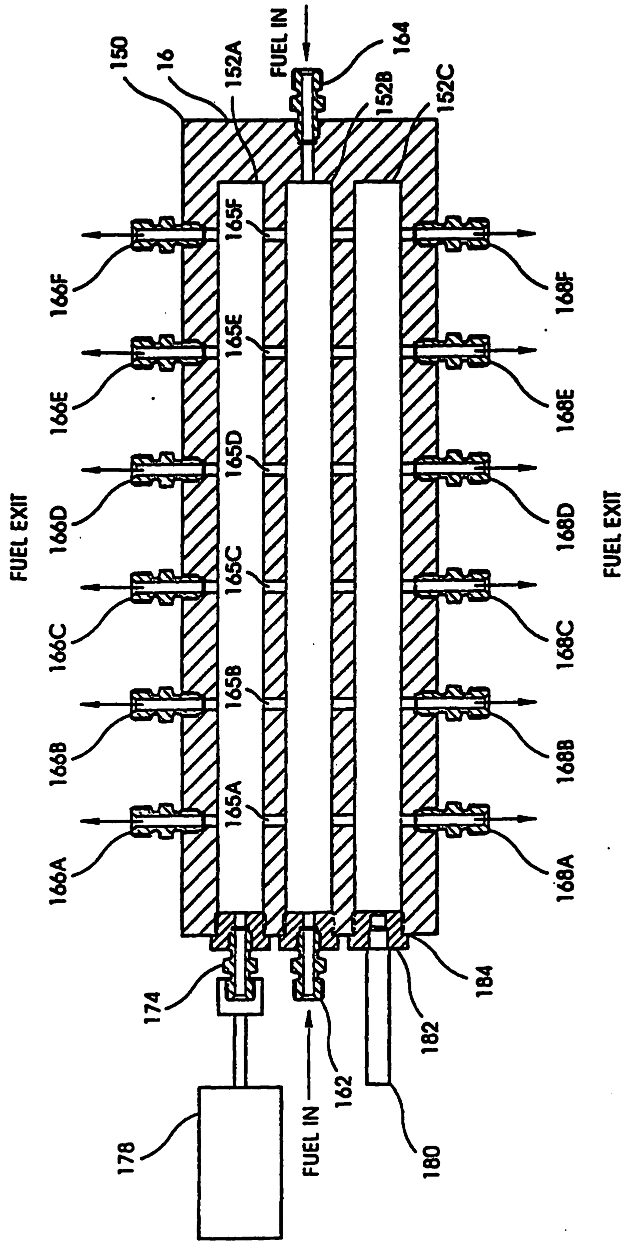
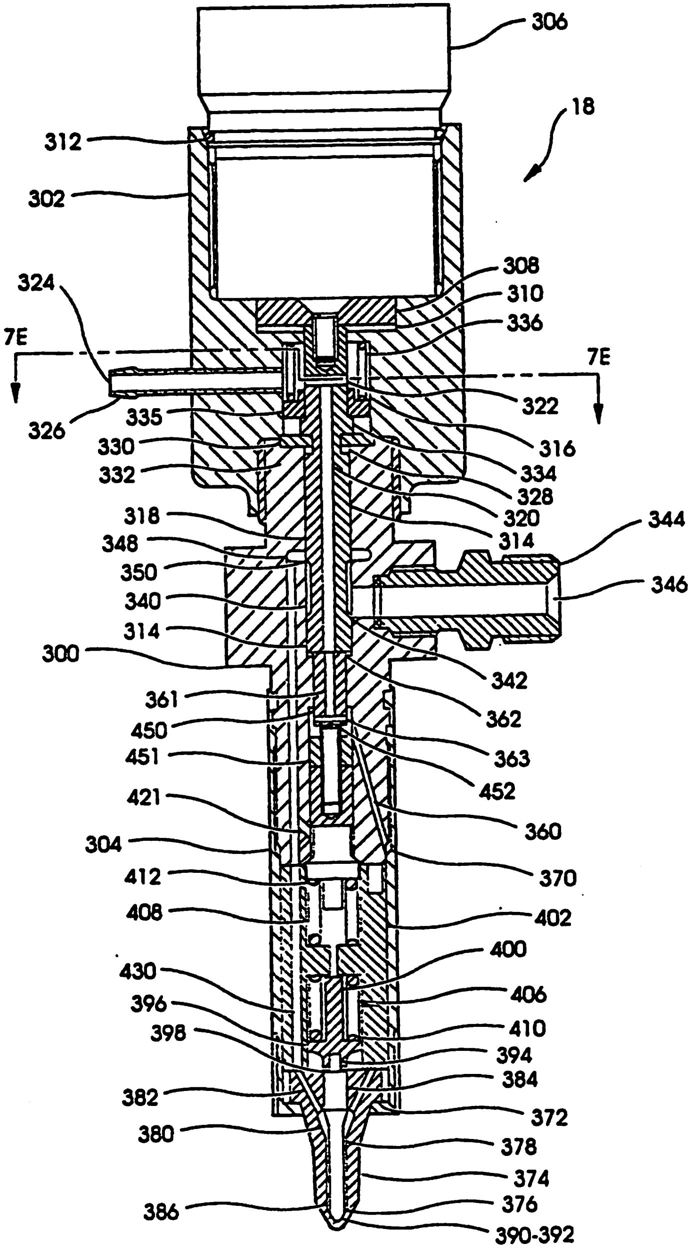

FUEL EXIT
166A
166B
166C
166D
166E
166F
150
16
152A
FUEL IN
164
152B
152C
165A
165B
165C
165D
165E
165F
168A
168B
168C
168D
168E
168F
FUEL EXIT
178
174
FUEL IN
162
180
182
184

Fig 8.


306
18
312
302
308
310
324
336
7E
7E
322
326
335
316
330
334
332
328
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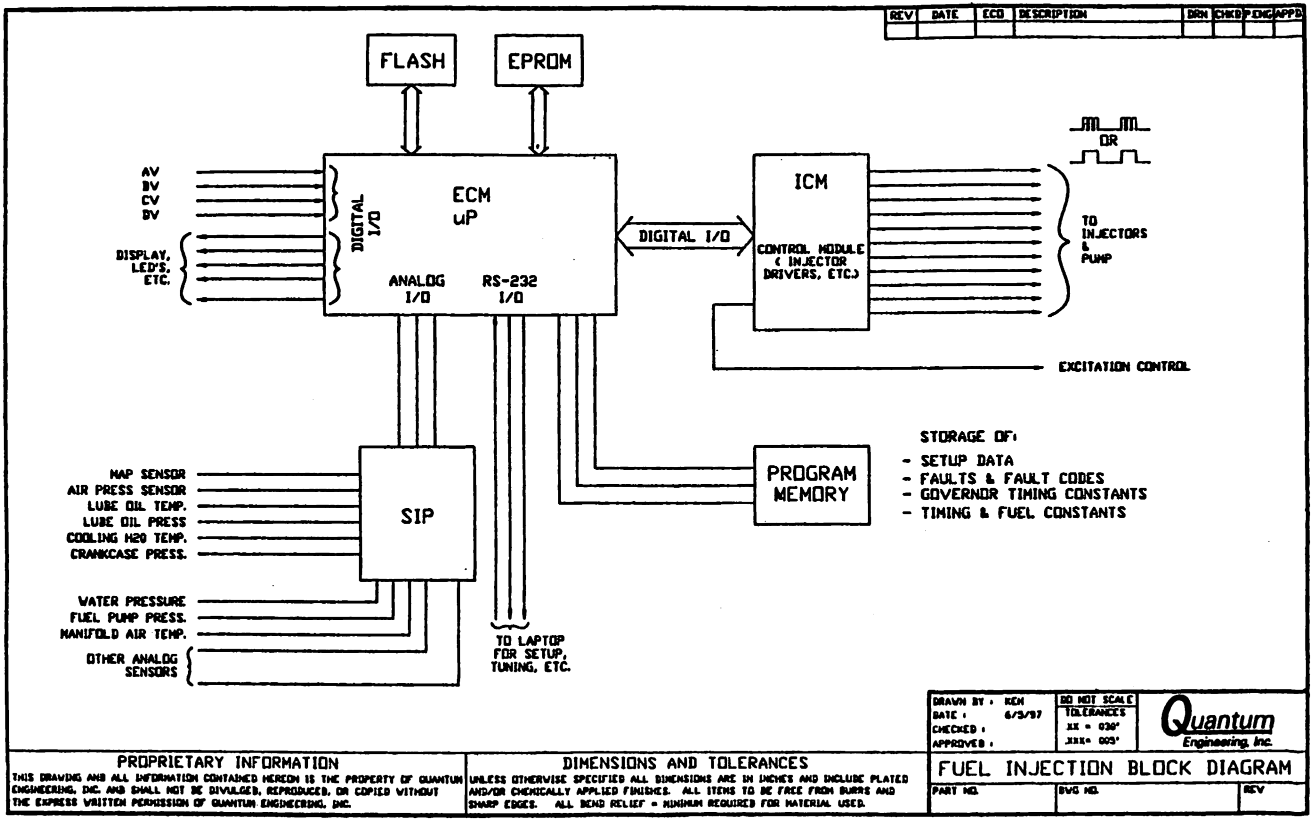
318
314
344
348
350
346
340
314
300
342
361
362
450
363
451
452
421
360
304
370
412
408
402
400
430
406
396
410
398
394
384
382
372
380
378
374
386
376
390-392

Fig 9.


REV
DATE
ECO
DESCRIPTION
DRN
CHKD
P.ENG
APPD
FLASH
EPROM
AV
BV
CV
DV
DISPLAY, LED'S, ETC.
DIGITAL I/O
ECM uP
ANALOG I/O
RS-232 I/O
DIGITAL I/O
ICM
CONTROL MODULE (INJECTOR DRIVERS, ETC.)
OR
TO INJECTORS & PUMP
EXCITATION CONTROL
PROGRAM MEMORY
STORAGE OF:
- SETUP DATA
- FAULTS & FAULT CODES
- GOVERNOR TIMING CONSTANTS
- TIMING & FUEL CONSTANTS
MAP SENSOR
AIR PRESS SENSOR
LUBE OIL TEMP.
LUBE OIL PRESS
COOLING H20 TEMP.
CRANKCASE PRESS.
SIP
WATER PRESSURE
FUEL PUMP PRESS.
MANIFOLD AIR TEMP.
OTHER ANALOG SENSORS
TO LAPTOP FOR SETUP, TUNING, ETC.
DRAWN BY: KEH
DATE: 6/5/97
CHECKED:
APPROVED:
DO NOT SCALE
TOLERANCES
.XX = .030"
.XXX= .005"
Quantum
Engineering, Inc.
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UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES AND INCLUDE PLATED AND/OR CHEMICALLY APPLIED FINISHES. ALL ITEMS TO BE FREE FROM BURRS AND SHARP EDGES. ALL BEND RELIEF = MINIMUM REQUIRED FOR MATERIAL USED.
FUEL INJECTION BLOCK DIAGRAM
PART NO.
DWG NO.
REV

Fig 10.

CONSTITUTION AND BY-LAWS LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

Article I - Title:

The name of this Association shall be the Locomotive Maintenance Officers Association (LMOA).

Article II - Purpose of the Association

The purpose of the Association, a non-profit organization, shall be to improve the interests of its members through education, to supply locomotive maintenance information to their employers, to exchange knowledge and information with members of the Association, to make constructive recommendations on locomotive maintenance procedures through the technical committee reports for the benefit of the railroad industry.

Article III - Membership

Section 1 - Active Railroad Membership shall be composed of persons employed by a railroad company and interested in locomotive maintenance. 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, and, if they choose, continue to serve as an executive officer and be allowed to elevate through the ranks as naturally occurs, to include the office of President.

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

DIESEL MECHANICAL MAINTENANCE COMMITTEE SIXTEEN YEAR INDEX

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
SIXTEEN YEAR INDEX

1996

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

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
SIXTEEN YEAR INDEX

1996

1. Locomotive Painting
2. Drop Table Tooling for New EMD and GE Locomotives

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.

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 SIXTEEN YEAR INDEX

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
FOURTEEN YEAR INDEX

1996
1. Activities Toward New Safety Standards for Passenger Equipment
2. SP-3 Thin Sensor Technology for Variable Force Measurement
3. Top-Of-Rail Lubrication
4. Traction Motor Vibration and its Effects

1995
1. Beltpack Locomotive Control System
2. The MK1200G Switching Locomotive
3. Advanced Traction Motor Testing

1994
1. Electronic Fuel Injection 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 SIXTEEN YEAR INDEX

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE SIXTEEN YEAR INDEX

1986

1. Extended Performance Lubricants Through Better Chemistry.
2. Fuels and Lubricants Handling Hygiene.
3. Fuels Availability and Price Outlook.
4. Selection of Lubricants for Wheel Flange and Rail Lubricators.

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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