

# **LMOA**

**Locomotive Maintenance Officers Association**

## **Proceedings of the 64th Annual Meeting**

**September 23 - 25, 2002**

**Chicago Hilton & Towers**

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**Chicago, Illinois**



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## 2001 LMOA MVP RECIPIENTS

The executive board of LMOA wishes to congratulate the following individuals who were selected as the Most Valuable People of their respective committees in 2001.

| <u>Name</u>             | <u>Company</u>    | <u>Committee</u>        |
|-------------------------|-------------------|-------------------------|
| Ron Bartels             | Via Rail Canada   | Diesel Electrical       |
| Benoit Girard           | CP Railway        | Diesel Material Control |
| Wes Middleton           | Chevron Oronite   | Fuel, Lube & Environ.   |
| Jack Morin              | NEU International | Shop Equip. & Processes |
| Dennis Nott             | Motive Power Inc. | Diesel Mechanical       |
| James F.<br>O'Kelly III | Alstom Transport  | New Technologies        |

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

**LMOA EXECUTIVE COUNCIL**

**THE LMOA EXECUTIVE BOARD  
WOULD LIKE TO EXPRESS THEIR  
SINCERE APPRECIATION TO  
MR. B.J. RYAN  
AND  
MR. JOHN NIXON  
AND THE ENTIRE STAFF OF  
THE BNSF RAILWAY OPERATIONS  
CENTER IN FORT WORTH, TEXAS  
FOR HOSTING THE  
5TH ANNUAL LMOA JOINT TECHNICAL  
COMMITTEE MEETING  
ON  
APRIL 8 and 9, 2002.**

## PAST PRESIDENTS

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

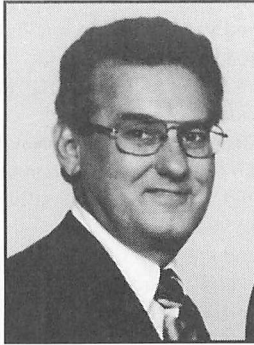
- 1980 - J. H. LONG, Retired Manager Locomotive Dept., Chessie System  
5454 Cleander Drive, Cincinnati, OH 45238
- 1981 - R. G. CLEVENGER, Retired General Electrical Foreman, Atchison, Topeka & Sante Fe Rwy.
- 1982 - N.A. BUSKEY (Deceased) Asst. General Manager-Locomotive, Chessie System
- 1983 - F. 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
- 1986 - D. H. PROPP, (Retired) Director-Mktg, New York Air Brake,  
10823 W. 164th, Olathe, KS 66062
- 1987 - D. L. WARD, (Deceased) Coord.-Quality Safety & Tech. Trng. Burlington Northern R.R.
- 1988 - D.G. GOEHRING, Retired, Supt. Loco. Maint., National RR Passenger Corp.,  
1408 Monroe, Lewisburg, PA 17837
- 1989 - WILLIAM A. BROWN Representative, BP Associate,  
11237 N. Madison, Kansas City, MO 64155
- 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, Bombardier Transit, Los Angeles, CA 90065
- 1994 - M.A. COLES, Senior Mgr.-Loco. Engineering & Quality, Union Pacific R.R.  
1416 Dodge St., Omaha, NE 68179
- 1995 - C.A. MILLER, Retired, Mgr.-Loco. Engineering & Quality, Union Pacific RR.  
1728 S. 167 Circle, Omaha, NE 68130
- 1996 - G.J. BRUNO, Asst. General Mgr. - Terminal Services,  
Amtrak, 187 S. Holgate St., Ste B., Seattle, WA 98134
- 1997 - D.M. WETMORE, General Supt. - Equipment, NJT Rail Opns.  
1148 Newark Turnpike, Kearny, NJ 07032
- 1998 - H.H. (MIKE) PENNELL, Elcon National, 1016 Williamsburg Lane,  
Keller, TX 76248
- 1999 - JAKE VASQUEZ, Superintendent, Amtrak  
3319 Earhart Blvd., New Orleans, LA 70125
- 2000 - RON LODOWSKI, Superintendent Locomotives, CSX Transportation  
Selkirk, NY 12158
- 2001 - LOU CALA, Consultant, LJC Rail, Duncansville, PA 16635

## HONORARY LIFE MEMBERS

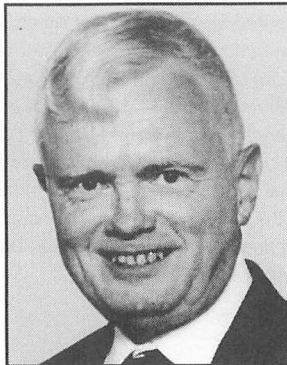
- KJELL AXELSON**, Retired Superintendent Motive Power, Burlington Northern, 36-716 Bluebird Ave., Rancho Mirage, CA 92270
- F. W. BUNCE**, Retired Chief Mech. Officer, Milwaukee Road.
- J. J. BUTLER**, Retired Chief Mech. Officer, Consolidated Rail Corp., 158 Woodgate Ln., Paoli, PA 19301
- OWEN CLARKE**, Retired Vice-President, Chesapeake & Ohio Ry., Cleveland, Ohio
- B. A. CUMBEA**, Retired Mgr. Loco. Maint.-Engr., Chessie System, 310 Cherokee Trail, Huntington, WV 25705
- N. C. ECKERLE**, Sales Mgr. Specialty Chem., Nalco Chem. Co., 2901 Butterfield Rd., Oak Brook, IL 60521
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- DONALD GRAAB,** Director - Loco. Maintenance, Norfolk Southern  
Box 78 110 Franklin Road SE, Roanoke, VA 24042
- S. GRAHAM HAMILTON,** President, Global Group, Inc., P.O. Box 2024, Winter Park, FL 32790
- W. J. HARRIS,** Retired V. Pres., Research & Test Dept., Assn. of American Railroads, Washington, D.C.
- H. W. HAYWARD,** Retired Chief M.P. & R. S., CP Rail, Montreal 101, Quebec, Canada
- D. W. HENDERSON,** V.P.-Technology, Engr. & Maint. Burlington Northern RR, 9401 Indian Creek Pkwy., Overland Park, KS 66210
- JOHN H. HERTOG,** Retired V. Pres. Operations, Burlington Northern, Inc., St. Paul, MN 55101
- JOHN W. INGRAM,** Retired Pres. and Chief Executive Officer, Chicago, Rock Island and Pacific Railroad Co.
- A. W. JOHNSON,** Retired, V. Pres. of Opns. and Maint., Assoc. of American RR, Washington, D.C.
- JACK L. KUHNS,** Retired Mgr. Plng. & Maint., CSX Transp., 401 Brookview Rd., Louisville, KY 40207
- R. M. McDONALD,** Retired Dir. of Opns., Brd. of Transport, Commissioners for Canada, Ottawa, Ont., Canada
- J. F. McDONOUGH,** Retired Asst. V. P.-Mechanical, Union Pacific RR, 12225 Farnum St., Omaha, NE 68154
- R. G. RAY BURN,** Retired Executive V.P.-Operations, Chessie System, Baltimore, MD
- H.P. RODES,** Pres., General Motors Institute, Flint, MI 48502
- F. R. RUSSELL,** Retired Chief Mech. Off., Southern Pacific Co., San Francisco, CA
- L. G. SALTS,** Retired, AT&SF Rwy., Topeka, KS
- H. L. SCOTT, JR.,** Retired Sr. V.P. and Chief Mech. Off. Norfolk Southern, Corp.
- C. M. SMITH,** Retired Mgr-Mech. Engr.-Passenger and Loco. Consolidated Rail Corp., 3 Princeton Rd., Strafford-Wayne, PA 19087
- R. D. SPENCE,** Retired Executive V.P.-Operations, Seaboard System RR
- J. TAGGART,** Retired System Mechanical Officer-Motive Power, CN Rail, 655 Richmond Road, Unit 45, Ottawa, Ontario K2A 3Y3
- M. L. VARNs,** Retired, BN RR, 111 So. Greenfield Rd. #385, Mesa, AZ 85206
- R. W. VITEK,** VP - Sales and Leasing, Omnitrax, Cicero, IL
- C.N.. WIGGINS,** Retired V.P. and Asst. to Pres., Louisville & Nashville R.R., Louisville KY

## OUR OFFICERS

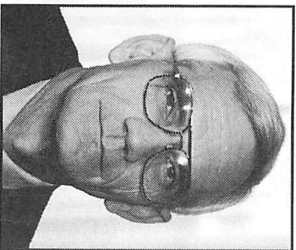


Chairman of the Board  
**MR. LOU CALA**  
(Former Norfolk Southern Corp.)  
LJC Rail Consultant  
Duncansville, PA 16635

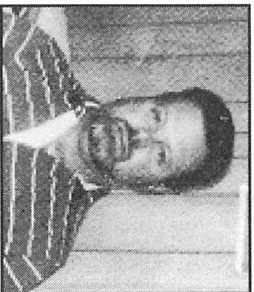


Our President  
**MR. ROBERT RUNYON**  
(Retired Norfolk Southern Corp.)  
Engineering Consultant  
Roanoke, VA 24042

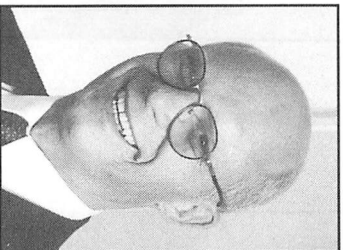
## OUR OFFICERS



1st Vice President  
**MR. BRIAN HATHAWAY**  
**Director - Shop Operations**  
Susquehanna Locomotive & Railcar  
Utica, NY 13502

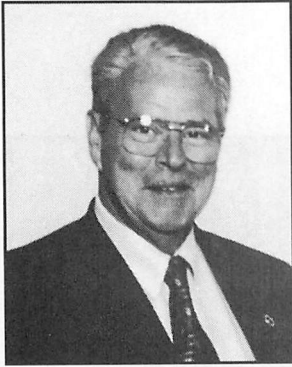


2nd Vice President  
**MR. WILLIAM LECHNER**  
**Senior General Foreman,**  
**Insourcing Air Brakes, Governors,**  
**Injectors**  
Norfolk Southern  
Altoona, PA 16603

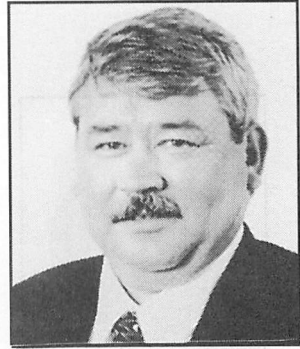


3rd Vice President  
**MR. TAD H. VOLKMANN**  
**Manager - Loco. Facility -**  
**Engine Components**  
Union Pacific  
North Little Rock, AR 72114

## OUR PAST PRESIDENTS



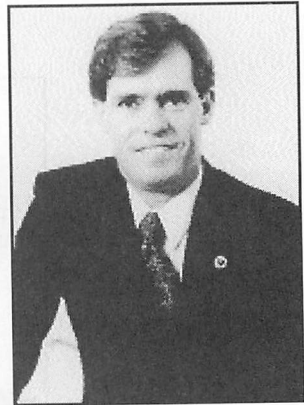
**MR. WILLIAM BROWN**  
**Representative**  
 BP Associates  
 Kansas City, MO 64155



**MR. GIL BRUNO**  
**Assistant. Gen. Mgr.**  
**Terminal Services**  
 Amtrak  
 Seattle, WA 98134

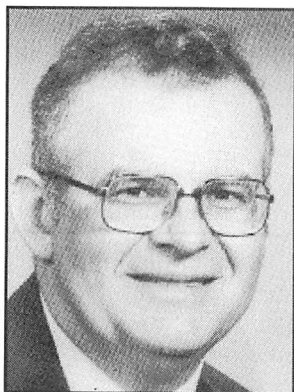


**MR. MARK COLES**  
**Senior Manager - Loco.**  
**Engineering & Quality**  
 Union Pacific Railroad  
 Omaha, NE 68179



**MR. WEYLIN R. DOYLE**  
 Bombardier Transit  
 Los Angeles, CA 90065

## OUR PAST PRESIDENTS



**MR. ALLEN KELLER**  
**Director - Loco. Projects**  
Reading Railroad Services Co.  
Cleona, PA 17042

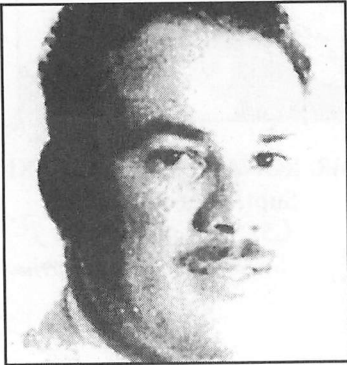


**MR. RONALD R. LODOWSKI**  
**Supt. - Locomotives**  
CSX Transportation  
Selkirk, NY 12158

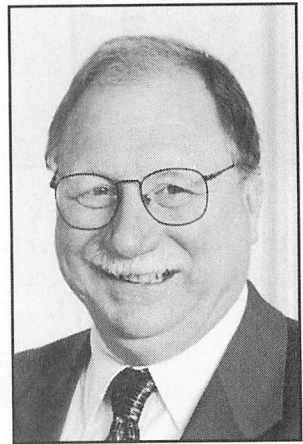


**MR. H.H. (MIKE) PENNELL**  
Ellcon National  
Keller, TX 76248

## OUR PAST PRESIDENTS



**MR. JAKE VASQUEZ**  
**Superintendent**  
Amtrak  
New Orleans, LA 70125



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

## OUR REGIONAL EXECUTIVES



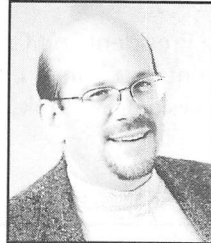
**MR. GLENN BOWEN**  
Director - Lab Services  
BNSF Rwy  
Topeka, KS 66616



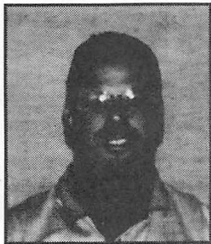
**MR. JOHN BRAWLEY**  
Director-Material Management  
Amtrak  
Beech Grove, IN 46107



**JAY HOLLEY**  
Director - 97  
Mechanical  
Operations  
CSX Transportation



Jacksonville, FL 32254  
**MR. BRUCE A. KEHE**  
Manager Mech. Svcs.  
EJ & E  
Gary, IN 46402



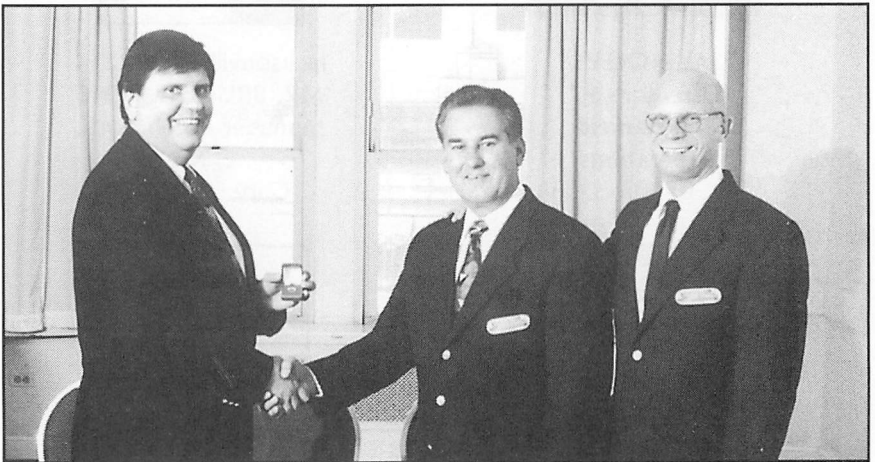
**MR. MIKE SCARINGE**  
Asst. Chief Mechanical  
Officer - West  
Amtrak  
Beech Grove, IN 46107



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



Outgoing President Lou Cala (center), LJC Rail, presents gavel to newly elected President Bob Runyon, Engineering Consultant, as Chairman of the Board Ron Lodowski, CSX, looks on.



Chairman of the Board Ron Lodowski, CSX, presents Past President's Pin to outgoing President, Lou Cala, LJC Rail. Newly elected 3rd Vice President, Tad Volkmann, Union Pacific, witnesses the ceremony.



Newly elected President Bob Runyon, Engineering Consultant, assists newly elected 3rd Vice President Tad Volkmann, Union Pacific, with his LMOA blazer. Past President Jake Vasquez, Amtrak, gives his approval.



Past President Jake Vasquez, Amtrak, presents the General Desk Set to outgoing President Lou Cala, LJC Rail, as Past President Tom Harley retired, looks on.



**General Executive Committee Members:**

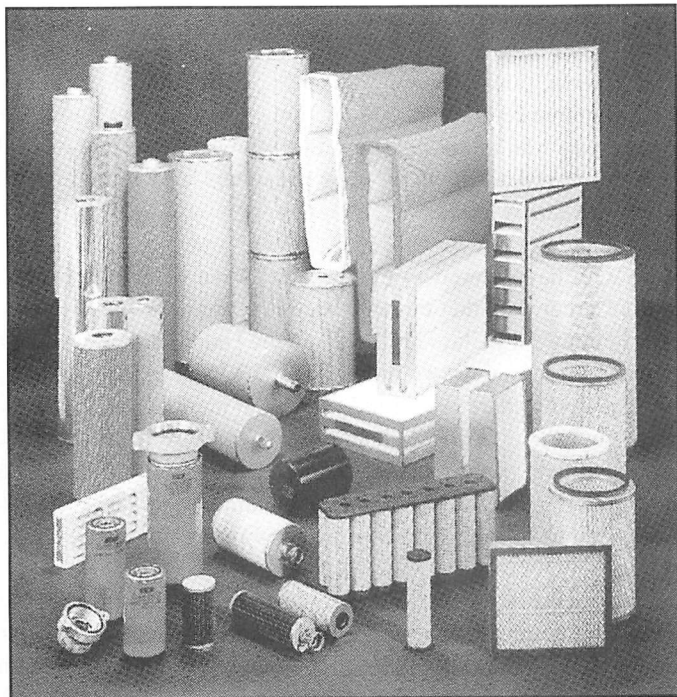
(seated - left to right): Past President Tom Harley (retired); Past President Jake Vasquez, Amtrak; outgoing President Lou Cala, LJC Rail; Chairman of the Board Ron Lodowski, CSX Transportation;

(standing - left to right): newly elected 3rd Vice President Tad Volkmann, Union Pacific RR; Editorial Director Tom Shedd; Secretary Treasurer Ron Ponder; newly elected President Bob Runyon, Engineering Consultant.



Newly elected 3rd Vice President Tad Volkmann (left), Union Pacific RR, presents LMOA attache' bag to newly intalled Chairman of the Diesel Mechanical Committee, Dennis Nott, Motive Power, Inc.

Outgoing President Lou Cala, LJC Rail, was present at the ceremony.



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**State of the Union Address  
by President Robert Runyon  
September 23, 2002**

Fellow officers, members, ladies and gentlemen:

Good afternoon, and welcome to the 64th annual meeting of the Locomotive Maintenance Officers Association. Most of you know who I am; and for those of you who might not, I am Bob Runyon, president of LMOA and presently self-employed as an engineering consultant, and retired from Norfolk Southern after 30 years' service.

All of us who have served in this capacity have experienced one circumstance above all other, and that circumstance is change. When I joined LMOA 15 years ago, I counted 13 Class I railroads in the United States and Canada, and I may have overlooked one or two more. With the large number of mergers and acquisitions that have occurred over the years, that number has dwindled to only seven for both countries. While the combined locomotive fleets of the Class I's have shrunk in rough proportion to the number of railroads, the combined attrition of employees assigned to locomotive maintenance has been far greater, leaving fewer persons to look after equipment of increasing complexity.

During my career with the railroad, we took a hands-on approach to all aspects of locomotive maintenance and tried to be self-supporting so far as possible. I believe the railroads should be directly involved not only in maintenance but also in design, performance, post-delivery improvements, and setting standards for functional and operational compatibility. With the advent of modern control systems and peripheral devices on our locomotives and the growing practice of interchanging locomotives among the railroads, the compatibility issue becomes more important than ever. Beneficial involvement in the standards-setting process requires communication and active participation by knowledgeable railroad personnel, notwithstanding the competing demands for time to be spent on work of more immediate concern.

A railroad that chooses not to become involved with these issues will eventually find itself at the mercy of those who do. That being said, we have at our disposal the means to facilitate and encourage open discussion of locomotive related issues among members of the rail industry. I refer, of course, to the LMOA and in particular to the six technical committees which do the lion's share of the work within our organization. In the course of meeting several times throughout the years to prepare technical reports, committee members can exchange ideas and take the better ones back to the work place for application.

Of course this process also works in reverse: the same committee members

should be alert for suggestions from their upper management as to what topics should be discussed, and bring these to our attention for further action as warranted. At this point, a quote from one of our past presidents is appropriate: "Our organization will only be as good as our continued member involvement."

Over the years the LMOA has looked for ways to improve itself; and one of these is the recent practice of holding a mid-year joint meeting of all six technical committees. The first of these was held in March 1998 at Little Rock, inspired by the rousing success of a joint three-committee meeting held in January 1997. We have continued this practice in subsequent years with full joint meetings at Las Vegas, Roanoke, Jacksonville and this year at Fort Worth. The latter was hosted by our friends at BNSF, to whom I want to express my appreciation for a job well done.

Time does not permit me to individually name all the LMOA members and others who have given me their support during my year as president. But I want to mention one man in particular who has supported all of us during my 15 years of membership. That man is Ron Pondel, our secretary and treasurer, who has managed most of the administrative details and provides our officers with much needed continuity of experience.

Thank you very much; and enjoy the convention!

REPORT OF THE COMMITTEE  
ON DIESEL ELECTRICAL MAINTENANCE

MONDAY, SEPTEMBER 23, 2002

10:15 A.M.



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Canadian Pacific Railway  
Calgary, Alberta

Vice Chairman

**K. GAZAROV**

Manager Electrical Engineering  
CSX Transportation  
Jacksonville, FL

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New Committee Members: Chuck Benson, GETS; Curt Meyers, BNSF Railway

## PERSONAL HISTORY

*Bob Reynolds*  
*Manager Locomotive Systems*  
*Canadian Pacific Railway*

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

In 1981 he joined the Mechanical department as an electronics specialist in the equipment engineering group. Since that time he has been involved with

improvements and modifications to electrical and electronics equipment on the locomotive fleet. In recent years he has prepared specifications for new locomotives and worked with locomotive builders to ensure new orders met technical requirements and reliability standards.

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

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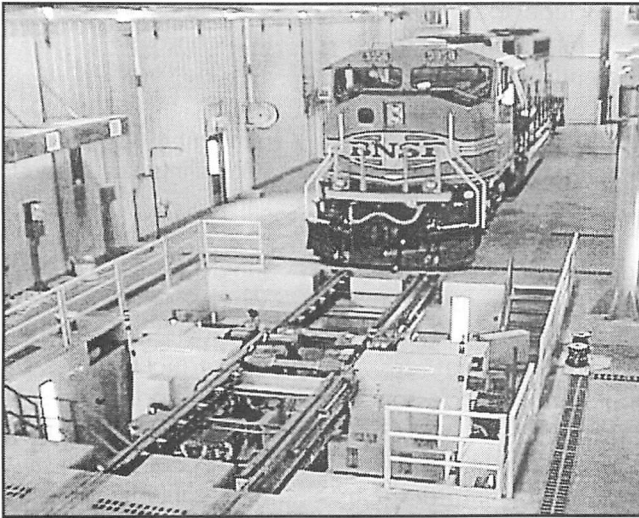
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## I. COMMUTATOR PROFILING

*By Bob McCaffrey,*

*Manager Transportation Products,  
National Electrical Carbon  
Products, Inc.*

Commutator profiling is the use of instrumentation to accurately measure the radial dimensions of a commutator. These measurements will include total indicated runout (TIR), maximum bar to bar height differential (BTB), the individual height of each bar with relation to the reference bar, and the shape of each bar if desired.

Motors that are within specifications with regard to TIR and BTB will provide superior performance, and profiling can insure that motors do meet specifications. Specifically, motors that are in good condition will have longer brush life, fewer flashovers, and less sparking at the brushes. Properly operating motors can reduce operating and maintenance costs. Commutator profiling is now relatively easy to perform with portable, highly accurate, and economical tools.

Commutator profiling has become relatively common on stationary motors used in industrial applications. Also, many transit authorities are using commutator profiling to qualify motors, and to check motors in service.

Mainline railroads are not using profiling to any extent. There are a number of reasons for this. First, it is extremely difficult to profile a traction motor while it is in the locomotive. Profiling other DC

machines on the locomotives is easier, but still can be difficult. Profiling, however, can produce many benefits. Included are a reduction in road failures, reduction in flashovers, reduced motor repair costs, and increased brush life. And there are times when profiling can be performed easily, such as with traction motors on the shop floor, even when assembled into combos. Motors of all types can be profiled in the rebuild shops, and at the facilities of independent motor repair companies.

Profiling can be performed with various instruments. Dial Indicators are frequently used to get a rough profile of a commutator. Various sensors attached to chart recorders can also be used. One of the most practical and easy to use methods is the profiler kit from CommTest Instruments. This kit consists of several parts, including the profiler unit itself, the sensor that mounts in the motor, a portable printer, software that permits downloading and analysis by computer, and the necessary adapters and connecting cables. (See figure 1). The kit may also be used for profiling ship rings.

Profiling is performed by mounting the sensor in a brush holder from which the brush has been removed (See figure 2 and 3). The unit is then set to record, and the commutator is rotated one revolution. The profiler records the data as the armature is being rotated. Once recorded the data may be viewed on the profiler screen, printed out on the portable printer

(See figure 4 and 5), or downloaded to a computer.

Once downloaded to a computer the measurement analysis software (MAS) allows the data to be viewed in a number of ways.

- It can be viewed as a rectilinear chart (See figure 6).
- It can be viewed as a radial plot (See figure 7).
- It can be viewed as a histogram (See figure 8).

Multiple profiles can also be plotted together, to show changes in a given commutator over time, or to compare commutator before and after reconditioning, etc.

(See figures 9, 10 and 11).

For traction motors, both OEM's have a specification of 0.001" TIR and 0.0001" BTB for new motors. For used motors the specification is 0.003" TIR and 0.0003" BTB.

Traction motors can be profiled, out of the locomotive, to verify the integrity of remanufactured motors, to qualify used motors for reuse, and verify the results of stoning or other resurfacing of the commutator.

Figure 12 shows the profile of a commercially remanufactured EMD D78 commutator. The profile indicates a TIR of 1.34 mils (0.00134") and a max BTB of 0.75 mil (0.00075"). Both these numbers exceed the OEM specification for a remanufactured motor. In this case, the quality of the rebuilder's work could be brought into question. Quality can be improved by insisting rebuilders supply profiles of motors.

As a case history of the benefits of profiling, we can use an example from a major transit authority. Recently, the second largest commuter rail property in New York embarked on a multi-faceted phased in program to reduce failures of double-ended blower motors, which were causing numerous road failures and secondary train delays. Of utmost importance was that the rail property had suffered extensive damage due to under car fires on two cars.

This rail property chose to utilize commutator profilers as the primary means of detecting and monitoring the condition of blower motor commutators. One component of this program, continuous profiling of commutators, was incorporated into the 60 day maintenance program at two maintenance facilities.

Within 60 days, the entire fleet had been profiled to assess the condition of double ended blower commutators.

Within 30 days the subsequent analysis of the data collected resulted in the development of a remediation program which included the identification of a preliminary running maintenance TIR condemning limit, and development of a procedure that allowed commutators to be stoned in place.

The efforts by this rail property made an immediate impact. The commutator TIR mean average dropped from 0.0086" to 0.0012". Within one year their equipment availability and rotating equipment

reliability improved dramatically.

After two years of commutator profiling, the subject commuter rail property has enjoyed increased reliability to the double-ended blower motor. In addition to the increased reliability they have reduced their total R&R budget by approximately 50% as it pertains to the aggregate repair cost of catastrophic failure modes.

Prior to the program, the failure mode of the blowers was approximately 80% armature and field related failures. After two years this failure mode was reduced to 20%.

The increased reliability of the double ended blower motor was the result of several improvements that included changes to the auxiliary power system. However, this rail property is confident that diligent commutator profiling and the subsequent service maintenance of the commutator was a major contributing factor towards mitigating repeat failures of this particular motor.

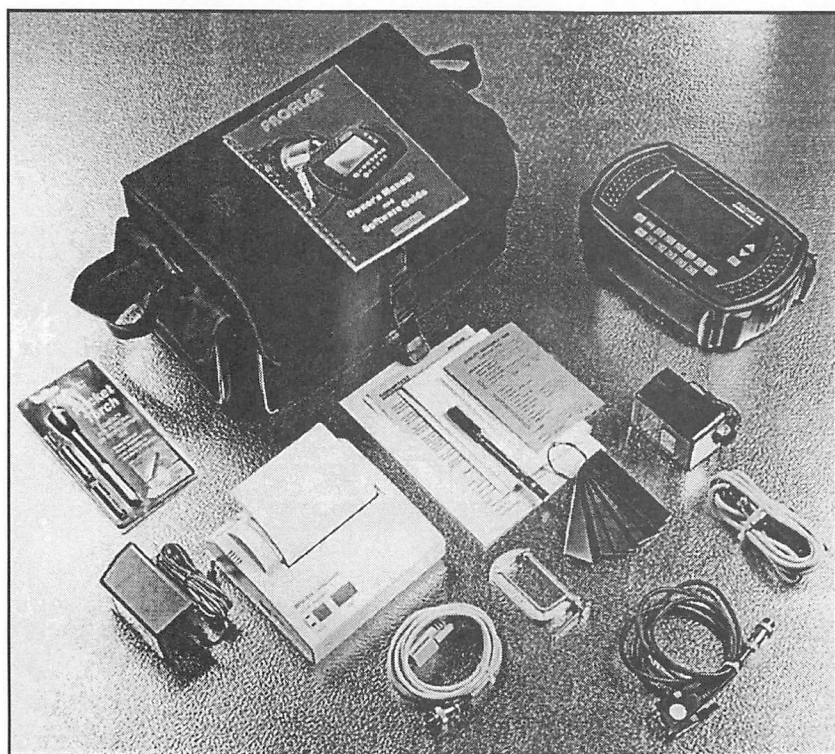
Figure 13 is a graph showing the repair history of the double-ended blowers over a two year period. The overall trend is steadily downward, with the exception of a peak approximately midway through the second year. This peak was related to a problem in the power supply system associated with a track outage.

The rail property plans to expand commutator profiling into other rotating equipment systems in their fleet. Ironically enough, not because of failure modes but

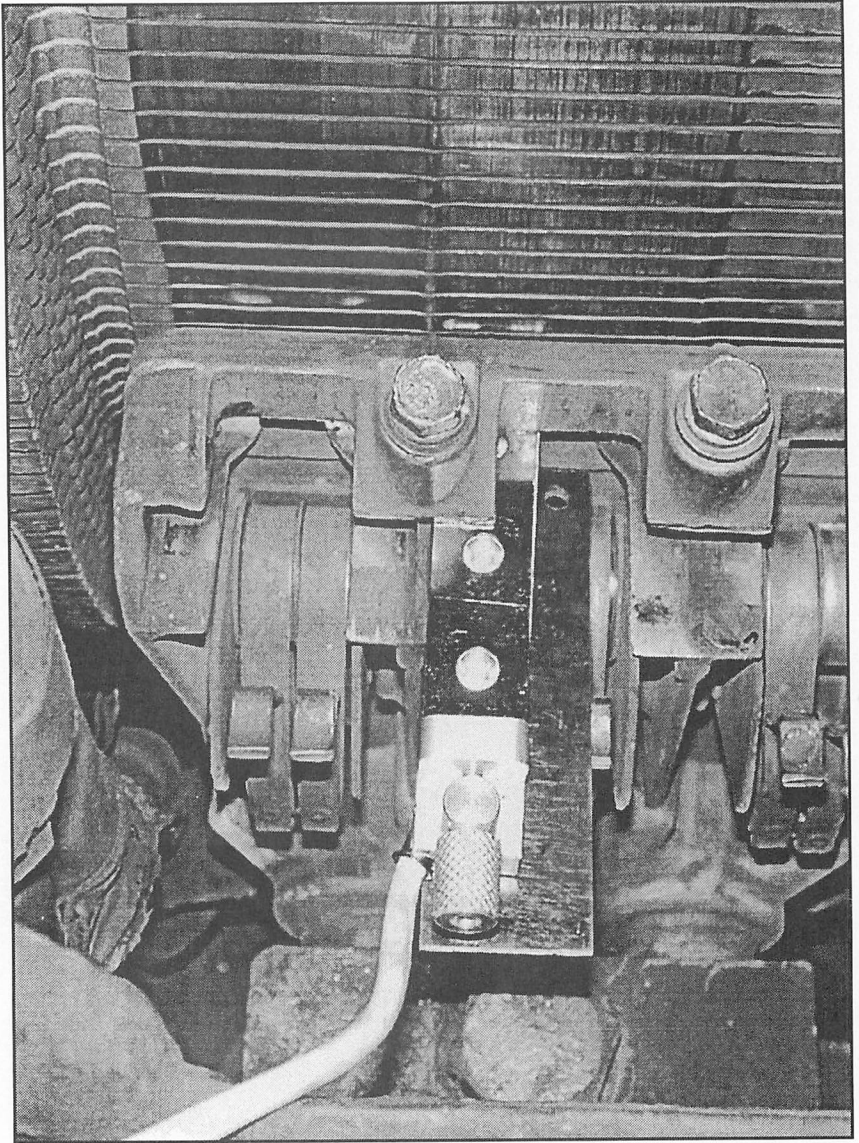
for the information this powerful system is capable of providing. The profiler is considered a powerful diagnostic tool employed to uncover potential failures before they happen and a source of data critical to the development of an effective reliability centered maintenance program.

A minimum investment in time and money in instituting a profiling program can provide significant benefits. It should ensure that only motors meeting specifications are installed for use in locomotives, thus increasing life and providing improved performance. Additionally, commutators can be qualified for re-use that might otherwise go for rebuilding, and conversely, commutators that are not within specifications, will not be put back in locomotives. Flashovers and road failures will be reduced as a result.

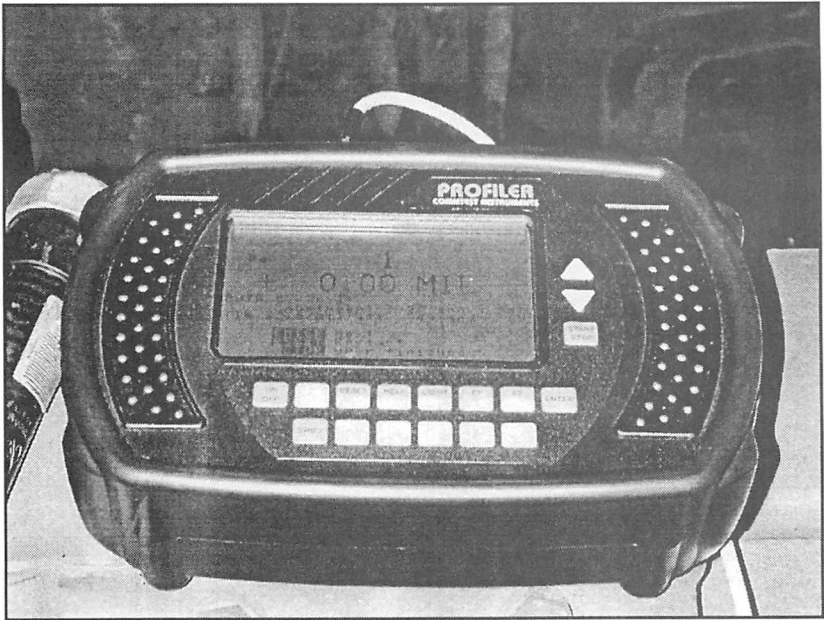
The track record in other industries clearly shows the advantages of a profiling program. I believe that a properly constituted program of profiling commutators on mainline railroads can achieve improved performance and cost savings.



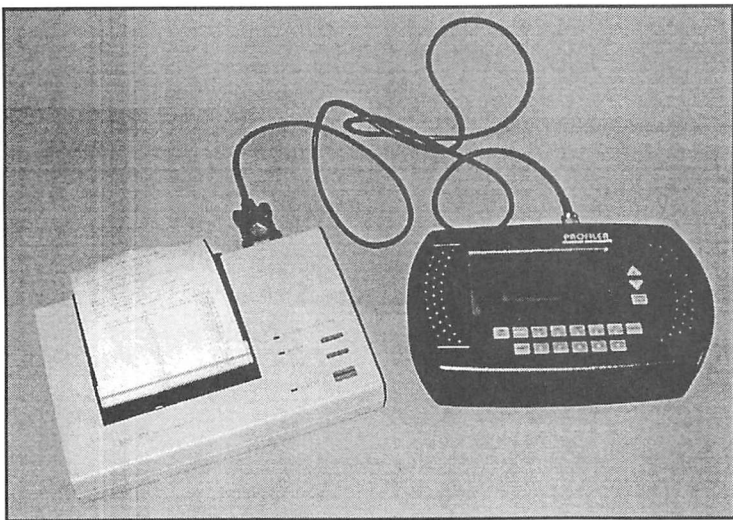
**Figure 1**  
**Profiler Kit.**



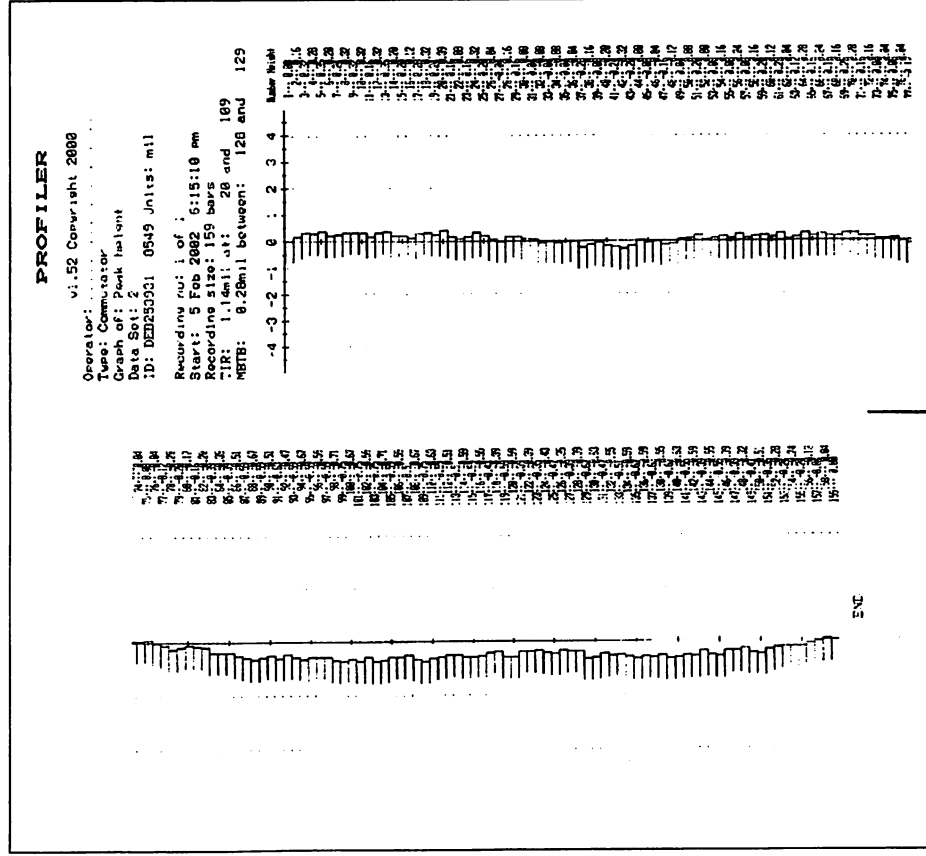
**Figure 2**  
**Sensor mounted in D77 Traction Motor**



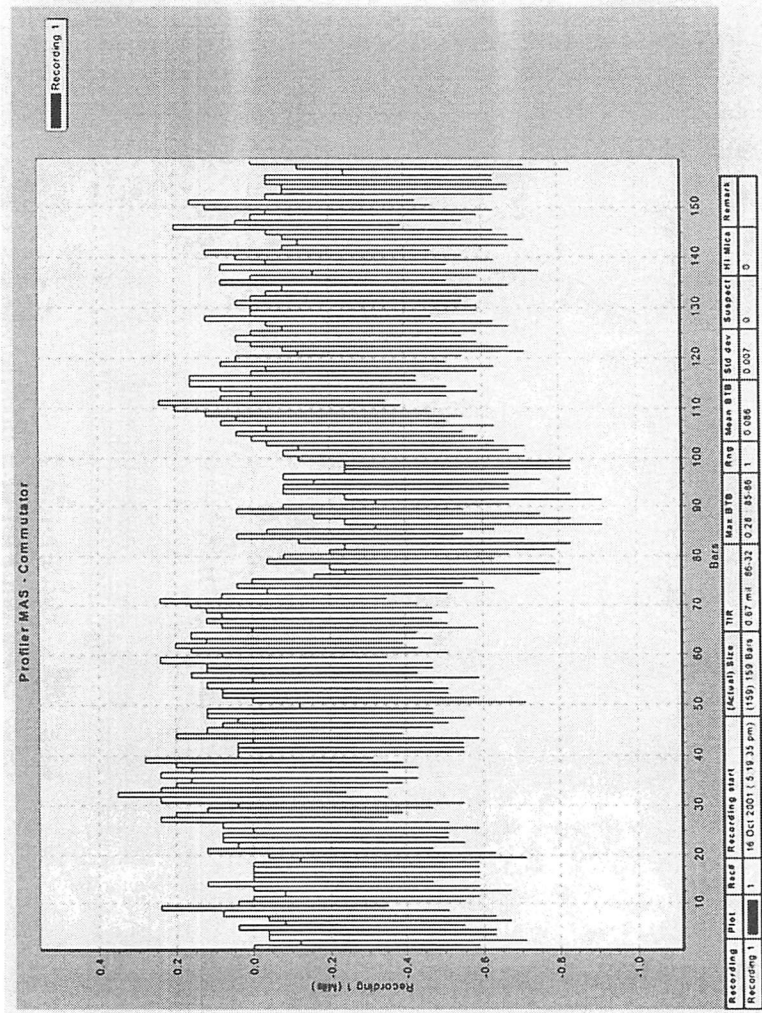
**Figure 3**  
**Profiler unit ready to take measurements**



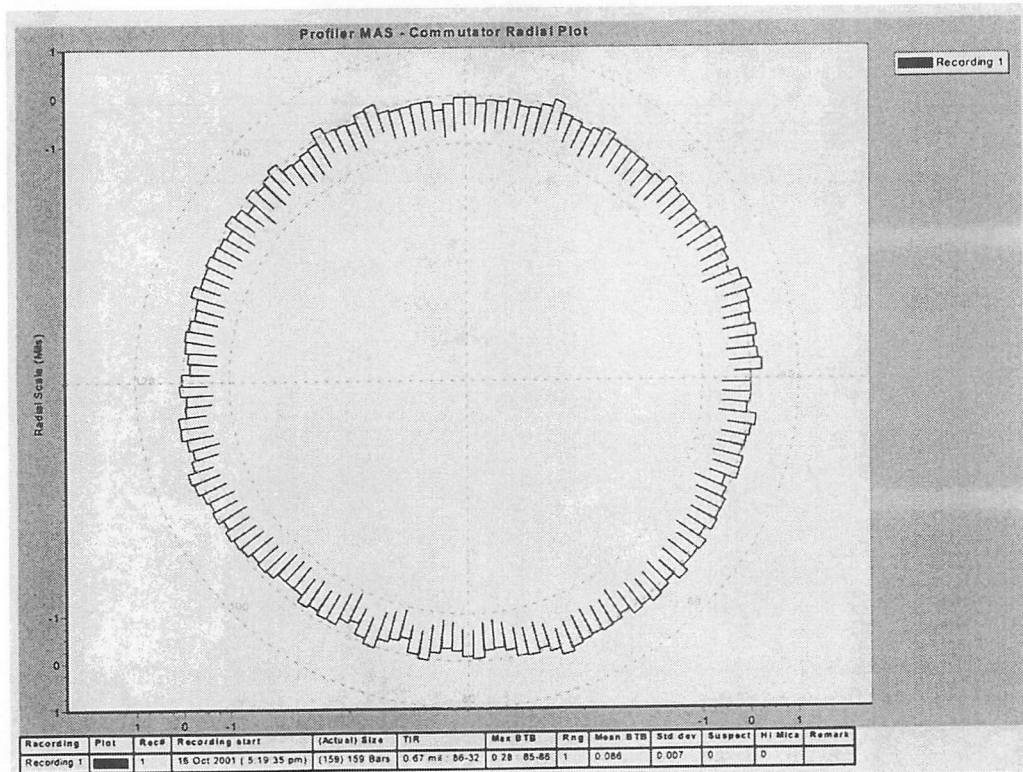
**Figure 4**  
**Profiler connected to portable printer**



**Figure 5**  
**Print out of a profile**



**Figure 6**  
Rectilinear chart of a profile



**Figure 7**  
**Radial Plot of a profile**

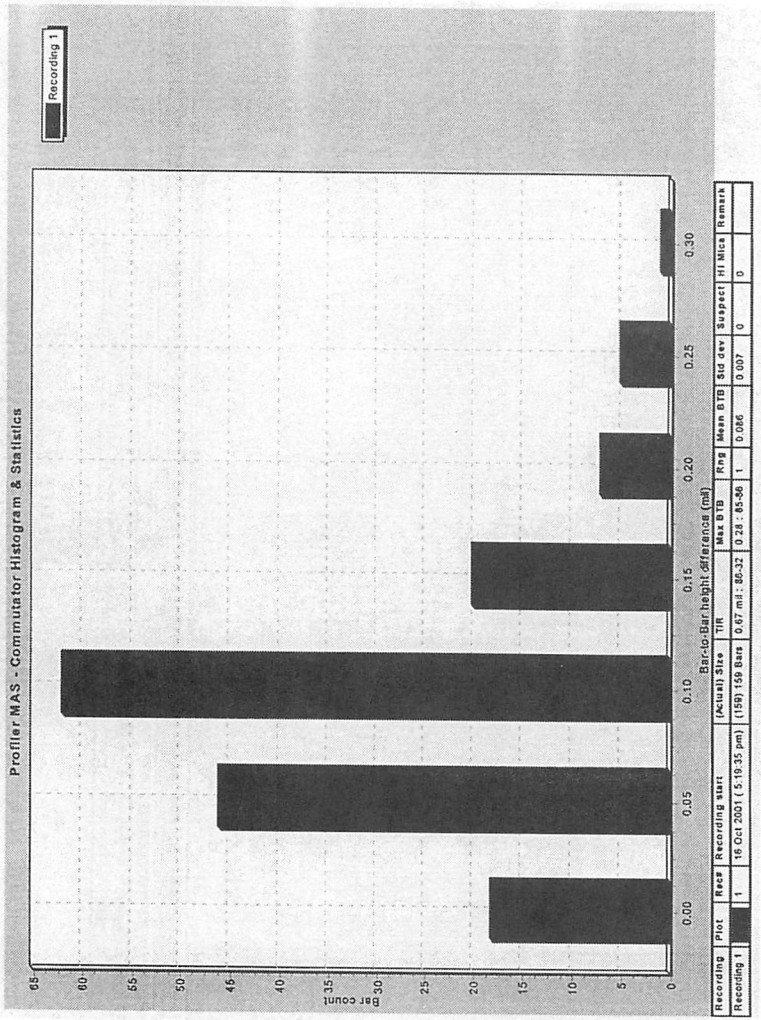


Figure 8  
Histogram chart of a profile

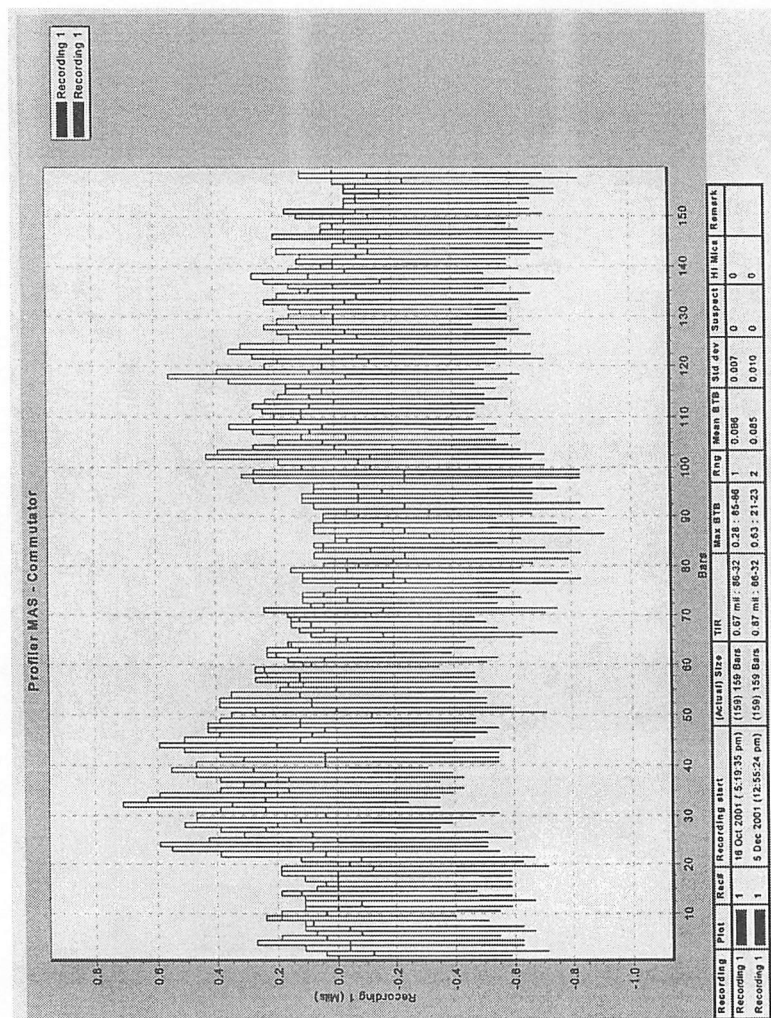
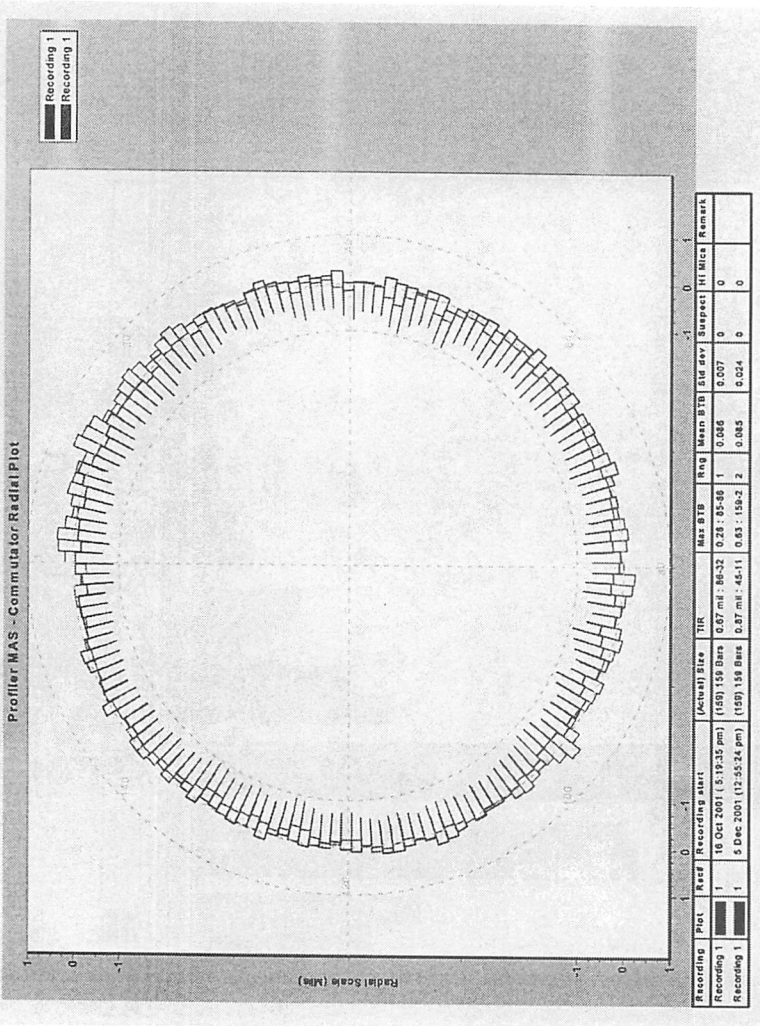


Figure 9  
Chart comparing two profiles



**Figure 10**  
Radial plot comparing two profiles

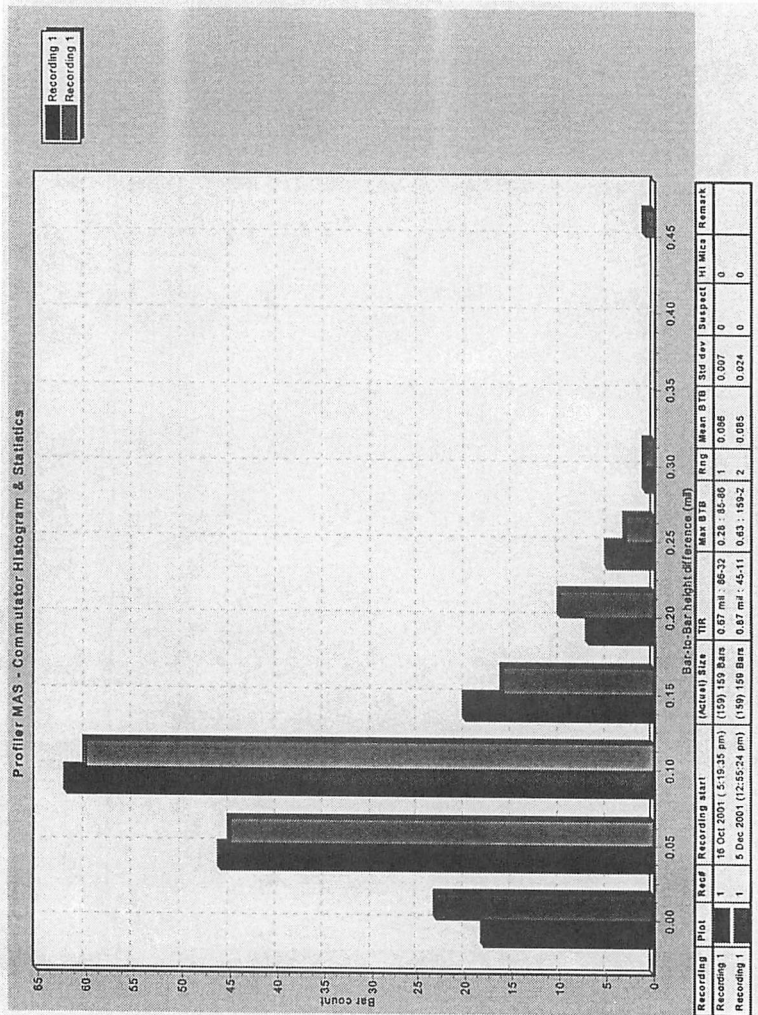


Figure 11  
Histogram comparing two profiles

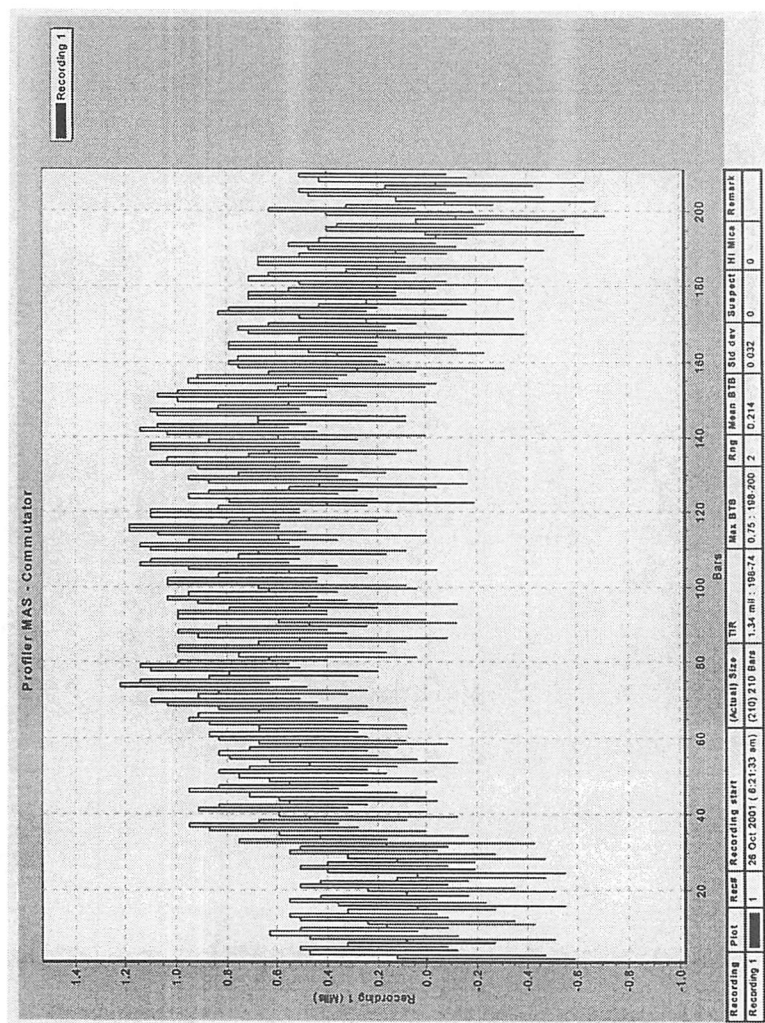


Figure 12  
Profile of a remanufactured EMD D78 traction motor

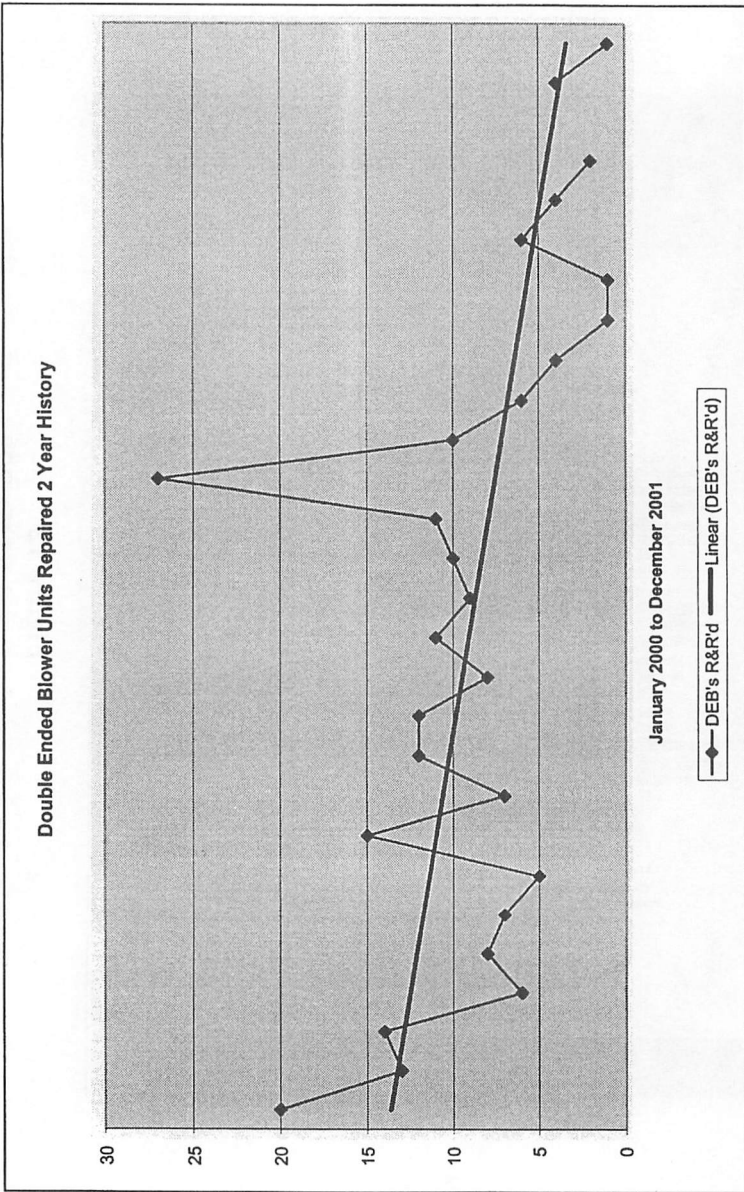


Figure 13  
Graph showing two year repair history of blower motors

  
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## II. BASICS OF AN OPERATION CENTER

*Presented by Tom Nudds,  
ZTR Control Systems*

### Introduction

All businesses strive to find that competitive edge, usually trying to separate themselves from others through product differentiation. Most successful companies attempt to provide the best quality product at the lowest possible price. Through the years, many companies have utilized new technologies to aid in the advancement of their products or to improve the efficiencies of their organization. These advancements have included new manufacturing methodologies and implementation of computer based systems. The lines that differentiate the services and products offered by companies are becoming blurry.

Twenty-five years ago, a North American automotive manufacturer would design a piston. They would then design, down to each nut and bolt, a machine to manufacture that piston. Finally, tenders would be sent to a selection of machine builders to supply the machine. Today, those same companies will send out a drawing of the piston and say, "I need a machine to manufacture this piston in these quantities by this date." The machine builder industry was transformed almost overnight from a labor based product supplier to a design/build/service provider. If that isn't radical enough, automotive companies

now are specifying complete systems (such as air conditioning or steering) based on performance criteria alone.

The world has changed such that today, there is less focus on products and more focus on solutions. Companies are evolving to offer more complete and often turnkey packages. Suppliers are partnering with the customer through design, implementation and ongoing operations and maintenance. A lot less emphasis is placed on products and we have now turned our attention to services. There are many different forms of automation being implemented to aid in this process, but the real key factor is information.

For a real world example let's look at a segment of the railway industry, more specifically the locomotive. Many advancements in locomotive controls have taken place over the years. Some of the most significant advancements have been in the area of onboard electronic controls. With these advancements have come a hidden treasure which we have really only started to harvest. This treasure is the data that these control products have been able to log away. Of course harvesting the data and turning it into useful information is really the challenge. The answer is the Op Center....

### What is an Operation Center?

An operation center is an effective blend of people, policies, procedures, systems (hardware and software) and data. It provides

unique solutions to effectively aid in managing a company's assets 24 hours a day, 7 days a weeks, from a single location. The services can include remote monitoring, analysis, remote control, problem tracking, service dispatching and reporting.

The system collects data, analyzes it and furnishes meaningful information on remote equipment or sites (called assets). This methodology of information collection can dramatically reduce cost of operations. It can also assist with decisions affecting the operation, maintenance and servicing of these assets.

### **Key Components of an Operation Center**

At a minimum, an operation center requires data, procedures and people.

- Data is the harvested product held in various media and formats.
- Procedures are used to define how the data is collected, stored and analyzed and what actions are required based on the type of data received.
- People are needed to oversee the procedures and to ensure that whatever actions have been specified are carried out. (Figure 1).

Having established the minimum requirements for an operation center, there are many ways that the effectiveness, efficiency and scope can be expanded. The most prevalent way is through automation, by utilizing sophisticated hardware

and software systems. These systems allow for reduction in manpower requirements, more detailed data analysis, enhancements to services such as on-line customer access and the scalability required to handle higher business volumes. A breakdown of the components found at the operation center is as follows:

- **Hardware** includes numerous client and server class computers, routers, modem banks, tape backups and much more. Just as important is the hardware required for a backup facility. The backup should allow for at least the minimum amount of functionality necessary if the primary facility were to become disabled. Disability can take many forms including but not limited to major hardware failures and acts of God.
- **Systems/Applications** include the operating systems, database management, network management, web services and portals as well as the operation center specific applications (as described in next section) that run on the system and hardware.
- **Communications** at this level primarily deals with connections between the operation center and the users. These are the media used to collect and distribute the data, information, reports and other functions that are requirements of the services being offered. The possible media include but are not limited to land based telephones, satellites, cellular, Internet, paging

and even the post office.

• **Services** are not a component, but an output of the operation center. The services that you want to enhance or perform via the operation center define most if not all of the characteristics of the other components. Typically far too much focus is placed on the hardware and remote monitoring systems (i.e. black boxes) that are installed on the asset. The key thing to remember is that the operation center is not a product in itself, but is used to improve services, either for your own internal/competitive advantage, or those being sold to your end customers. Typical offerings include:

- 24/7 active monitoring of alarms
- Data collection and processing
- Customer web access:
  - Real time access to site
  - Access to raw data
  - Standard and custom reporting
  - Trending
  - GPS - asset location verification
- Remote control capability
- First point of contact
- Problem tracking
- Environmental and compliance management
- Prognostics
- Aiding technical services
- And more. . . .

The people, procedures, data,

systems, communications, hardware and services make up the “core” of the operation center. To get a better look behind the scenes, we need to drill deeper into the operation center’s specific software applications, the onsite hardware and their associated communications as well as the assets we are monitoring. All of these make up the other key layers of the operation center.

### **Behind the Scenes of an Operation Center**

It is important to note that not all operation centers are built the same. Some are designed to handle one specific task and may or may not include all the layers that we described. It is also important to note that the terminology may be different, but if you have a center that enhances services for a number of different types of assets, the concepts being described should exist. (Figure 2)

The next four layers best describe the categories of specific software applications needed by the operation center.

They include:

- Core applications
- Industry applications
- Gateways / translators
- Custom applications.
- The basic function that a core application performs is not restricted by the unique characteristic of an asset or industry. As part of the design, many options are usually available to accommodate some special

desires, but the application's outputs are usually consistent. An example of a core application would be an "alarm board". From strictly a data perspective, an alarm from wayside equipment at a signal crossing is no different than an alarm from the on-board controller of a locomotive. The alarm board would allow for special desires such as displaying priorities and color settings but the general format (output) would be the display of the alarm. A core application may also be something that is fundamental to the architecture of the operation center. An example of this would be the "message dispatcher" that would receive incoming data messages from multiple sources and route them to the appropriate application.

- Unlike a core application an asset/Industry Application is designed to meet the unique needs of a specific asset or industry. But not unlike the core application, the asset / industry application should transcend most, if not all "like" assets. An example of an industry application would be fuel management. This application may receive locomotive fuel level readings from multiple sources, and determine and report when, where and who to dispatch to refuel the locomotive. This application on the other hand would have little or no use in a wayside application.

- Gateways/Translators:  
Remote monitoring and control systems (black boxes) have been developed to perform multiple functions to or for an asset. As stated earlier, a large part of the value that these devices hold is the data that they log away. The problem facing the railway industry has been establishing communications standards (i.e. protocols) and trying to get all vendors to adhere to such standards. Vendors in turn, have business and security concerns about releasing internal data maps of their systems and protocol information. An operation center on the other hand should have an open communications protocol / vocabulary (i.e. eXtensible Markup Language - XML) that follows for easy integration, keeping hardware independent. Gateways are software applications that translate between the vendors' proprietary protocols into the open protocol of the operation center. The job of the Gateway or translator is to deliver the data from the asset to the operation center in a format that the op center can *reliably* use. It can also be used to receive information or instructions from the op center and forward it to the asset's black box.
- Custom Applications are special designed software applications that have no other purpose but to meet the needs of a specific customer or a specific asset.

As you can see, the core, core applications, industry applications and gateways allow for a true plug and play type of environment. Every asset you tie into the operation center automatically gets to take advantage of everything that applies to it. The next layer of the operation center, communication media, deals with the physical transmission of data from the asset to the operation center.

- Communication Media are the physical methods or combination of methods used to get the data to and from the asset.

Present options include:

- Wireless (analog and digital)
- Internet
- Satellite
- LAN (local area network)
- Land based phones
- Cellemetry

Each of these items has advantages and disadvantages. The communication scheme that is decided on is a function of several significant factors. These include:

- Coverage
- Operating Costs
- Reliability
- Capability
- Technology maturity
- Industry maturity

Note that all of the factors that are part of the consideration change almost daily and an operation center should be set up to take advantage of the available and emerging technology as it applies to an application.

- Assets are the target for perform-

ance and efficiency improvements possible with an operation center. A good operation center would allow for larger volumes of different categories of assets. Examples of these can be:

- Locomotives
- Cars
- Backup power generators
- Wastewater treatment facilities
- Turbines
- Practically anything else...

### **Standard Remote Monitoring and Control System**

It is important that you understand the difference between an operation center and a standard remote monitoring and control system. The key difference is that standard systems are typically designed to meet the needs of an individual asset (silo) and do not offer the centralization / integration capabilities of multiple asset and asset types. These systems are a key component in automating the processes of the operation center. We need to look at the layers of a standard system to get a better understanding of its operation and how it integrates with the operation center. Let's consider what is required simply to monitor a locomotive. The following figure shows the hierarchy of these layers that constitute a "silo of layers." (Figure 3)

In looking at the layers of a standard monitoring system, you will quickly identify some areas of

commonality with the layers of the operation center. The main difference in some of these layers is scope and scalability.

**Infrastructure:** This may simply be a single PC that hosts a stand alone application, with one communication connection to an asset. This PC may be hooked up to the customer's network allowing for some limited multi-user capabilities and utilizing their existing backup systems.

**Data Storage:** In most cases this is the hard-drive of the PC referenced in the infrastructure layer above.

**Reporting:** This simply accesses data stored in the data storage layer and produces very specific reports for the asset.

The Remote HMI (Human Machine Interface) gives an operation center worker remote access to real-time data from the site.

**Communications** is the actual transfer of data to and from the asset.

These layers all have some commonality with layers of the operation center, but these next three layers are quite different from one asset to another.

The Control Hardware is the intelligent device in the field that monitors and gathers the data that are transferred to the operation center. It is also referred to as the "black box." It can also be used to perform local control as well as provide remote control capabilities.

I/O Interfaces are used to collect

specific information about the asset and transfer that information to the control hardware. These interfaces can be set up to determine the ON/OFF state of switches, pushbuttons or interlocks. They can be transducers used to measure actual values such as temperature, current or pressure. They can also be used to gather or transmit data through a serial interface to other intelligent devices associated with your asset.

At the top of the system is the Local HMI. This is the optional on-site display that provides viewing and control access to the data stored in the control hardware.

We have just described the layers of a single remote monitoring application of an operation center. Although they can be effective in a single application, once multiple and varying assets are considered, applications can become much more complex.

### **Multiple Asset Monitoring**

Now let's consider various types of assets that a customer may have. Note that any specific layer, while unique, may share common characteristics with other industries. However, in this case, each type of asset can have its own silo with individual code written. The huge development, logistics and supports costs of maintaining and using each of these silos can be overwhelming. (Figure 4)

Earlier, we spoke of the common elements of an operation

center infrastructure. We then went into specific layers that comprise individual applications or assets. Finally, these are placed together in the drawing below to demonstrate the complete relationship. (Figure 5)

Note that instead of huge silos of isolation, the integration of the op center allows one to use common applications resulting in smaller and simpler silos. The top three layers (local HMI, I/O and control hardware) actually define the on-site hardware and software pieces. A well-developed operation center should be truly hardware independent. This type of plug and play feature results in much less development and maintenance issues for the developers, resulting in savings for the customer.

### **Where the wheel meets the rail - A real life example**

**Brief Description:** SmartStart® and SmartLink are used to transmit data from the locomotive to the operation center. These are used to generate reports that are then used to optimize the effectiveness of the fuel management group as well as to perform low-level health monitoring. SmartLink supplies once daily GPS reports to locate the locomotive as well as to track movements. The customer has the ability through a secure web based interface to ping the locomotive and to establish its location or to generate on the spot reports. Event driven alarms pro-

vide real-time notification of items that need to be acted upon. (Figure 6)

A small mid-western railroad has a fleet of 12 SmartStart equipped locomotives. The SmartStart systems are tied into the operation center located in Shakopee, Minnesota through the SmartLink satellite interface. Each unit is set up to download complete fuel saving and duty cycle reports monthly as well as daily spot GPS reporting.

The customer has secure access to reports and information through his Internet browser. His first page has the menu selection that prompts for the specific locomotive or fleet of locomotives he is interested in. It is important to note that since this is a core application; it can also be used as a front end to obtain information on other customer assets. (Figure 7)

When an alarm is generated and received by the 24/7 operation center, there is a specific set of rules that must be followed. A dead engine in the summer will invoke a different priority or urgency than at 2:00 am in January. Contact instructions vary from emails only, to priority phone calls to a list of personnel. Every alarm is in one of three color coded states:

- Active and not acknowledged
- Not active and not acknowledged
- Active and acknowledged.

When an alarm is returned to normal and it is acknowledged, it

is cleared from the alarm screen and archived forever.

Typical alarms in this case can be:

- Dead engine
- SmartStart disabled
- Unauthorized loading.

Again, since this is a core application, this same software can be used to alarm other customer assets without the need for additional code. (Figure 8)

The customer has access to the asset tracker that is set up to show where the locomotive is at a specific time every day. GPS information can be quickly blown down to a detailed map showing all active rails in the United States. It can be used to track a single asset as well as a combination of locomotives up to the entire fleet. (Figure 9)

The following reports are asset / industry specific and are typical of what are generated by SmartStart on a single locomotive. In this case, they provide detailed information of the actual fuel savings and opportunities for a specific locomotive... (Figure 10) as well as its utilization. (Figure 11)

More importantly, the operation center has a number of fleet-wide analyzers that present the information in an organized fashion. Some reports will highlight potential problem areas that need either a review (yellow) or immediate attention (red). (Figure 12)

As a result of this type of reporting, the following email was gen-

erated after approximately three months of operation:

Hi Peter,

**I thought you would like a quick update on the SmartStart units. Looking at the reports, I have noticed the following items that you may want to have your guys look into:**

**2004 - Large number of restarts due to Main Reservoir Pressure and Compressor preventing shutdown may suggest major air leaks - \$342.00**

**4300 - Battery Charging preventing shutdown for many hours may suggest locomotive batteries needs changing out - \$461.00**

**4302 - Unit still in test mode (9998) - \$96.00**

**Please let me know if you would like any more specifics.**

## Conclusion

An operation center is not just a number of software applications running on a PC. A true facility starts with the most important piece, the "core". which includes people, procedures, policies and data. At some point your customers, who may be located anywhere in the world, are going to want to speak to a human voice. Their expectations are that you are on-guard 24 hours a day, 7 days a week.

It's important to note that developing and operating your own operation center may not make sense for everyone. It is possible

for you to have all of the benefits of an operation center without incurring all of the costs to develop the hardware and software to operate one. Because the operation center is really a process, you could contract the services of an existing operation center to provide your own personalized fully functional operation center for your customer.

If you do choose to develop internally, make sure you consider your volume expectations, time to market and system complexity when determining your return on investment. There are vendors who offer the services with varying degrees of capabilities and sophistication. In making a selection make sure you look at your long-term needs to ensure that your choice has the scalability to meet your current and future expectations. Scalability takes two forms: one deals with the ability to affordably handle small and large volumes of assets and the other allows for varying types of assets. A well thought out operation center considers all of the assets and will integrate key elements so that software development and support, as well as hardware service can be shared to allow a more efficient integration of technology. Don't let your choice today limit your ability to enhance your services on any asset or industry that you serve.

In looking at utilizing an operation center, it is important to first identify the services that you are

trying to provide and how the operation center can enhance your offering. Remember that you should not look at an operation center as a product in itself. You should be looking at the competitive advantages that you obtain from being able to offer your customers a complete solution.

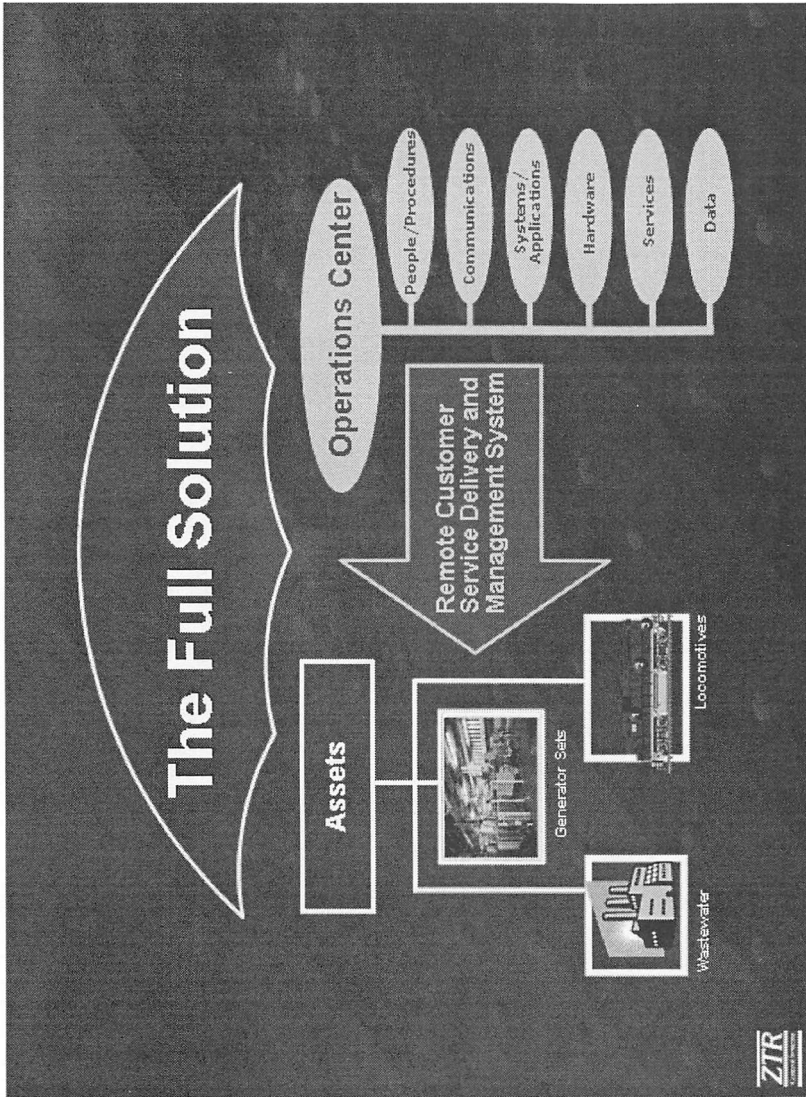


Figure 1

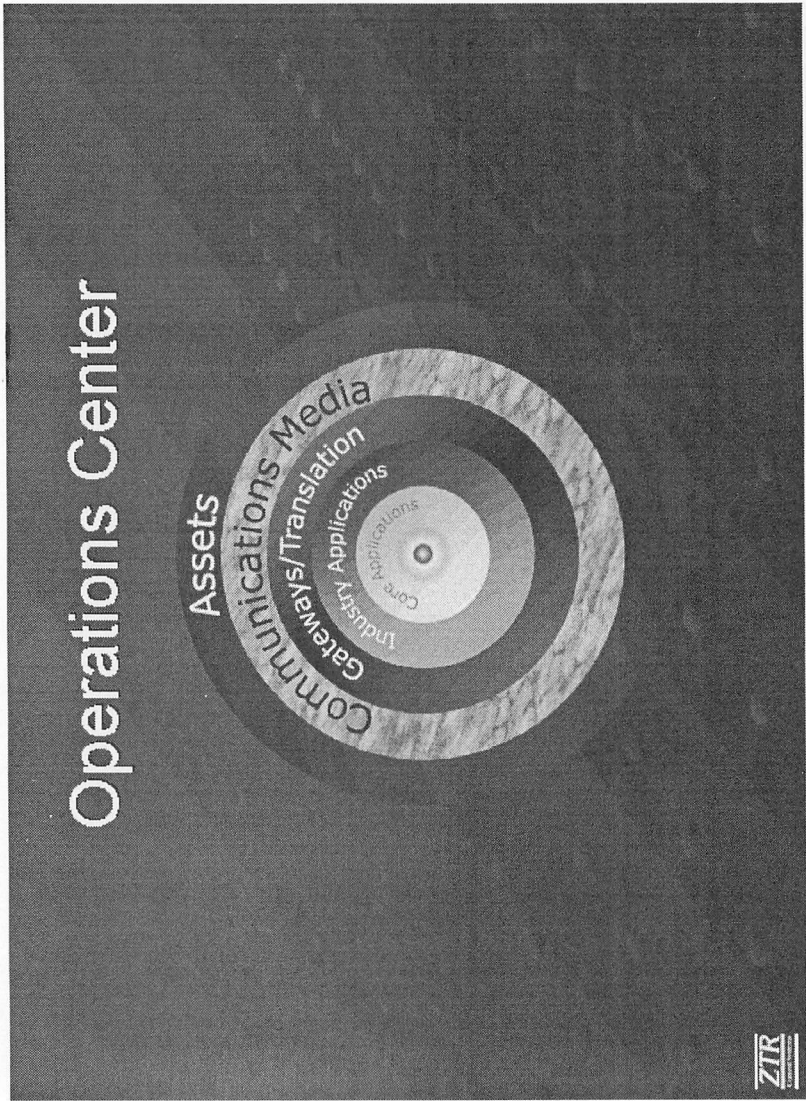


Figure 2

# Components of a Monitoring System

**Locomotive**



- Local HMI
- I/O Interfaces
- Control Hardware
- Communications
- Remote HMI
- Reporting
- Data Storage
- Infrastructure



**Figure 3**

# Silo Effect of Multiple Asset Monitoring

**Locomotive**



|                  |
|------------------|
| Local HMI        |
| I/O Interfaces   |
| Control Hardware |
| Communications   |
| Remote HMI       |
| Reporting        |
| Data Storage     |
| Infrastructure   |

**Freight**



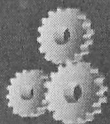
|                  |
|------------------|
| Local HMI        |
| I/O Interfaces   |
| Control Hardware |
| Communications   |
| Remote HMI       |
| Data Storage     |
| Reporting        |
| Infrastructure   |

**Waste Water**



|                  |
|------------------|
| Local HMI        |
| I/O Interfaces   |
| Control Hardware |
| Communications   |
| Remote HMI       |
| Data Storage     |
| Reporting        |
| Infrastructure   |

**Generator Sets**



|                  |
|------------------|
| Local HMI        |
| I/O Interfaces   |
| Control Hardware |
| Communications   |
| Remote HMI       |
| Data Storage     |
| Reporting        |
| Infrastructure   |

Figure 4

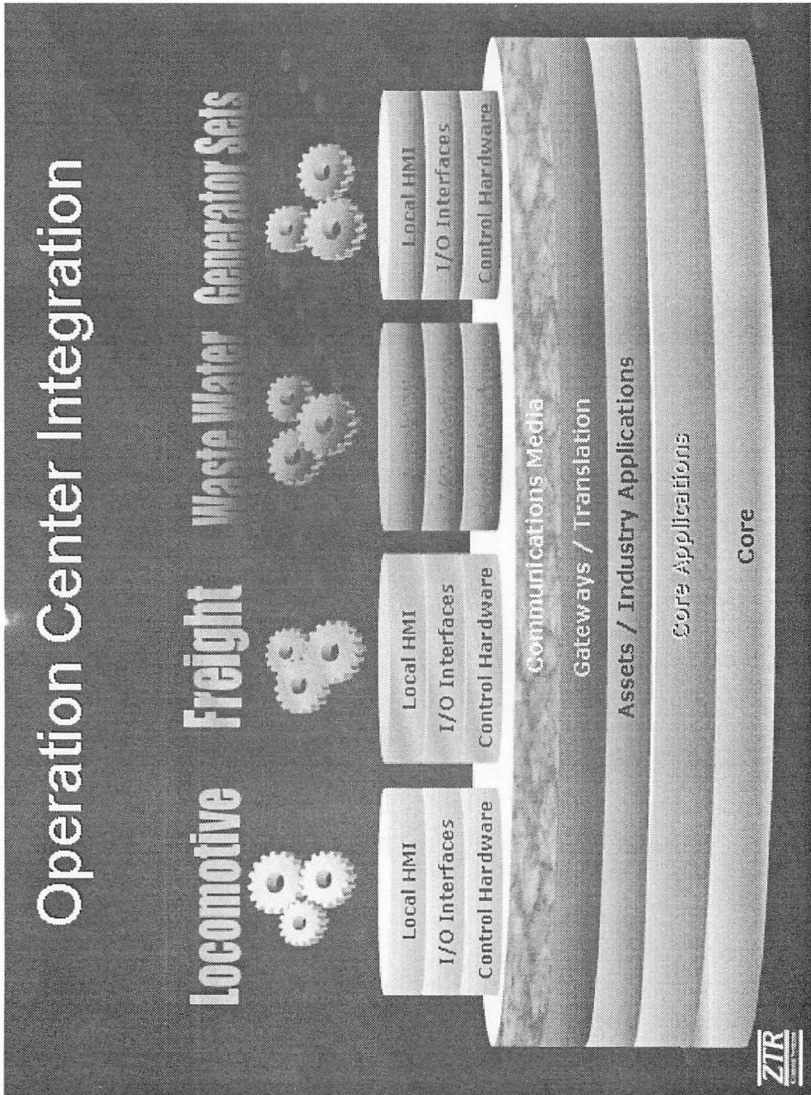


Figure 5

# Transmit SmartStart Data From Locomotive to Op Center via Satellite

Satellite Link



Operations Center Service

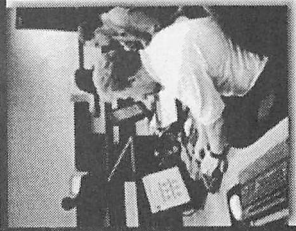


Figure 6

# Web Interface

**ZTR Control Systems - Home**

Home | Engineering | Support | Links | Help/FAQ | Administrator | Home

**All units**

## Operations Center

From ZTR Control Systems

### What Is It?

The Operation Center is an effective blend of people, policies, procedures, systems (hardware and software) and data. It provides a unique solution to effectively and in managing your assets 24 hours a day, 7 days a week, from a single location. The services can include remote monitoring, analysis, remote control, problem tracking, advice on diagnosing and reporting. Some applications include locomotives, wastewater facilities and genset sites.

### What Does It Do For You?

The system collects data, analyzes it and furnishes you with meaningful information on all of your remote equipment or sites. This methodology of information collection will dramatically ease your cost of operations. Let us show you the advantages and solutions with respect to the operation, maintenance and servicing of your equipment or sites.

### How Is the Information Accessed?

The information securely resides within the Operations Center system and is internet accessible. All you need is a PC with a web browser and a proper password.

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Figure 7

# Alarming

Alarms - Personnel - Alarmed Equipment

File Edit View Favorites Tools Help

Back Home Forward Stop Refresh

Address: http://www.ztr.com/alarms.html

**ZTR Control Systems - Alarms**

Alarms | Responsibilities | Reports | GPS | Help/Info | Administration | Home

1682

| Date Received       | Description                   | Retained | Print Returned      | Addressed/Log |
|---------------------|-------------------------------|----------|---------------------|---------------|
| 2001-08-21 09:27:59 | Switch Program Disabled       | YES      | 2001-09-16 21:56:13 | YES           |
| 2001-08-21 12:46:09 | Unknown Shutdown (Unattended) | YES      | 2001-08-22 19:24:35 | YES           |
| 2001-09-04 23:18:42 | Unknown Shutdown (Unattended) | NO       | N/A                 | YES           |
| 2001-09-06 17:27:47 | Locomotive Overspeed          | YES      | 2001-09-06 17:48:22 | YES           |
| 2001-09-24 10:48:15 | Fault to Restart              | YES      | 2001-09-24 12:55:15 | YES           |
| 2001-10-30 11:38:56 | Locomotive Overspeed          | YES      | 2001-10-30 13:45:46 | YES           |

Alarms are provided for individual locomotives. For more information, please contact your ZTR representative.

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ZTR  
CONTROL SYSTEMS

Figure 8

# Global Positioning

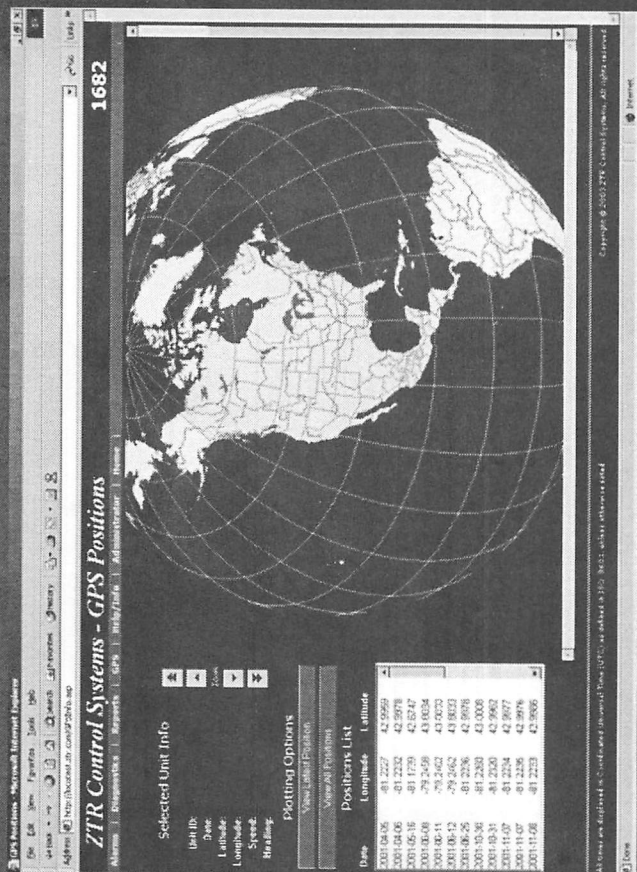


Figure 9



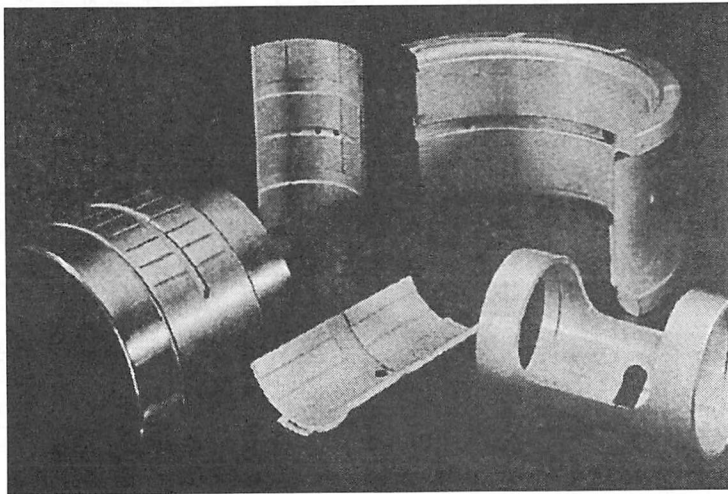




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### III. DIAGNOSTICS FOR OLDER LOCOMOTIVES

*Prepared by: M.E. Drylie,  
CSX Transportation and  
T.S. Olson, Wabtec Railway  
Electronics*

#### Introduction

Troubleshooting of locomotives is a daily task performed across the rail industry. When the locomotive arrives at a service center or shop there will be incidents written against the locomotive where an incident is defined as what is broken/wrong with a given locomotive system. Usually the craftsman is provided an incident code, with generic wording, along with a time, date, and general location the incident occurred. Some examples could be DBP (Dead Battery Problem), TMP (Traction Motor Problem), ECD (Engine Component Defect), or LWP (Water Leak Problem). Often with little else to work with the craftsman must try to solve the problem. In receiving the corrective actions for these problems it is not uncommon to see; locomotive running when arrived, charged batteries, filled with water, performed load test, or tested on test track as common fixes where it appears as if the craftsman could not find anything wrong with the locomotive. In some cases, the no problem found situation may be accurate, but more often than not the locomotive will have the same or similar problem in a number of days or weeks. Newer locomotives have fault monitoring capabilities to aid

the craftsmen in seeing more of what was happening with the locomotive when the incident occurred. This is a look at how one railroad is developing a health monitoring and communications system to use on its fleet of older locomotives.

#### Background

In the late 1970's computers began to become commonplace in many industries. Locomotive manufacturers and suppliers saw the advantages of computers for locomotive control and diagnostics. The technological step from a Dash 7 to a Dash 8 or a Dash 2, or 50 Series, to a 60 series was much more than an increase in horsepower, but even more it was a giant leap forward in computerized control.

The Dash 8 and 60 Series locomotives came out in the early to mid 80's. Those locomotives had the first control systems using computers, and had limited diagnostics using programmable screens to monitor water temperature, horsepower, A, B, C, and D valves, and various other control settings and data. Today the majority of locomotives in North America are equipped with diagnostics of some fashion. There are many systems available to upgrade the Dash 2 and earlier locomotives, to what is commonly called on the EMD side, a Dash 3 locomotive. The common thread between all these systems is the use of onboard processors and sensors.

Until this date, CSX has only

used diagnostics on new locomotives. While the value of a locomotive health monitoring system has always been evident, CSX has waited for the proper opportunity to implement a diagnostic system. This opportunity presented itself with the need for monitoring the Auxiliary Power Unit (APU) being installed on the CSX fleet. CSX is now in the midst of a fleet-wide implementation of a diagnostic system for the older locomotives.

### **Why a new system?**

Over the next 5 years, CSX has a plan to install an Auxiliary Power Unit (APU) on each locomotive to meet EPA requirements; generate EPA credits; and/or to reduce fuel consumption. The APU is an important piece of an idling reduction strategy which when implemented on a locomotive will allow the locomotive to be shut down during any season of the year, and not just during the summer. While shutting down the locomotives is good, - what happens if the APU fails to start, or perform as desired? The potential for an engine failure due to freeze damage increases dramatically when shutting down the locomotives in the cold.

To prevent/reduce potential engine failures CSX saw a need for a communication system. The communication system should provide the CSX Operation Center with information regarding what is wrong, what locomotive is in trouble, the locomotive location, and the urgency for attention (based upon whether or not the ambient

temperature at that location is above or below a specified level).

### **What should be in a new diagnostic system?**

If a railroad wants a health monitoring system what does it need? What is currently available and what improvements should be made to make that system more useful to the user? The following items have been determined important for any diagnostic system.

The system should:

1. Have a generic application designed to work on multiple locomotive types.
2. Have faults and notification methods useful to management and craftsmen.
3. Have well defined faults.
4. Have a Communication System to generate messages that a monitored system has failed.
5. Provide automatic updates to locomotive maintenance records so that maintenance shops personnel will have information before the locomotive arrives at a shop.

In trying to develop a generic system it is often necessary to duplicate existing sensors and/or monitoring systems. Examples of duplicated sensors are water temperature probes/sensors, air pressure sensors, and traction motor

current sensors. Examples of duplicate monitoring are Event Recorder monitored signals, such as speed, throttle position, and reverser position. While duplication of existing systems may add some costs, it makes the new system easier to apply and use when each system is identical.

In picking what faults/systems are to be monitored, it is important that monitoring a system will provide reduced failures in that system and the information provided to maintenance crews be useful in troubleshooting. If the craftsman sees no "value" in the diagnostic system he will not use it.

Faults need to be well defined. Improper or inadequate definition may result in the generation of fault messages which are not indicative of the true health of a system, or produce faults so often they are ignored.

To obtain the most benefit from a diagnostic system, a communication system is needed. Knowing a system is failing which may render a locomotive out of service can assist transportation managers in the consisting decisions or whether pulling a locomotive into a service center or shop for an inspection might be useful. Without an automatic communication system, decision makers can not know the condition of monitored systems.

Providing inputs to maintenance screens can also be useful in allowing shops the opportunity to obtain needed material before the locomotive arrives. As an exam-

ple, if traction motor overheating is accurately detected a shop can have traction motors available for installation.

### **System Implementation**

One of the first steps in diagnostic system implementation is to identify those locomotive systems to be monitored. After much consideration and study the decision was made to keep the fault definitions as simple as possible. We focused upon reporting problems, which are basic to locomotive performance and locomotive protection.

The next tasks are to determine which signals to monitor, what sensors are necessary to monitor those signals, and establishing the performance limits of those signals and systems.

The communication system completes the overall implementation. The message routing is critical to a successful program. After an incident has occurred, data related to the incident is stored in an incident log, and the appropriate notification process as previously described is completed.

### **Basic System Requirements**

A basic system requires sensors to monitor signals, onboard processing of those signals, a communication system, and automated notification of personnel.

In the CSX application sensors for water temperature, traction motor current, main generator voltage, and air pressure, are used to monitor locomotive signals.

Discrete inputs for trainline signals, relay and contactor position are also used.

As an onboard processor CSX worked with Wabtec to expand an existing computer system. The main area of expansion was to increase internal memory by a factor of 16 with the desire to record 3 months of data.

As a communication network, two pathways were selected. As mentioned before, satellite communication provides instant/near instant messaging of faults, and a spread spectrum ground station based communication system provides full data history for use in troubleshooting and EPA reporting.

When a defined fault is detected, the CSX operation center is automatically notified; the mainframe computer updated, and selected personnel are notified. Which personnel are notified is determined by which fault is reported.

### **Systems Monitored:**

#### **A Practical Example**

In reviewing incident history, CSX determined that we were having too many traction motor failures. Often the traction motors are overheated. There is a load meter on the control stand that measures the current through TM#2. Placing a current sensor around the TM cable allows the diagnostics system to monitor the traction motor and to calculate when they are overheated. An algorithm equating temperature and current is used to record the overheat condition when the load

meter parameters are violated. In order to use the same detection device across many classes of power, the 15-minute rating of the given locomotive is input into the computer memory as a parameter when the system is first installed.

Other locomotive performance criteria monitored in the CSX system are Low Horsepower, Dynamic Braking, Ground Relay Faults and APU Alarm and APU Performance. Low Horsepower is defined as not making 90% rated horsepower while in Notch 8 for at least 2 minutes and while traveling at least 20 miles per hour. Dynamic Braking Fault is based upon not obtaining 500 Amps of braking power in full braking while at a speed greater than 22 miles per hours. Less than 4 ground relays an hour are acceptable. An APU Performance failure occurs when the Engine Run Manager asks the locomotive main engine to start to maintain a parameter (water temp, air pressure, or battery voltage) that it had already asked the APU to start in order to maintain that parameter.

Other areas being considered by CSX are fuel flow through filters, inertial filter performance, tractive effort and/or adhesion. Incorporation of these systems into the overall package is planned over the next few years as the systems matures.

### **Communication System**

Each railroad needs to determine the appropriate transmission means for given signals. Each

added communication path increase initial hardware costs, infrastructure costs, and sometimes, transmission costs.

With a satellite communication system, the system itself limits the user to determining how many systems are to be monitored and developing a pass/fail criteria that can set up as "1" or a "0". Other limitations in a satellite system are that each bit and byte of data that is added will bring higher transmission costs. The advantage of a satellite system is most satellites "see" everywhere, that is, they have fewer blind spot than most other communication systems. Some satellite systems also provide the user with near instant messaging.

What about the rest of the data? Can the data wait until the locomotive is brought in for maintenance or is there a faster way to obtain all/most of the data? A spread spectrum radio system is capable of passing large amounts of data quickly, reliably, and at a low transmission cost. CSX is placing spread spectrum access points in service centers to transmit full downloads to our network drives to aid in troubleshooting and to provide EPA data.

### **How is the System Used?**

In the CSX diagnostic system, there are many data screens that are available for troubleshooting. With knowledge that a system is failing or a fault has occurred, an experienced person can review the ALARM LIST to determine if any

alarms were recorded around the time frame of an incident. If an alarm is noted, the ALARM RECORD can then be reviewed. Following that, the graphical portrayal of data related to the incident can be reviewed. When evaluating the data graphically, the display can be changed to allow additional or even different signals to be looked at and compared. The data can be examined over a large period of time looking for a general trend, or in small increments of time to see "which event occurred first." Recent examples of how this technique has been used include determining that a governor had the "D-Valve" sticking, and another locomotive had a cold water dump valve (Guru valve) that tended to open at a higher temperature than desired.

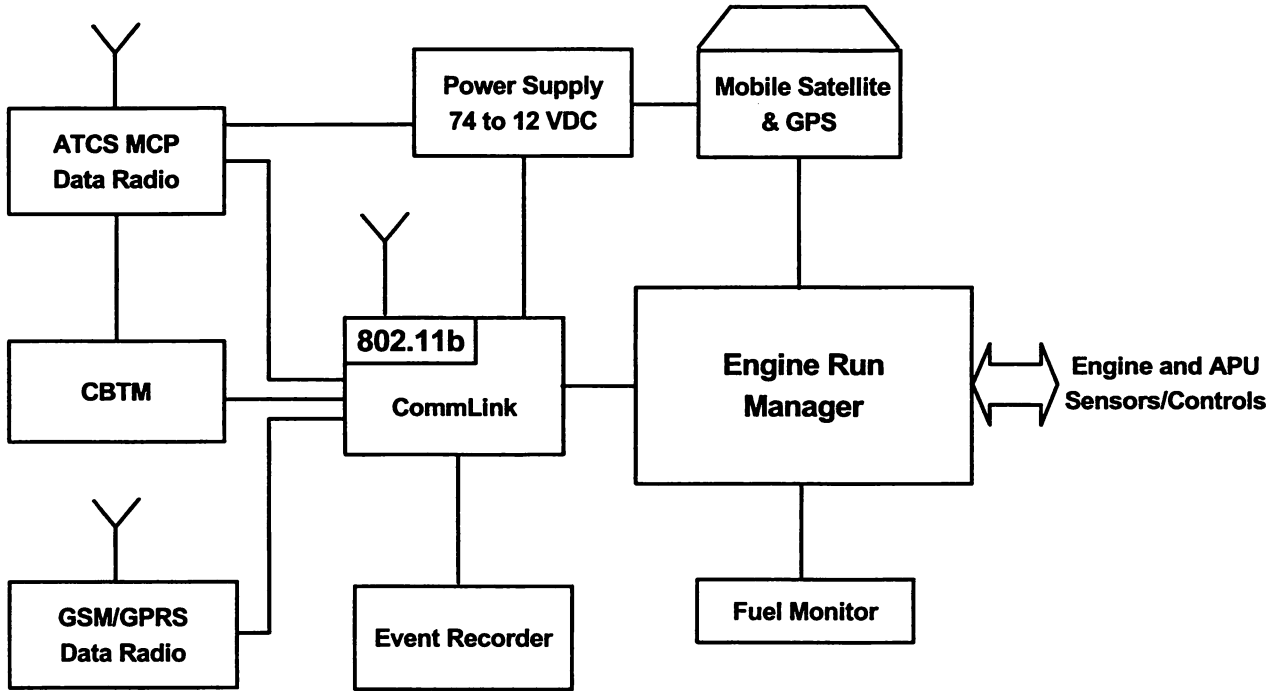
Action taken to compensate for Guru valve tolerance (opening at a higher than desired temperature) was to change the system operating parameters. In the case of the governor, replacing the governor corrected that locomotives' problem.

Could these incidents have been identified and corrected without the use of a diagnostic system? Probably, but certainly not as quickly. In the case of the governor, a few hours of troubleshooting was avoided. In the case of the Guru valve on this one locomotive had opened early a few weeks previously, but was thought to be a secondary factor instead of the primary failure. The difference? The diagnostic system was added after

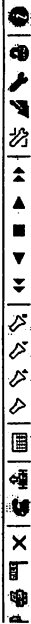
the first failure and review of the data clearly showed the 40-degree Guru valve opened when the water temperature was 51 degrees.

### **Acknowledgments**

The writers of this paper wish to thank the LMOA and RSA for the opportunity to present our findings, the CP and CSX for the data from their equipped locomotives, and our companies for the opportunity to work together in a fun and fulfilling project.



6 Communications Report View Graph Search Setup Help



uel Report | Statistics | Statistics Graph | Alarm List | Alarm Record | Extended | Extended Graph |

General/Engine Operation/Throttle/Shutdown Times/Restart Counts/

.OCO NUMBER = 00008712 (SD60/I/M)

:COLLECTED ON T/D = 14:17:23 03/05/02

:SYSTEM TIME/DATE = 14:16:22 03/05/02

'UEL CONSUMPT IN IDLE= 4.00 gal/hr (USING DEFAULT)

'UEL COST = \$0.50 dollars/gal

'UEL SAVINGS LIFETIME STATISTICS SHORT TERM STATISTICS

:SINCE TIME/DATE 15:30:17 12/20/01 12:54:49 03/05/02

ANUAL SHUTDOWN SAVINGS GALLONS SAVINGS GALLONS

AUTOSTART SHUTDOWN \$649.09 1298 \$0.22 0

INREALIZED SAVINGS \$429.51 859 \$1.72 3

\$98.00 196 \$0.00 0

:ESTIMATED ANNUAL AUTOSTART SHUTDOWN SAVINGS \$11008.30 22017

#### IV. TRACTION MOTOR PROTECTION PANEL

*Presented by Kar Gazarov,  
CSX Transportation*

Ownership of AC locomotives has increased in recent years and represents approximately 20% of the fleet.

Mixed consists with AC and higher HP locomotives in the lead may damage traction motors on trailing DC or lower HP units.

Special instructions were published to outline the consist building requirements.

Some locations have limited, or no capabilities to turn the locomotives around to comply with the requirements.

Last DC locomotives have built-in OEM designed traction motor protection systems.

Estimates of up to 30% of traction motor failures directly attributed to overheating.

Challenge - identify cost effective solution to protect Dash 2 (33% of the fleet) and Dash 7 (7% of the fleet) locomotives.

There were several systems available for retrofit, but were cost prohibitive.

Efforts were directed to develop a simple system and involved several aftermarket suppliers in the process.

To eliminate non-recurring engineering cost, inexpensive modules currently available on the market, were utilized such as traction motor current module, excitation control module, etc..

#### System Requirements

- Current input signal to system.
- Continuous computation of time exceeding the short time rating.
- Reduction of output by an amount sufficient to protect the traction motors.
- Values corrected to ambient temperature.
- Simple built-in recorder.
- The first prototype system was installed in 2000 and had high failure rate.
- The second system was prototyped in 2001 and performs as expected.

#### What's Next?

At the present time, ten locomotives are being monitored.

Regular read-outs indicate protection system activates and protects traction motors as intended.

Other Class I railroads are considering application of TMPP to DC fleet.

Test will be concluded in December of 2002.

# New

**Wick Lubricators for  
Traction Motors**

**Locomotive Gear Case Seals**

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Pedestal Liners**

**Filler Caps**

---

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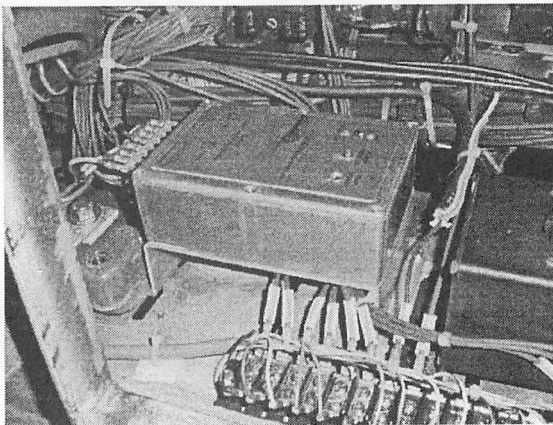
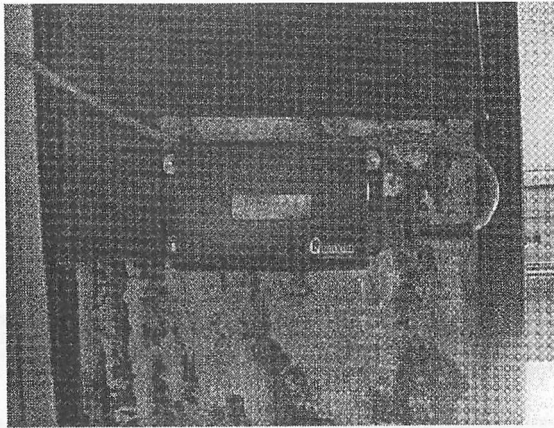
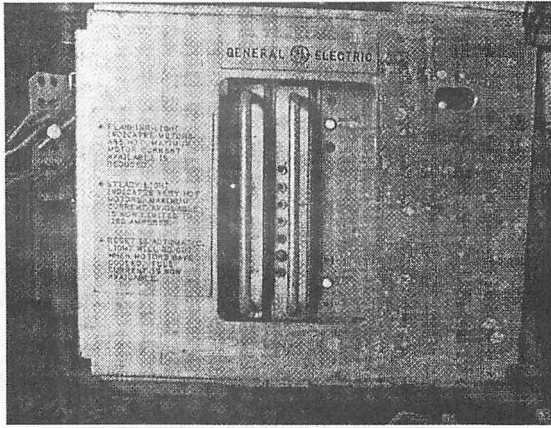
*1155 East 8th Street Winona, MN 55987*

*Call Kristi Corey at 507/452-2461*

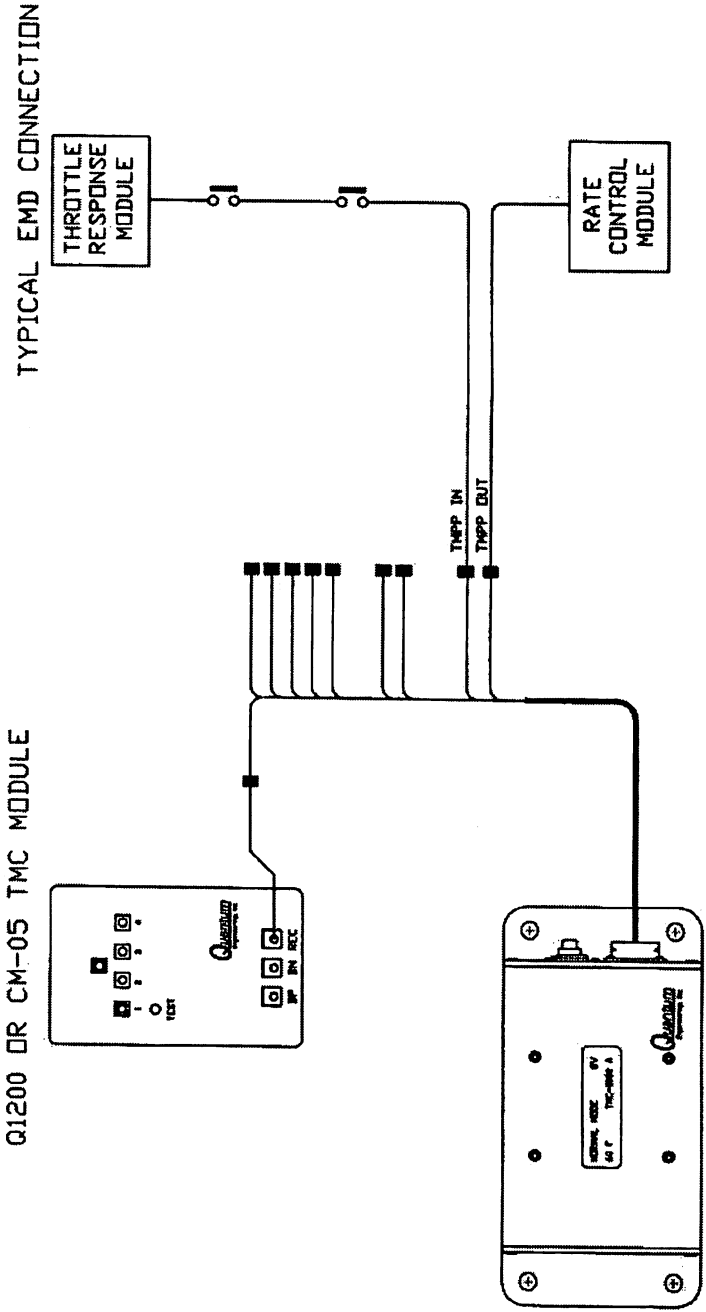
*or Rich Eagan at 610/356-8482*

*Parts are available for both EMD & GE locomotives.*

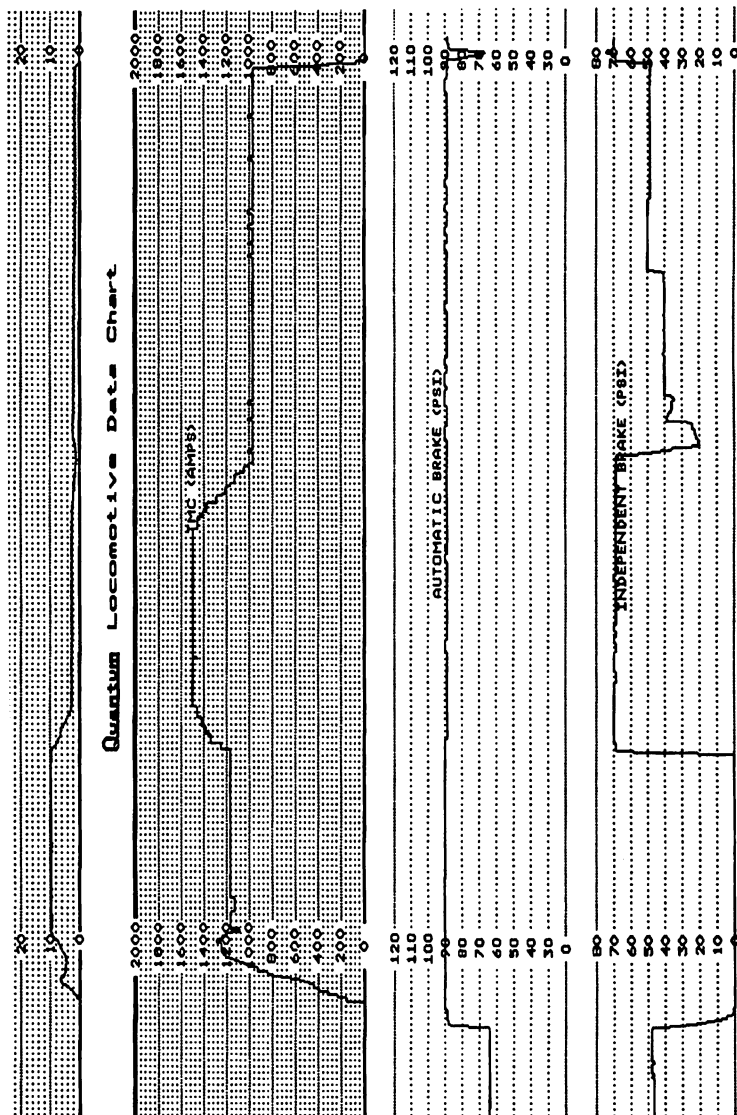
## Available Systems



# Typical EMD Connection



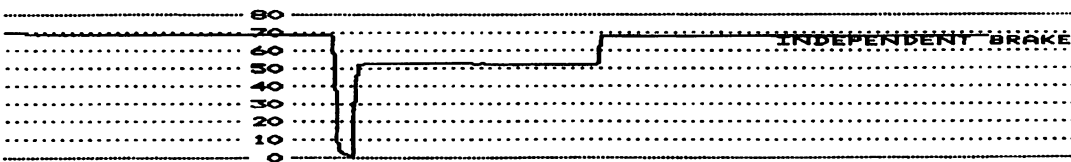
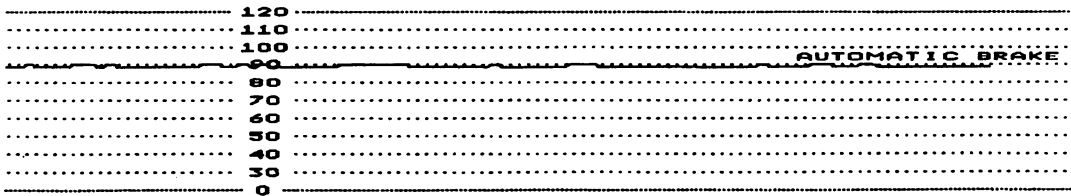
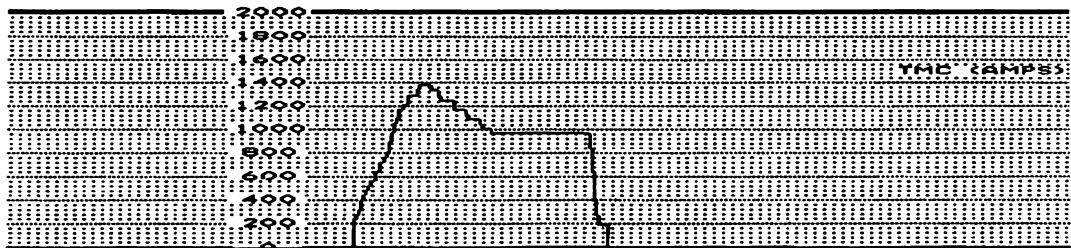
## SD40-2 Initial Test Run



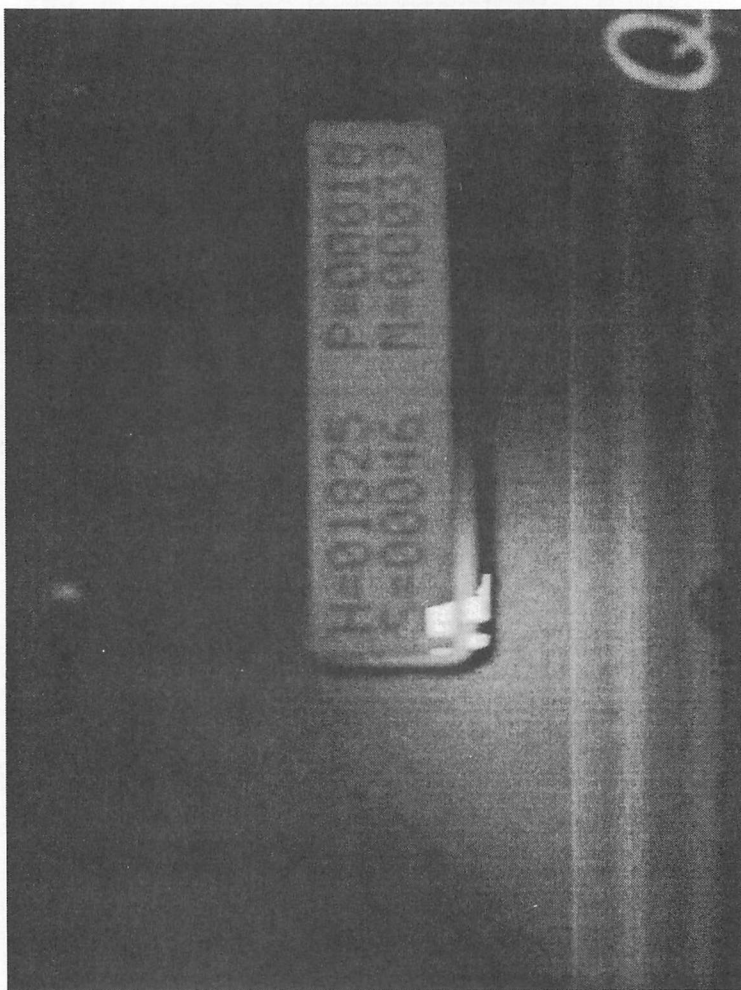
# SD40-2 Initial Test Run



## Quantum Locomotive I

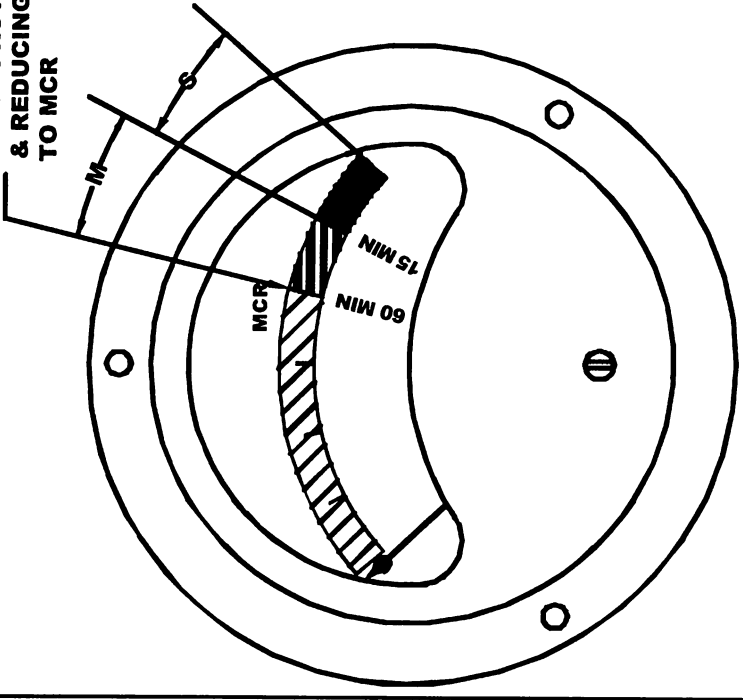


### Cumulative Time Indication (CTI)



CTI Legend

P = TOTAL TIME, IN MINUTES,  
TMPP "PROTECTING TRACTION MOTORS"  
& REDUCING TRACTION MOTOR CURRENT  
TO MCR



## V. "LOCOMOTIVE AUXILIARY POWER UNITS" LESSONS LEARNED

*Presented by Lawrence J. Biess,  
CSX Transportation*

### Introduction

Locomotives typically idle 40-60% of the time that the main engine is in operation. Depending on total main engine runtime, idle hours per day can be anywhere from eight to twelve hours, on average. Operating policies, automatic start/shutdown devices, and layover systems have all been developed to reduce main engine idling. Each of these solutions can have the effect of reducing idle time to some degree. Unfortunately, each of these solutions can have the effect of increasing wear on main engine starting system components or otherwise reducing locomotive reliability. None of the solutions provide for a comprehensive year-round solution.

Choosing the best solution then becomes one of economics: Is it less costly to replace starters, batteries, deal with line of road failures caused by repeated shutdowns and restarts, system failures, and operator error? Or is one better off incurring the direct (fuel and wear) and social costs (emissions and noise) inherent in a fleet of locomotives that never shutdown? All too often railroads have chosen the latter solution.

Three years ago CSX Transportation began asking a different set of questions. What if a

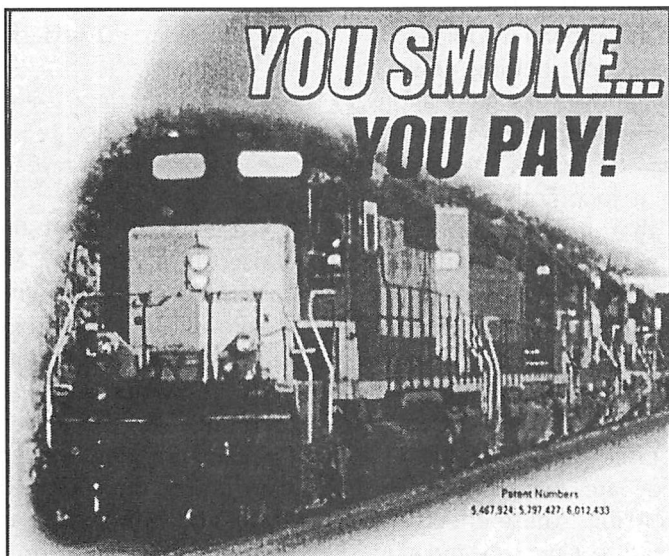
device could be designed to address all of the reasons why a locomotive engine idles? What if a companion engine of suitable size was installed on a locomotive with sufficient automation to eliminate or greatly reduce locomotive idle time? What if the main engine was only started and operated to move the locomotive? What would the economic picture look like then?

In November of 1999 CSX Transportation's Cumberland Locomotive Shop modified and assigned a GP38-2, CSXT 2629, into captive switching service. Equipped with an automated 17kva auxiliary power unit, or APU, and a variety of 120vac and 240vac appliances the locomotive would be subjected to winter and summer operations to determine system efficacy and the feasibility of changing 40+ years of operating and maintenance habits. Other issues relating to United States Environmental Protection Agency (USEPA) emission compliance and credit trading would also be explored.

In this paper we will review the results of the 2629 field test. We will also address issues relating to prototype product evolution, prototype crew feedback, cultural changes, and acceptance (or lack thereof) relating to the new operating paradigm.

### Reasons for Idling

All railroads are familiar with the reasons for main engine idling: freeze protection, battery charge, crew comfort, and break pipe leak-



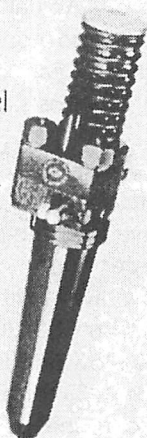
Patent Numbers  
5,467,924; 5,797,427; 6,012,433

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age. However, the most significant but less obvious set of reasons for idling may be cultural: fear of restart, ownership and accountability, the real and perceived financial insignificance of shutting down a single unit, and several generations of ingrained operating habits. Moreover, if you ask crews why they idle a locomotive, they will respond that it is because they want to "get in and go" and when they are idling they are maintaining crew comfort appliances, locomotive air, and they have a main engine that is ready to load.

### Effects of Idling

Railroads are familiar with the effects of idling. These effects can be divided in social costs and actual costs. Social costs are noise and air pollution. Actual costs are more tangible and consist of fuel costs, engine wear costs, and engine reliability costs.

### Fuel, Road units:

Assumptions:

- Locomotive fuel rate at idle = 4 gallons per hour
- Locomotive availability = 95% (based on CSX/GE Computer Downloads)
- Idle time = 42% (based on CSX study of road units).
- Idle reduction opportunity = 80% (a conservative estimate).

So fuel savings, per year, assuming 80% of the existing idle is eliminated comes to:

- 4 gallons/hour x 24 hours/day x .95 x .42 x .8 x 365 days/year

= 11,185 gallons/year.

### Fuel, Switch Engines:

Assumptions:

Same set, assume 58% idle (CSX/Chessie derived duty cycle for switchers);

- 4 gallons/hour x 24 hours/day x .95 x .58 x .8 x 365 days/year = 15,446 gallons a year.

We feel that these estimates are conservative for a variety of reasons. One might reason that there is zero idle reduction opportunity in the summer, especially for road units. CSX studied 763 GE road locomotives equipped with Pinpoint tracking systems for 6 days during the month of August 2000. CSX discovered that these locomotives idled, on average, 9.78 hours per day. One might argue that fuel rate at idle is less than 4 gallons per hour. Indeed, on some EFI engines fuel rate may approach 3-3.5 gallons per hour at low idle. However, engines do not remain at low idle during all periods of idle. Fuel rate rises 150% for each notch increase with the generator unloaded. (Figure 1)

### Engine wear costs:

Determining engine wear costs or otherwise quantifying "wear and tear" has been problematic. If one were to tie fuel rate directly to wear rate, then the engine wear savings associated with the idle reductions we assume represent single digit percentages.

Intuitively, one cannot reasonably tie engine wear directly to the fuel rate. The locomotive engine

and associated support systems are all designed to operate to deliver maximum horsepower. At idle, are the lube oil, fuel, cooling, and air intake systems operating at peak efficiency? Since speed of lube oil and water pumps are tied directly to crankshaft speed, it would seem that fluid system operation at anything less than notch 8 is a compromise.

Is engine wear directly proportional to fuel rate? Probably not. Is engine wear at idle the same as engine wear at notch 8? Probably not. Engine wear at idle may be a function of fuel rate and a weighting factor for each notch in the duty cycle.

CSX has asked The Department of Energy (DOE) at Argonne National Labs, the American Trucking Association, and engine manufacturers for engine wear characteristics at idle. Unfortunately, hard data for locomotive engine wear at idle does not exist. Instead, each of these sources uses heuristics (such as run hours, MWhrs, condition monitoring, load testing) to determine estimated engine wear and overhaul cycles. To date, the only heuristics available on the subject of idle reduction come from a TMC study RP1108 dated 3/95. Using the assumptions in this study and applying them to a 3600hp engine we calculate the following cost savings due to idle reduction:

#### ***Idle fuel cost per day***

For a truck engine, the savings is 6 dollars per day.

For a locomotive, the savings for fuel is:

4 gallons per hour x 10 hours per day x \$1.00/gallon = 40 dollars per day, or 14,600 dollars/year.

#### ***Idling preventive maintenance cost per day***

For a truck engine, the savings is 0.72 cents per day.

If we use ratio and proportion, and base this on the idle fuel reduction, then:

$40/6=x/0.72$ ,  $x=6.6667 \times 0.72 = 4.80$  a day, or 1,752 dollars a year.

#### ***Idle overhaul cost per day***

For a truck engine, the savings are based on a 5,000 dollar overhaul at 500,000 miles. The estimate for savings is tied to the idle reduction of 6 dollars per day. The reduction due to idling comes to \$0.41 cents per day.

Once again, if we use a simple ratio and proportion on the idle fuel savings, we get:

$40/6=x/0.41$ ,  $x=6.6667 \times 0.41 = 2.73$  a day, or 996 dollars a year.

To get a clearer understanding of the effects of idling on locomotive engines, CSX ran a 645E roots blown engine at idle for 16 days during mild winter conditions (32 degrees F to 60 degrees F). During this period of time, lube oil consumption, lube oil chemistry (TBN, Iron, Barium, Boron), and stack emissions were monitored. An independent lab performed the tests and monitored ambient temperature, crankshaft temperature, oil temperature, and water temper-

ature. No appreciable engine wear was evidenced by constant iron for the period. However, lube oil consumption and TBN were both effected by the idle period. Based on the test, about 1/3 of lube oil alkalinity will be lost over the course of a year assuming 30-50% idle duty cycle. The engine consumed 20 gallons of lube oil, or about .05 gallons per hour. The souped liquids from the exhaust stack were analyzed and determined to be 80% lube oil.

Based on these numbers, and the switcher engine idle assumptions used to calculate fuel savings, lube oil savings for the course of a year as a result of idle reduction are estimated to be:

.05 gallons/hour x 24 hours/day x .95 x .58 x .8 x 365 days/year = 193 gallons per year.

This is a significant number, especially when one considers that the majority of this oil is deposited on the car body and right of way, contaminating our environment. When one multiplies this volume by the number of locomotives in a fleet the true magnitude of this loss come to light. Although enlightening, long-term studies are required to determine true wear and the associated costs of all locomotive systems at idle.

### ***Locomotive reliability issues as a result of idling***

Locomotive maintenance and reliability issues which are either aggravated by or directly caused by extended idling include oil out of the stack, intake port deposits

(GE), dead or drained batteries, brush wear, frozen toilets, and wear on the air compressor and other ancillary systems. If a locomotive engine fails during cold weather, the engine must be drained of coolant to avoid freeze damage. These problems are further aggravated by the fact that at low idle, many locomotives have so many 74vdc loads that the auxiliary generators are not capable of maintaining locomotive battery charge. If a locomotive is shut-down and restarted on batteries that are low on charge, starting motor current will rise, raising motor temperatures and stressing windings. Often engine idle speed is increased manually or using automatic engine control systems to maintain battery state, all at the expense of fuel burn at idle.

### **Locomotive reliability issues: The 74vdc locomotive supply industry**

Locomotive electrical appliances for hotel use are typically powered off of the 74vdc system (auxiliary generator) or the companion alternator. In either case, the equipment that is designed to operate on these power supplies is expensive and their reliability can be compromised if 74 volt direct current inverters are used to convert auxiliary generator output to a more usable alternating current. And, if these units are run for crew comfort, idle time is increased, along with fuel rate at idle.

## The APU:

### A new locomotive system

A CSX Mechanical Systems Engineer examined each of these issues and interviewed a captive crew that operates a switch engine at a remote classification yard in order to develop a list of design constraints. The crew provided the Engineer with the following feedback:

- They would support forced shutdowns, but wanted a method to over-ride if operating.
  - Prior to a shutdown, they wanted a warning, both audible and visual, so that they could actuate the over-ride.
  - Alarm over-ride must be via the alertor reset button—they wanted a “one-button silences all interface.”
  - Since this was a yard unit, they felt they did not need shutdown air.
  - If the main engine shut down, it had to restart reliably.
  - If the unit shutdown while they were in it, they would accept the shutdown if crew comfort and a radio was maintained.
  - They wanted an air conditioner.
  - If the unit shutdown, they would restart from the engine start station.
  - If idle time was to be clocked, they wanted 30 minutes. Anything shorter was thought to be a nuisance.
  - They liked the idea of a locomotive that was shutdown, unless used in switching.
  - They wanted a simple interface with the system.
- They did not want to be bothered with any maintenance of the system.
  - They did not want to operate by a different set of operating rules.
  - They would respond to a system malfunction, but it had to be seen and heard from outside of the cab.
  - The crew felt that starting the APU for crew comfort was acceptable, however APU start for locomotive system maintenance (freeze protection) should be automatic.

CSX Mechanical Engineering and with their partner; (International Road and Rail), examined these crew constraints and developed the following design criteria:

- The system would provide adequate auxiliary power to allow it to be used as a platform that could be leveraged for a variety of uses, including air conditioning, air compressors, and other hotel loads. The more power available, the more flexible the system.
- The auxiliary diesel engine would start and shutdown automatically, in response to any number of inputs, including locomotive coolant temperature, locomotive air pressure, operator request, and periodic forced runs for 12 volt system health.
- A main engine shutdown timer would shut the main engine down after a period of idle.
- The idle timer would warn crew of an impending shutdown, and that alertor reset button would

be used to silence the alarm and reset the time to extend main engine idle.

- Locomotive battery load shed would automatically isolate the locomotive battery from all loads, except the radio, following a forced shutdown.
- The auxiliary engine must be able to provide maximum output with the main engine operating at peak horsepower.
- The auxiliary power unit electrical distribution system would be equipped with relay logic to prevent operating air conditioners and heaters simultaneously, and priority would be given to air pressure, then locomotive coolant water temperature, then crew comfort appliances.
- It had to be rugged, extremely reliable, low maintenance, and suited for the locomotive operating environment.

The prototype system was built and consists of the following:

- Standby power unit that delivers 16kva of 240/120vac single-phase power.
- Engine is a four-cylinder Kubota, rated at 56 peak continuous horsepower, producing 27 horsepower at 16kva and 1800 rpm.
- A locomotive oil and water recirculating system that automatically maintains locomotive water and oil at a suitable temperature during shutdown periods.
- An engine control unit that automatically starts and shuts down the generator set for either low

water temperature or upon operator request with the capability of starting on air or low battery voltage.

- A 240vac air conditioner, 240vac heaters, and 120volt outlets in the cab.
- 120volt interior and exterior lighting.
- A simple cab-mounted toggle switch for APU start and stop with a power indicating light for crew directed starts and stops of the APU.
- A shutdown timer mounted to the control stand that flashes and beeps 25 minutes prior to a shutdown.
- Shutdown over-ride tied into the alertor reset switch that, once pressed, silences the alarm and extends the idle 30 minutes.
- 74volt lighting load shed that drops 74volt lighting 2 minutes after a shutdown.
- A battery charger (240vac/74vdc) that charges the locomotive batteries whenever the APU is running.
- An exterior strobe alarm with siren tied to the ECU alarm panel.

The prototype system was installed on CSXT 2629 at the Cumberland Locomotive Shop in Western Maryland. Since this locomotive was in captive service, and since it would be serviced at the installing shop, a set of drawings and instructions were drawn up and given to the technical director at this shop. Once again, the cognizant Mechanical Systems

Engineer would be called in the event that the locomotive was in-shopped for an APU-related failure. Following installation and shop testing, the locomotive was delivered to the captive crewmembers that were each trained on how the new unit worked, and were given the following instructions:

- Operate the locomotive no differently from the current operating rules. However, they were told that the system would shut the locomotive down automatically, and that if the locomotive was abandoned it must be secured by applying hand-brakes and applying the independent brake, once again in accordance with the operating rules.
- The crew was invited to shut the locomotive down consistent with the CSX fuel conservation policy, which is to keep the unit idling if the temperature is expected to drop to less than 40 degrees F.
- The crew was given a demonstration of the air conditioner operation, and was told that as long as the system remained on line (the crew did not turn the APU off by pressing the emergency shutdown or disable the shutdown timer) that the air conditioner would work on demand.
- The purpose of the external alarm was explained, and the crew was asked to secure the alarm by pressing the APU emergency shutdown button and told to contact a cognizant CSX Mechanical Systems Engineer if

they ever had to take this corrective action.

- Decals explaining all of the operating characteristics, with instructions and phone numbers, were applied to the locomotive.

By the time the design parameters were met and the system was released into service, CSX had the project evaluated to determine if it was sufficiently unique to warrant a patent. This query has resulted in the award of multiple national and international patents.

### **CSXT 2629 today**

The prototype APU and air conditioner were inspected August 15 of this year and are still functioning exactly as they were originally installed. 2629 performance to date:

- 1,500 hours of run time.
- Lowest recorded ambient temperature: -5 degrees F.
- Maintained coolant temperature during this ambient: 80 degrees F.
- Maintained lube oil temperature during this ambient: 50 degrees F.
- Cycle time during this ambient: one hour on, one hour off.
- Estimated 14,000 gallons fuel savings each year.
- Air conditioner was repaired for a refrigerant leak 33 months ago, and for a bad contact 20 months ago. Since this last repair the unit has functioned without incident.
- APU has been shopped for hose breaks, broken mounting bolts,

low lube oil shutdowns, and oil and water leaks from the heater tank.

- The APU oil and water filter have been replaced once - no other maintenance has been performed.

The crew was recently interviewed about the performance of the APU and operating issues with the new system, and they state that they like the new system:

- The crew does not use the interior or exterior lighting.
- The crew does use the 120vac outlet in the cab.
- The crew enjoys the air conditioning, and quickly notifies Mechanical forces if the APU malfunctions because of loss of air conditioning.
- The crew shuts the locomotive down manually during warm months. The engine shutdown timer shuts the locomotive down automatically during cold months when crew leaves it idling.
- The crew has accepted the shutdown timer and reset.
- The crew does not take issue with restarting the locomotive if it is left unattended so long as they have a method for preventing a shutdown while it is attended.
- Although reluctant to allow the locomotive to shutdown during the coldest winter nights, they have gotten confident in the ability of the APU to maintain locomotive battery charge and system temperatures to provide

a reliable main engine start.

The most significant issue that the new system faced was the periodic introduction of a new crewmember. Inevitably, these workers learned through trial and error (and from more senior crewmembers) how the system behaved. Familiarity and training would be a recurring issue during the subsequent CSX rollout.

#### **Effects of idle reduction: fuel and emmissions**

On the prototype unit, idle hour reductions of 8 hours a day during winter operations were observed. The cyclical use of the unit by a three-shift crew operating seven days a week meant that the 8 hours of daily savings occurred on a locomotive that had high utilization. Furthermore the main engine seldom had a chance to cool down enough during the 2-3 hour period of time between shifts for the APU to start on low cooling water temperature. Based on our observations the change in idle duty cycle on this unit resulted in an annual fuel savings of close to 15,000 gallons.

At first, reductions on NOx were calculated by multiplying the NOx emission rate at idle by the total number of hours that the unit was shut down. Using this method, CSX determined that the APU reduced NOx emissions by nearly two tons over the course of a year.

Following the winter test, the locomotive and APU were sent to an independent emission laborato-

ry to absolutely quantify the APU emissions under a variety of loads and the main engine under each notch.

Using some very conservative idle hour reductions, and making adjustments to the EMD fuel delivery system, CSX has been able to convey the APU emission reductions listed in Figure 2 into a proven emission reduction strategy. To date CSX has obtained EPA approval of the APU as an emission reduction strategy that meets tier 0 compliance on 8 classes of EMD engines. Instead of buying OEM emission kits, suffering a fuel/horsepower penalty, and being forced to periodically purchase OEM specified fuel injectors, CSX has begun to apply APUs and main engine equipment at a competitive price, all without incurring the fuel penalty and recurring component replacement prices associated with OEM kits. In the process, CSX will reduce other costs associated with main engine idling, and enjoy the electrical appliance flexibility that the APU affords.

### **Secondary benefits**

In order to fully explore the potential of the APU, 2629 was equipped with 120 and 240vac distribution systems that powered 120vac lights in the engine room, 120vac motion-sensitive floodlights on the #1 and #2 end, weather tight 120vac outlets, 120vac motion sensitive florescent lighting for the cab and toilet compartment, thermostatically con-

trolled cab and toilet compartment heaters, and a 240vac 36,000btu rooftop cab air conditioner unit. During the winter, the APU switch lineup is made to permit automatic cab heat and engine heat. During the summer, the APU switch lineup is made to permit manual cab control of the APU for air conditioner operation.

The presence of the APU allows for the purchase and installation of these devices at a low cost without having to endure the design, manufacture, test, and rent-seeking supplier behavior cycle inherent to the 74vdc locomotive appliance industry. Marine-grade or penalinstitute grade Underwriter-Laboratory listed appliances with factory warranties that are manufactured by the thousands mean that purchases can be made from Grainger or a local hardware stores and installed in short order. In the simple case of air conditioning, rooftop or under roof air conditioners can be installed for a fraction of the cost of self-invented units. In addition to the purchase savings, cost associated with auxiliary generator upgrades (which may be required on older locomotives) are avoided.

The presence of such devices does require that the APU be operated in order to provide for their power. On the other hand, the presence of the APU means that the main engine does not need to idle in order to provide for crew comfort and convenience.

### Barriers and unanswered questions

The APU is an exciting new locomotive operating system that has many potential benefits. However, the barriers to successfully implementing the new system and changing 40+ years of railroad operating practice are great.

### Operating constraints

The original manifestation of the CSX project worked using the constraints that were given by an industrial switching crew. Broader use of the product on line-haul, especially idling main-line trains, requires a more conservative set of constraints. Issues such as lead and trail headlights, train line air, and maintenance of radio and head of train device power become priorities. Line-haul consists that idle on the main line need to move as soon as a crew boards. Therefore, it may be necessary to forego maximizing idle time reductions in order to permit "get in and go" operating requirements of the crew.

### Air

Air requirements vary depending upon the operating rules of the respective railroad. Most of the main engine start/stop systems maintain pressure in the #2 reservoir between 110 and 130psi all the time. For an EMD that leaks, or has spitters, this can mean repetitive starting and stopping and unnecessary idling of light locomotives for air. At CSX the need for air was examined based on the

root cause for the need.

The following rules are in effect for an idling locomotive that is left unattended:

- Full service application (brake pipe at 64psi).
- Apply all handbrakes (or chalk chains) to the locomotive in the consist, and 10% of the cars, or at least one car, whichever is greater.

So, if air is left to bleed off an idling train, the train is secure. However, train crews want to "get in and go." If a train is left off of air for too long, the on-coming crew will need to walk the train to perform the terminal brake test. The FRA power brake rule states that:

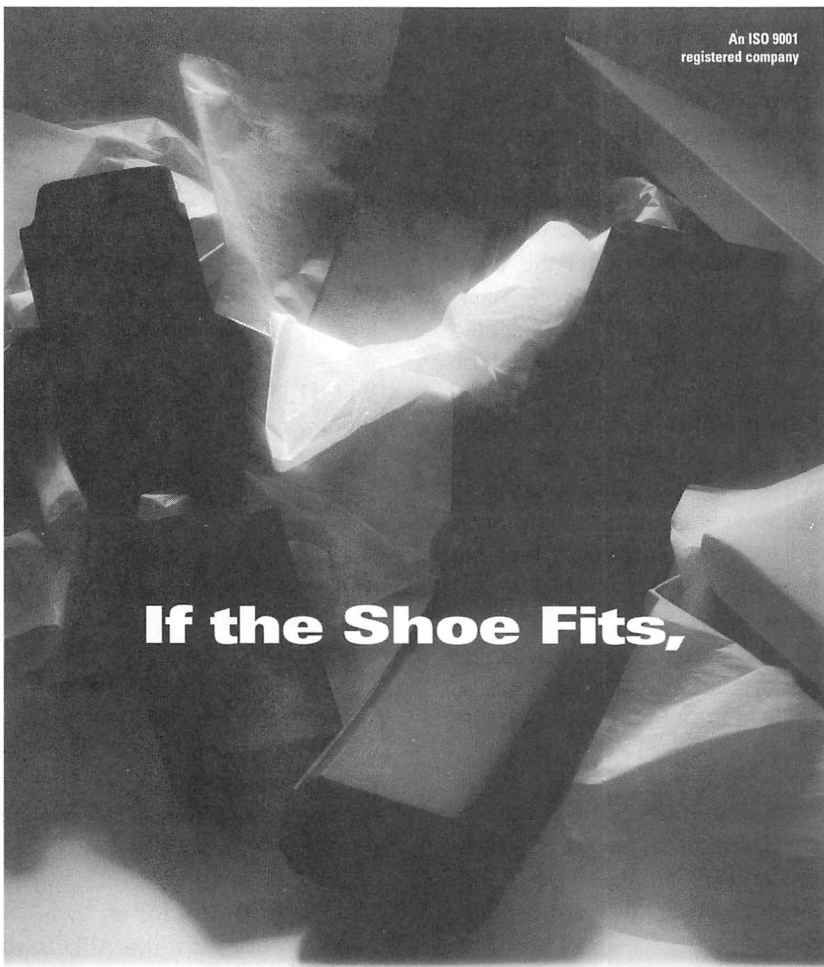
- A train is "on air" if the end of train pressure is 60psi or greater.
- A train does not need a terminal brake test as long as it is on air.
- If end of train pressure drops to less than 60psi, a terminal brake test is not needed unless air pressure is less than 60psi for more than four hours.

Why do the crews want air?

- To avoid performing a terminal brake test on the line of road.
- "Get in and go."

How much air is needed to maintain the train line for an unattended train when brake pipe is 64psi? To answer this question, Wabtec was consulted and data provided (Figure 3).

Based on this data, we see that a train, 100 - 50ft. cars, with a 5lb/minute leak rate at 90psi, con-



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sumes 20 standard cubic feet per minute (SCFM) of air at 64psi brake pipe.

Then the air question becomes one of air compressor capacity, and whether or not an air compressor of sufficient size can be powered by the auxiliary power unit. In order to answer this question, we decided to work backwards, that is to say, we selected an air compressor that could be reliably powered by the APU and did the math to see if it would supply at least 20 SCFM of air.

We selected an oil-free air two-horsepower compressor, that is rated to deliver 10 cubic feet per minute at 100psig.

Step 1: convert the trainline requirement to cubic meters at standard temperature and pressure (STP):

Air requirement = 20 SCFM  
1 cubic meter of air at 1 atmosphere and 32 degrees F = 37.326 cubic feet of air at 1 atmosphere and 60 degrees F.

Converting the air requirement from SCFM to cubic meters at STP yields:  
 $20\text{SCF}/37.326\text{SCF}/\text{cubic meters at STP}=0.536$  cubic meters at STP.

Step 2: convert the air compressor rating to cubic meters at STP:

Air supply=10cfm at 100psig  
Converting to STP, we will use the universal gas law, and the following inputs:

10 cubic feet=283.1685 liters  
140 degree outlet temperature-  
333.15 degrees K  
114.7psia=7.805 atmospheres  
0 degrees C=273.15 degrees K

$$P1V1/T1=P2V2/T2$$

$$(7.805 \text{ atm}) \times (283.1685 \text{ liters})/333.15 \text{ degrees K}=(1\text{atm}) \times (Y \text{ liters})/273.15 \text{ degrees K}$$

$Y=1,812.1$  liters, or 1.812 cubic meters at STP.

Step 3: Compare to two values:

Air requirement=0.536 cubic meters at STP/minute.

Air compressor product=1.812 cubic meters at STP.

Therefore, we conclude that the air compressor we have selected produces three times the air required for a train at 64psi brake pipe.

**Control for air**

We do not want the APU to run for air to run except when a train is parked in accordance with our operating rules. Therefore the APU air system on CSX locomotives is set up so that when brake pipe is between 60 and 75psi, the air compressor charges the #2 reservoir to maintain pressure between 105psi and 120psi. If brake pipe is above 75psi the system "sees" that the brakes are released and air is no longer required. If brake pipe is below 60psi, the APU "sees" a light loco-

motive and will not run for air.

This algorithm works for CSX, but other roads have different operating rules. The economics of air and individual algorithms will need to be developed to suit the needs of other roads.

### **Culture**

In order for a successful implementation of the APU to occur there must be an explanation, training, acceptance, and clear expectations provided to the crews that operate locomotives with these new systems. Locomotive operators must each get some experience operating without idling.

The crew that operates the 2629 was asked to participate in the initial design (active voice), they were given operating instructions, and the concept and predicted benefits of the new system were fully explained to them. When the crew shut the locomotive down for the first winter night, they did so with some reluctance. However, following the first overnight shut-down, the crew started the locomotive without any difficulty or hesitation. As the crew spent more time with the locomotive, they became so comfortable with the new unit that they began to ask when other locomotives would be similarly equipped.

### **Alignment**

In order for the APU to succeed, each of the stakeholders within each railroad must have goals and metrics that are in alignment. If the

goal of management is to reduce idling to save fuel and reduce maintenance costs, and the goal of the operating crew is to "get in and go" will the fuel and maintenance reductions be foiled by crewmembers who disable a system because they feel that an idling unit is a good unit? If Transportation owns the fuel budget, but has no interest in the operation and maintenance of the APU outside of the fuel savings, will Transportation consider the erosion of budgeted fuel savings a problem that is the domain of Mechanical? In order for alignment of objectives to occur, every department with an interest in the APU must work in concert with each other.

### **Incentives**

How can the APU be protected then if so many stakeholders have so many differing objectives? Incentives, such as fuel savings and emission compliance and credits, which should be shared across operating groups, will go a long way towards minimizing the discomfort and inconvenience of installing the APU and changing operating practices. Public relations affects from reduced idling will also provide an incentive for using the new system.

The most critical stakeholder is the locomotive operator. On the 2629 total acceptance of the system came when an air conditioner was mounted on the cab roof and a 120vac outlet was placed in the cab. Once the operators understood that the air conditioner and

outlet only functioned when the APU functioned and main engine shutdown system functioned, they became keenly interested in proper operation of the APU.

### **CSX approach on latest generation APUs**

CSX is currently installing APUs on its entire EMD fleet. These units are equipped with supplemental APU driven air compressors, main engine shutdown timers, load shedding devices, and a central processing unit that controls both APU and main engine start/stop parameters for pressure, temperature, and battery charge. The system also records and processes information for locomotive health and fuel saving reports.

Each of these locomotives is equipped with a thermal drain valve (in the event of a full system failure and no operator action) and a tie in for wireless communications. A variety of communication solutions are being evaluated, with the goal of being able to record when/if an APU alarms or is manually disabled or if the locomotive experiences a steady or transient failure.

These APUs are built with "hooks" that allow them to be started remotely from the cab, that are timer operated, and that possess logic that prevents overloading of the APU electrical system. CSX is in the process of installing APU-driven cab heating systems and air conditioners that will be evaluated for fleet use.

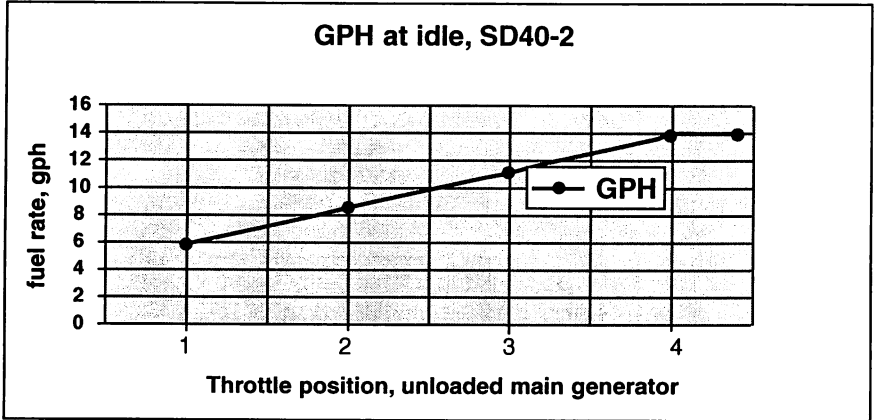
### **Conclusion**

CSX's prototype APU verified system efficacy, was found to reduce fuel consumption and emissions, and was successfully accepted by a captive crew. There are several patents pending on the new system. It has also piqued the interest of the DOE, the USEPA, independent research labs and other potential vendors. In response to the positive performance and economic impact of the new devices, CSX Transportation will install approximately 800 units by year's end.

The key lesson learned in the evolution of the APU is that all departments within the railroad must be involved with establishing the operating constraints. Perhaps the most important group to be consulted is the end users, the operating crews, who must be given an active voice in the development of the device, and they must be given an incentive to use it. Without their cooperation and involvement, the APU will not deliver the savings that are promised.

**Figure 1**

Source: The Railway Fuel and Operating Association, Chicago, 1974



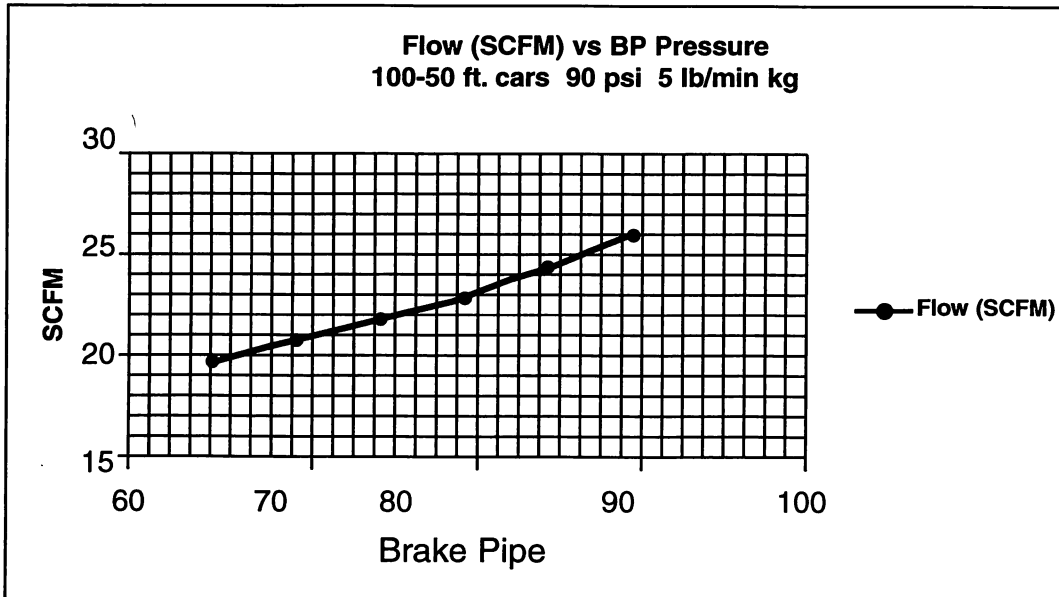
**Figure 2**

Data source: CSX/SWRI Test Data

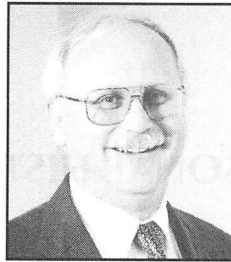
|              | SD40-2 | APU |
|--------------|--------|-----|
| Fuel, lbs/hr | 23     | 4.8 |
|              | SD40-2 | APU |
| Nox, gms/hr  | 605    | 53  |
|              | SD40-2 | APU |
| HC, gms/hr   | 76     | 4.3 |
|              | SD40-2 | APU |
| CO, gms/hr   | 150    | 6.1 |
|              | SD40-2 | APU |
| PM, gms/hr   | 16.4   | 2.6 |

# Figure 3

Source: Wabtec  
Railway Electronics



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MONDAY, SEPTEMBER 23, 2002  
2:45 P.M.**



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| D. Rutkowski  | Chief Mech. Officer             | Providence &<br>Worcester RR    | Worcester, MA    |
| T. Stewart    | Mech. Systems Engr.             | CSX Transportation              | Jacksonville, FL |
| D. Taylor     | Mgr.-Customer Support           | GE Transportation<br>Systems    | Erie, PA         |

New Committee Members: David Miller, Union Pacific RR; Joe Smrz, Turbine Specialties, Inc.; George King III, St. Lawrence & Atlantic RR.

## PERSONAL HISTORY

### *Dennis L. Nott*

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

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

Currently, Dennis is Vice President of Sales and Marketing at MotivePower, Inc., a Wabtec Company. In addition to his

responsibilities for all locomotive sales and marketing at MotivePower, he is responsible for all locomotive contract maintenance and the service/warranty department.

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

Dennis and his wife Sarah have been married for 28 years and they reside in Boise, Idaho, with their two children Maggie, 17, and Adam, 14.

**THE LMOA DIESEL MECHANICAL  
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**Wishes to express their sincere gratitude  
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Committee meetings in  
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**Providence & Worcester Railroad  
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Worcester, MA  
November 3, 2001**

**Young Touchstone  
A Wabtec Company  
Jackson, TN  
May 17, 2002**

## I. DETRIMENTAL EFFECTS OF LOCOMOTIVE ENGINE IDLING

*Prepared by  
Ted Stewart,  
CSX Transportation*

### Introduction

The purpose of this paper is to further expound on the negative effects of long term locomotive engine idling. This subject was first presented by Mr. Larry Biess at the 2001 LMOA conference with a paper entitled: Locomotive Auxiliary Power Units: A locomotive system innovation that makes dollars and sense. In his paper, Mr. Biess provided the fundamental reasons why locomotive diesel engines are currently allowed to idle. He explained the problems and costs that are associated with this activity and then proposed an alternate solution for which the main locomotive engine is shut down and an auxiliary gen-set power unit is used. This paper will provide additional information and data as to why diesel engines should instead be shut down and not allowed to idle for prolonged time periods.

The "IDLE" parameter of a diesel engine is a necessary speed and load setting that allows the engine to just maintain an operating condition that keeps it ready for use. The engine speed is generally set at a minimum point that still allows for smooth running operation while providing the auxiliary loads necessary in the existing conditions.

It has been generally well accepted that most diesel engines should be idled for several reasons. The

main reasons, were that, compared to gasoline engines, diesel engines were much harder to start in cold ambient conditions; diesel fuel was significantly less expensive than gasoline and the exhaust production of carbon monoxide, CO, was not the serious health hazard it is with gasoline engines. It is also generally well accepted, that the larger the diesel engine becomes, the harder it can become to start. Therefore, the truck stops along the Interstates and many of the locomotive switching terminals are filled with engines that are rarely, if ever, shut down.

There are other important reasons why locomotive engines were allowed to run, which were discussed last year in Mr. Biess's paper. These reasons are freeze protection, battery charge, heating and air conditioning, (HVAC), and train line air pressure.

The railroad industry in the past generally did not use an anti-freeze solution in the locomotive's cooling system. Primarily, this was because of the cost, both for the anti-freeze and the consequential damage due to leaks. Locomotive cooling system capacities are usually 200-400 gallons, depending of course on the size of the engine. Past engine designs were plagued with sealing arrangements that leaked, both externally and internally. The internal water leaks then contaminated the engine's lube oil, which if severe and allowed to persist, could then lead to crankshaft bearing damage and consequential catastrophic engine failures.

If anti-freeze, such as ethylene

glycol, contaminated the lube oil due to leaks, the highly viscous fluid that resulted in the chemical reaction between the anti-freeze and the lube oil's additive package would very likely plug the lube oil filters, resulting in a low-oil pressure shut-down. Again consequential damage would occur if the filter housing relief valve opened in the by-pass condition allowing unfiltered oil into the bearings and pistons. Most railroads instead use a more compatible water treatment solution or rust inhibitor that can act as a trace element in the lube oil analysis, if and when there are internal water leaks. If the locomotive is shut down during cold weather conditions, the engine is protected by "dumping" the water, to keep the coolant system from freezing and damaging the engine and the associated piping.

Locomotive engines are also allowed to idle to maintain the electrical system's battery charge. If the engine had been previously shut down and now has to be restarted for any reason, the current 74v system needs to be as fully charged as possible. Fully charged batteries with good reliable starters help provide enough starting torque to turn the engine fast enough to build cylinder compression pressure, which is required to ignite the diesel fuel. To make matters worse, there is an inherent problem with older power assemblies on EMD engines. The exhaust valve seats can warp over time, which prevents the build-up of the required compression pressure, thus adding another reason for allowing the engine to run

continuously.

Cab comfort is another important factor for allowing the diesel engine to operate. Both heating and cooling systems, when in operation during their respective seasons, require high electrical loads for heaters, refrigerators and air conditioners. Locomotives parked at a siding waiting for track clearance, should have the necessary heating or cooling system to provide satisfactory operating conditions for the crew.

And the last important factor for idling is maintaining the train line air pressure in order to avoid the departure test. If the locomotive is shut down and the main air pressure is lost, there are many locations where trains are stopped for one reason or another, in which the safety of a crew member might be in question, if a departure test must be performed. The locomotives are thus allowed to run to maintain the train's air pressure, so that when the clearance is provided, the train can safely and legally proceed with operation, without any of the crew members leaving the cab.

The previous points presented in favor of keeping the engine running are valid reasons why idle is an important operating feature. However, the purpose of this paper is to expand on why the idling condition is detrimental to the engine's performance and overall durability.

There are four major detrimental cost factors that must be considered in the study of diesel engine idling. They are; fuel consumption, lube oil consumption, component wear and

noise. These four parameters added together can produce a major impact on the operator's bottom line.

Fuel consumption at idle is significant, not so much because of the rate of consumption, but because of the sheer amount of time most locomotives spend in idle. The following table presents actual test data collected at Southwest Research Institute's Locomotive Test facility. A follow-up example illustrates the fuel savings based on the amount of idle time and this fuel usage.

The EPA's locomotive emission regulations published expected industry idle duty cycle percentages of 59.8% for switchers and 38.0% for line haul units. A calculation using these EPA idle duty cycles, based on the following assumptions, (\$0.80/gallon and 75% idle shut-down), provides the estimated fuel savings of \$10,058 per year per switcher locomotive and \$11,944 per year per line haul unit, (using the average fuel rate for the respective models in Table 1).

Another fuel cost, although hidden, is associated with idling, and it directly leads into the next two major idling costs: lube oil consumption and wear. Due to the lower operating temperatures normally seen at the idle notch condition and because the fuel is being inefficiently burned, considerably more soot, (carbonaceous by-products of combustion), is formed. On locomotive engines, this soot deposits itself in the engine lube oil, the exhaust manifold and the intake air chamber. Without proper routine

cleaning, air box fires can occur on EMD engines, in which these soot deposits finally ignite in both the intake and the exhaust passages, and can result in turbocharger over-speed/overheat catastrophic failures. Also during this condition, the sulfur released from the diesel fuel during the process of combustion begins to react with the condensed water vapor from the intake air on the combustion chamber's piston crown, rings and cylinder walls. The resultant sulfuric acid fumes corrosively attack the exposed surfaces of the combustion chamber. These hot acidic combustion blow-by gases that are also pushed passed the rings into the crankcase, react with, contaminate and deteriorate the engine's lube oil.

All diesel engines are designed with a unique piston ring and liner structural relationship which must be carefully preserved in order to maintain the correct performance and oil consumption. The piston rings have two main purposes: one, to seal off the combustion firing pressure to maximize the power being generated by the burning fuel, (compression rings), and two, to minimize the consumption of engine lube oil being supplied for piston/ring/liner lubrication, (oil scraper ring). The cylinder liner walls have three purposes. The first is to provide a round bore surface that can be readily sealed by the compression rings. The second is to provide the same round bore in which the oil scraper ring can maximize the excess oil being returned to the sump and prevent it from getting past the compression rings into the

combustion chamber. The third function is to provide lubrication for the compression rings to reduce the sliding friction wear component on both the rings and liner. The soot and sulfuric acid compounds produced at idle attack all of these areas detrimentally.

When diesel engines idle, the cylinder firing pressures being generated are considerably reduced and therefore there is a less pressure to help push the compression rings out against the liner wall surfaces. Also at idle, the operating combustion temperatures are reduced, thus increasing the amount of soot, which then begins to find its way into and deposit itself in the cylinder wall crevices, displacing the necessary oil pockets. This is especially critical at the top ring's reversal region, which leads to increased ring wear. The soot also forms hard deposits inside the ring grooves, thus leading to stuck rings. The sulfuric acid compounds as discussed earlier are also being deposited on all of the combustion chamber surfaces, leading to increased chemical corrosion. And because of the reduction in combustion pressures, both contaminants find their way past the rings into the lube oil which carries them to the other critical wear components, such as bearings, to continue the attack.

Lube oil consumption at idle is affected in two ways; one obvious and the other that must be measured. The first detrimental effect is the condition known as, "souping, oil-out-the stack, etc.", which is the more obvious condition. As stated

above, the ring pressure against the cylinder liner walls is greatly reduced, the combustion temperatures are significantly lower and the cylinder walls themselves are significantly cooler and potentially less round. All of these conditions have a pronounced detrimental effect on the piston ring/liner system in that it begins pumping the oil up and out instead of pushing it back down. Both locomotive engine designs, two and four stroke, can have this condition. The second "somewhat hidden" cost is the effect that these contaminants have on the life of the lube oil. All combustion by-products that get past the rings into the lube oil cause dramatic changes in the oil and to the engine if allowed to exist for long periods of time. If the current railroad lube oil's additive package is broken down into components, one can see that each component is specially added to help reduce the detrimental effect on the critical wear components as well as provide for long oil life. The two oil package components that are vitally important to engine idling, are the dispersant and the total base number, TBN.

The dispersant component's purpose is to find and surround each and every soot particle that finds its way into the lube oil and keep it from attaching itself to other soot particles, in order to keep them as small as possible. An analysis of a "dirty" oil sample from a locomotive engine showed at 75% of the soot particles were less than 1 micron in size, with an average size of 0.75 micron, (CSX data). It is important to

keep these particles as small as possible to prevent disruption of critical bearing oil films, which could lead to increased wear and premature bearing failures. The TBN's purpose is to neutralize the acidic combustion byproducts in order to keep them from attacking and corroding the critical bearing wear surfaces. Oil quality or the oil's remaining useful life can be determined by laboratory measurements of soot content or pentane insoluble percentage, the lube oil's total base number and the oil's total acid number levels. An internal CSX study of the engine's lube oil consumption at idle, resulted in two significant findings. First, the oil consumption, (oil-out-the-stack), was found to be 1.3 gallons during 24 hours of idling on a GP38-2 locomotive which was estimated to be an average of 200 gallons per year per locomotive. Second, the total base number overall level decreased at a rate of about 1 TBN per month of idling, which was estimated to be an average of 30-40% of the oil's alkalinity lost in one year per locomotive.

Engine component wear due solely to locomotive idling is difficult to measure and objectively quantify. There are no known official papers presenting carefully conducted experimentation to accurately measure and record wear rates on components such as rings, liners and bearings. Even though this factor has yet to be thoroughly tested and proven, it has been estimated based on years of experience that a major reduction of idling may increase power assembly life by as much as

one year of additional service.

The last major cost factor to be discussed is another parameter that is difficult to measure and quantify, yet very real. That detrimental effect is noise. CSX conducted an internal study to determine the normal noise level of an idling locomotive. The following chart (Table 2) show the results taken at 100 feet from four orientations and then compare their results with the background noise levels.

The detrimental effect of locomotive noise is on the local areas surrounding the locomotive yards. This noise pollution is becoming an important concern that should be addressed if the railroads are to remain "good corporate citizens". The Federal EPA locomotive emission regulations pre-empted the states and local municipalities from legislating their own exhaust emission regulations, but did not address the possibility that noise emission regulations, once mandated, could become effective emission reduction strategies.

Currently, two methods are available reduce idling on locomotive engines. The first method involves electronic based technologies that are being offered to automatically shut-down and start up the locomotive engine itself. These systems monitor the critical fluid temperatures and when the lower control temperature is exceeded, the engine automatically starts up, to re-generate the necessary heat. once the upper limit is reached, the unit then shuts off, completing the cycle.

The second method, which was

described in Mr. Biess's paper uses a secondary source of heat that is generated by an auxiliary power gen-set. This arrangement can either be integrated into the locomotive's control system to make it automatic, or it can be separate setup in which the unit must be manually started and stopped. The same cycling sequence as described before is also used for the auxiliary gen sets; the only major difference is that the main engine remains shut down instead of cycling on and off to maintain fluid temperatures. The gen sets now maintain this function.

In conclusion, the idle speed and load setting for all diesel engines should be minimized as much as possible. Doing this will reduce fuel and lube oil consumption, will increase engine component wear life, and will reduce operating noise.

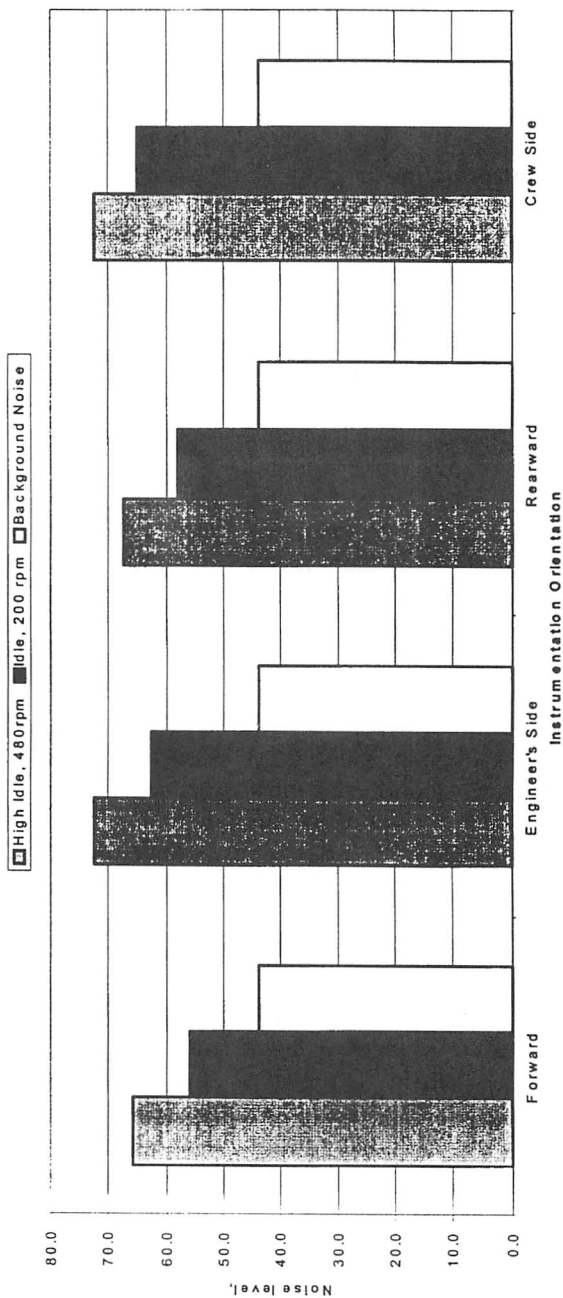
There are currently two methods available for implementing idle reduction technologies: automatic main engine stop and start systems, and the use of a separate auxiliary diesel engine generator set.

**Table 1:**  
**Locomotive Idle Fuel Rates by Class\***

| <b>Locomotive Class<br/>(Engine Model)</b> | <b>Idle Fuel Rate,<br/>Gal/Hr</b> |
|--|-----------------------------------|
| MP/GP15 (12-645E)                          | 3.8                               |
| MP/GP15T (8-645E3C)                        | 1.8                               |
| GP38-2 (16-645E)                           | 4.0                               |
| <b>Switcher Average</b>                    | <b>3.2</b>                        |
| GP/SD40-2 (16-645E3)                       | 3.2                               |
| GP/SD40-2 (16-645E3C)                      | 3.4                               |
| SD50 (16-645F3B)                           | 2.7                               |
| SD60 (16-710G3B)                           | 3.8                               |
| SD70 (16-710G3B-ES)                        | 5.1                               |
| SD80 (20-710G3B-ES)                        | 4.9                               |
| <b>Line Haul Average</b>                   | <b>3.8</b>                        |

\*Data from the Southwest Research Institute locomotive test facility

**Table 2:**  
**Main Engine Noise at Idle at 100 feet**



## II. EMISSIONS STANDARDS COMPLIANCE FOR THE GE DASH 8 LOCOMOTIVES

*Prepared by Bob Adcock,  
Norfolk Southern  
Presented by Ed Burrier*

### Introduction

Because of their lack of electronic fuel injection, the Dash 8 locomotives from General Electric Transportation Systems present special problems when attempting to meet or exceed the emissions standards set by the EPA. This report will present the package components and testing results for General Electric's Tier 0 kit along with giving an insight into Tier 0 testing, performed on two of these locomotives, by Norfolk Southern and Turbo and Compressor Maintenance..

### Objectives

Norfolk Southern, Turbo and Compressor Maintenance, and West Virginia University conducted emissions testing on two General Electric Dash 8 locomotives. The West Virginia University Transportable Heavy Vehicle Emissions Testing Laboratory was used to perform the testing (Figure 1). The purpose was to determine if a Dash 8 locomotive with retarded fuel injection timing could meet the EPA Tier 0 emissions standards for oxides of nitrogen (NOX) and total particulate matter (TPM) while avoiding an excessive fuel economy penalty that is normally associated with retarded timing.

### Testing Methods and Results

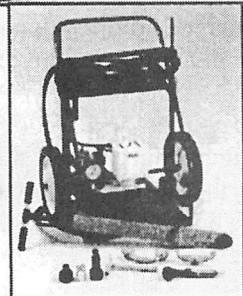
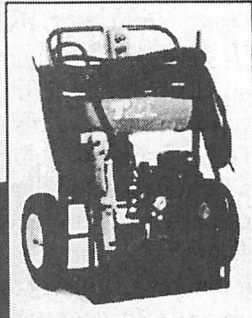
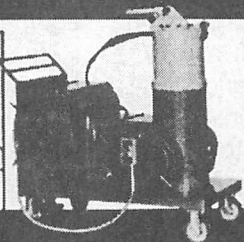
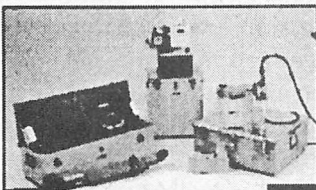
Tests were performed on a GE

D8-40C locomotive that was fresh from overhaul and equipped with a stock GE turbocharger. The same tests were conducted with a C39-8 locomotive equipped with a Turbo and Compressor Maintenance (TCM) Hispana Suiza turbocharger. Tests were conducted with a fuel injection timing setting of 8 degrees BTDC. The base injection timing for this engine is 12 degrees BTDC. Gaseous emissions (CO<sub>2</sub>, CO, NOX, THC), particulate matter emissions (PM) and exhaust opacity data were collected according to the guidelines set forth in CFR 40, Part 92, Subpart B.

The tests were completed according to the exhaust dilution methods described in CFR 40, Part 86, Subpart N. A full-flow exhaust dilution tunnel was utilized in order to simulate real world conditions and produce accurate data. A particulate sampling system, a gaseous emission sampling system, and several exhaust gas analyzers were used to gather data. Weighting factors defined in the CFR 40, Part 92, Subpart 2 (Table 1) were used to calculate weighted steady-state exhaust emissions results for comparison with the federal air quality emissions standards. The emissions tests results obtained from these locomotives were compared with Tier 0 standards given in Table 2.

Table 3 gives the results of tests conducted on the D8-40C locomotives with a stock GE turbocharger (Unit 8692) and the injection timing retarded 4 degrees. It is important to note that the unit did meet the certification level; however, only

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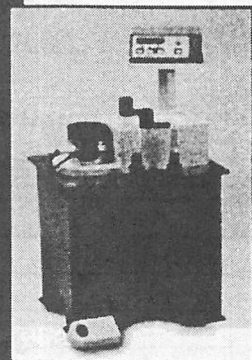


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slightly. Table 4 represents the test results from the C39-8 locomotive equipped with the TCM turbocharger (Unit 8678). Once again the injection timing was retarded 4 degrees to 8 degrees BTDC. Looking at Table 4 and comparing the THC, NO<sub>x</sub>, CO, PM, and CO<sub>2</sub> test results to the certification levels, it appears that this combination may produce satisfactory results.

Due to the budgetary impact of locomotive diesel fuel, all Class I railroads are eager to have emissions packages that provide little or no degradation of fuel economy. Fuel economy tests were completed on the C39-8 locomotive equipped with the Hispana Suiza turbocharger. Figure 2 is included to demonstrate the changes noted in the fuel economy when the injection timing was modified. As you can see from this graph, this particular locomotive did not see a significant loss of fuel economy until reaching notch 7 and 8.

The greatest variance recorded was 3.5% at notch 8.

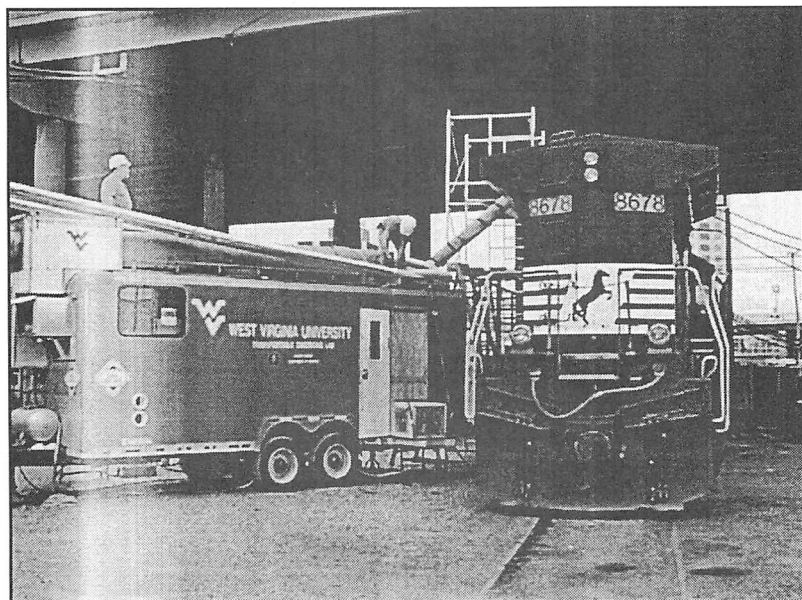
### Conclusion

From the test data shown it appears that the Dash 8 locomotive equipped with a Turbo and Compressor Maintenance turbocharger can meet the EPA guidelines for emissions. Further testing will be required to qualify the impact of retarding the locomotive's injection timing. Exactly how the locomotive will be affected operationally has yet to be determined. The two locomotives tested remain in operation at this time and Norfolk Southern is gathering data on their reliability. Further testing is planned both on these and other units.

**Table 1**  
**Locomotive Engine Certification Test Cycle**

| Test Mode | Engine Operating Point | Weighting Factor |
|-----------|------------------------|------------------|
| 1a        | Low Idle               | 0.19             |
| 1         | Normal Idle            | 0.19             |
| 2         | Dynamic Braking 4      | 0.125            |
| 3         | Notch 1                | 0.065            |
| 4         | Notch 2                | 0.065            |
| 5         | Notch 3                | 0.052            |
| 6         | Notch 4                | 0.044            |
| 7         | Notch 5                | 0.038            |
| 8         | Notch 6                | 0.039            |
| 9         | Notch 7                | 0.03             |
| 10        | Notch 8                | 0.162            |

**Figure 1**  
**The West Virginia University Transportable**  
**Testing Laboratory**



**Table 2**  
**Tier 0 Locomotive Standards**

|                | Line Haul Cycle Standard |
|----------------|--------------------------|
| <b>NOX</b>     | 9.5 g/bhp-hr             |
| <b>PM</b>      | 0.6 g/bhp-hr             |
| <b>CO</b>      | 5 g/bhp-hr               |
| <b>THC</b>     | 1 g/bhp-hr               |
| Opacity        |                          |
| Steady-State   | 30%                      |
| 30 second peak | 40%                      |
| 3 second peak  | 50%                      |

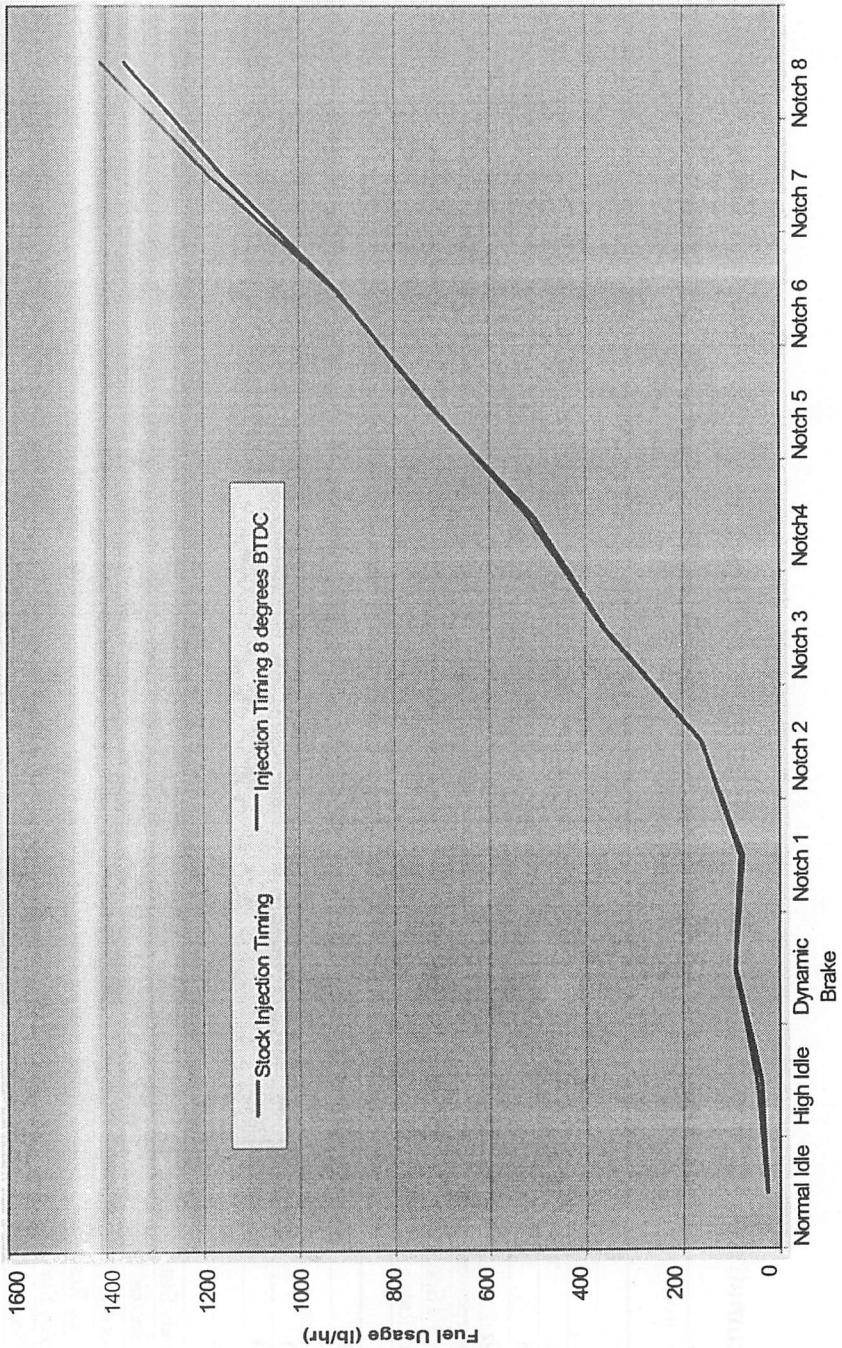
**Table 3**

**Locomotive ID 8692 (GE D8-40C with 1869 Turbo) Test Date 9/14/2001 Injection Timing: 8°BTDC**

| Test Results                             | Low Idle | Normal Idle | Dynamic Brake | Notch 1 | Notch 2 | Notch 3                                | Notch 4 | Notch 5 | Notch 6 | Notch 7 | Notch 8 |
|--|----------|-------------|---------------|---------|---------|--|---------|---------|---------|---------|---------|
| THC (g/bhp-hr)                           | 8.13     | 9.82        | 9.22          | 0.80    | 0.43    | 0.51                                   | 0.37    | 0.40    | 0.33    | 0.37    | 0.33    |
| NO <sub>x</sub> (g/bhp-hr)               | 28.05    | 33.25       | 29.72         | 12.10   | 10.70   | 10.95                                  | 10.55   | 9.29    | 8.86    | 8.98    | 7.95    |
| CO (g/bhp-hr)                            | 7.55     | 8.82        | 14.11         | 1.28    | 1.29    | 1.80                                   | 2.44    | 1.97    | 1.10    | 0.62    | 0.33    |
| PM (g/bhp-hr)                            | 2.24     | 3.01        | 7.22          | 0.89    | 0.71    | 0.55                                   | 0.36    | 0.17    | 0.23    | 0.22    | 0.42    |
| CO <sub>2</sub> (g/bhp-hr)               | 2851     | 2208        | 1861          | 584     | 533     | 533                                    | 513     | 497     | 483     | 474     | 484     |
| Horsepower (hp)                          | 14       | 25          | 71            | 189     | 423     | 948                                    | 1401    | 2053    | 2736    | 3440    | 4104    |
| Engine Speed (rpm)                       | 436      | 583         | 885           | 436     | 583     | 885                                    | 885     | 995     | 995     | 995     | 1050    |
| Fuel Rate (lbs/hr)                       | 28       | 39          | 94            | 77      | 157     | 353                                    | 502     | 713     | 920     | 1135    | 1380    |
| <b>Official Test Results - Line Haul</b> |          |             |               |         |         | <b>Certification Level - Line Haul</b> |         |         |         |         |         |
| THC (g/bhp-hr)                           | 0.49     |             |               |         |         | 1.0                                    |         |         |         |         |         |
| NO <sub>x</sub> (g/bhp-hr)               | 8.94     |             |               |         |         | 9.5                                    |         |         |         |         |         |
| CO (g/bhp-hr)                            | 0.92     |             |               |         |         | 5.0                                    |         |         |         |         |         |
| PM (g/bhp-hr)                            | 0.45     |             |               |         |         | 0.6                                    |         |         |         |         |         |
| CO <sub>2</sub> (g/bhp-hr)               | 514      |             |               |         |         | -                                      |         |         |         |         |         |
| <b>Smoke Results</b>                     |          |             |               |         |         |  |         |         |         |         |         |
| Steady State                             | 13.1     | 9.4         | 8.1           | 11.0    | 12.2    | 9.0                                    | 12.4    | 13.1    | 9.6     | 9.3     | 8.0     |
| 30 Second Peak                           | 9.8      | 7.4         | 9.7           | 14.0    | 13.9    | 16.9                                   | 16.3    | 17.0    | 12.2    | 9.1     | 6.9     |
| 3 Second Peak                            | 18.1     | 13.5        | 21.1          | 30.3    | 18.4    | 30.9                                   | 33.3    | 24.4    | 21.7    | 12.8    | 8.9     |
|  |          |             |               |         |         | <b>Certification Level - Line Haul</b> |         |         |         |         |         |
| Steady State                             |          |             |               |         |         | 30%                                    |         |         |         |         |         |
| 30 Second Peak                           |          |             |               |         |         | 40%                                    |         |         |         |         |         |
| 3 Second Peak                            |          |             |               |         |         | 50%                                    |         |         |         |         |         |



Figure 2: GE Dash 8 Fuel Economy Test Results

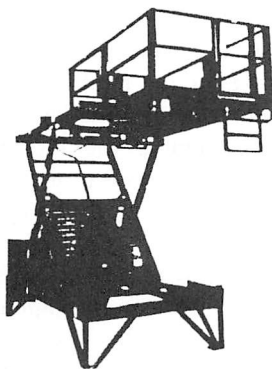
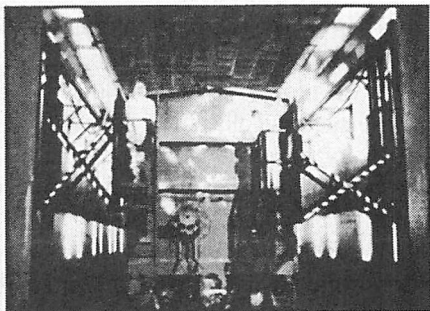


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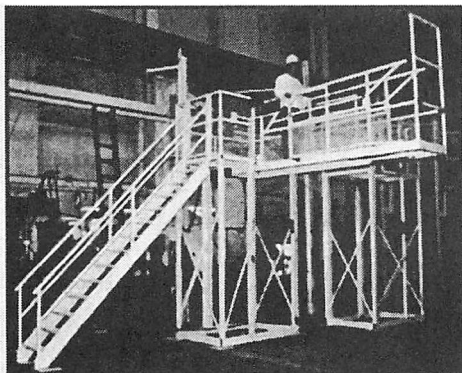
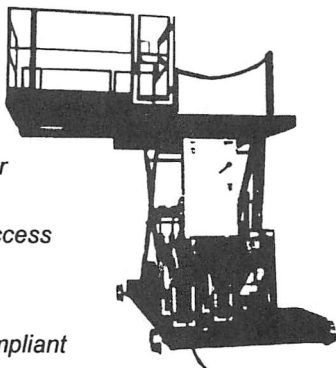
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### III. TIER 0 EMISSIONS COMPLIANCE FOR THE GE DASH 8 LOCOMOTIVE

*Prepared by  
Timothy Frederick and  
General Electric Transportation  
Systems*

#### Introduction

In order for the railroads to utilize the assets of older existing locomotives, GE developed a Tier 0 solution for the mechanically fuel injected Dash 8 locomotive support customer requirements of a low cost emissions compliant locomotive. A B40-8W mechanically fueled injected locomotive was borrowed from the Burlington Northern Sante Fe. The 1992 vintage locomotive, BNSF Unit #511, was baseline tested for fuel consumption and emissions shortly after overhaul. The locomotive was then upgraded to the Tier 0 configuration and retested for fuel consumption and emissions.

#### Design Path

It is common knowledge that retarding the fuel injection timing towards top dead center (TDC) decreases the peak cylinder firing pressure and cylinder temperature and thus reduces NO<sub>x</sub> and fuel efficiency. Other negative effects of retarding timing are increased particulate matter (PM) and increased smoke emissions, due to reduced injection pressure, and less complete combustion encountered, due to more of the combustion event occurring in the expansion part of the combustion cycle.

The main design change incorpo-

rated into the mechanically fuel injected solution was to re-phase the fuel cam consistent with the change in pump timing to maintain the fuel injection pressure with respect to the baseline engine. This change enables proper atomization of the fuel during injection and allows for more complete combustion. In addition to the re-phased cam, the engine operating speeds at the lower notches were increased to get a higher air to fuel ratio (A/F) to also reduce particulate matter and smoke. Notch 1 was changed to 720 RPM. Notch 2 was changed to 888 RPM. Notch 3 was changed to 995 RPM. Notch 4 was changed to 995 RPM. Notch 5, 6, and 7 were changed to 1050 RPM.

One risk associated with retarding the timing and not re-phasing the fuel cam is reduced cam life. By changing the timing, the lift area moves closer to the nose of the cam and is thereby subjected to higher Hertz stresses.

The target emissions level was set to account for the natural degradation in NO<sub>x</sub> due to changes in altitude, increased ambient temperature, and decreased cooling system performance since the EPA limits must be met over a wide range of operating conditions and for the life of the locomotive. The GE design target was 7.8 g/BHP-hr.

The locomotive will require a colascor with eductor applied to the muffler. Most Dash 8 locomotives already have this configuration. The pump timing must be adjusted. A new nameplate will be applied to the engine defining the new settings.

## Backgrounds

EPA emission regulations apply to new and existing locomotives with outputs greater than 1006 HP. Regulations apply to NO<sub>x</sub>, HC, CO, PM, and smoke emissions over the locomotive's useful life. The regulations provide preemption from states. The regulations apply to locomotives manufactured on or after January 1, 1973 and remanufactured on or after January 1, 2001. Additionally the regulations apply to domestic locomotives or foreign locomotives that spend substantial time in the United States.

### Tier 0 Line-Haul Emission Standards

|                 |               |
|-----------------|---------------|
| NO <sub>x</sub> | 9.5 g/BHP-hr  |
| PM              | 0.06 g/BHP-hr |
| CO              | 5.0 g/BHP-hr  |
| HC              | 1.0 g/BHP-hr  |

### Tier 0 Switcher-Duty

#### Emission Standards

|                 |               |
|-----------------|---------------|
| NO <sub>x</sub> | 14.0 g/BHP-hr |
| PM              | 0.72 g/BHP-hr |
| CO              | 8.0 g/BHP-hr  |
| HC              | 2.10 g/BHP-hr |

#### Smoke Standard

|               |             |
|---------------|-------------|
| Steady Smoke  | 30% Opacity |
| 30 Second Max | 40% Opacity |
| 3 Second Max  | 50% Opacity |

## Results

The emissions results discussed here will be directed towards NO<sub>x</sub> emissions vs. fuel consumption with the fuel comparisons kept on a relative basis, not an absolute basis, on the BNSF Unit #511. The baseline data obtained from the test locomotive is considered representative of the Dash 8 fleet based on emissions

testing performed on multiple locomotives at Southwest Research Institute and fuel consumption testing performed by GE on new locomotives. The baseline and compliance data on the BSNF test locomotive were collected at the GE Erie assembly plant in the locomotive test facility under the guidelines dictated by the EPA emission standards for locomotives, CFR 40, Part 92. The NO<sub>x</sub> value is calculated using the EPA line haul duty cycle and the fuel consumption is calculated using the AAR medium duty cycle on a brake specific basis.

## Conclusion

The emissions target of 7.8 g/BHP-hr NO<sub>x</sub> was achieved and exceeded with an acceptable reduction in fuel efficiency while maintaining or improving the other constituents of emissions. This was done at the lowest possible cost to the customer with no impact on reliability and maintainability.

Motoring MWHrs includes all work done by the engine during powered notches, idle, and dynamic braking. Depending on the application, the customer may elect to overhaul at an earlier interval to maintain optimal performance.

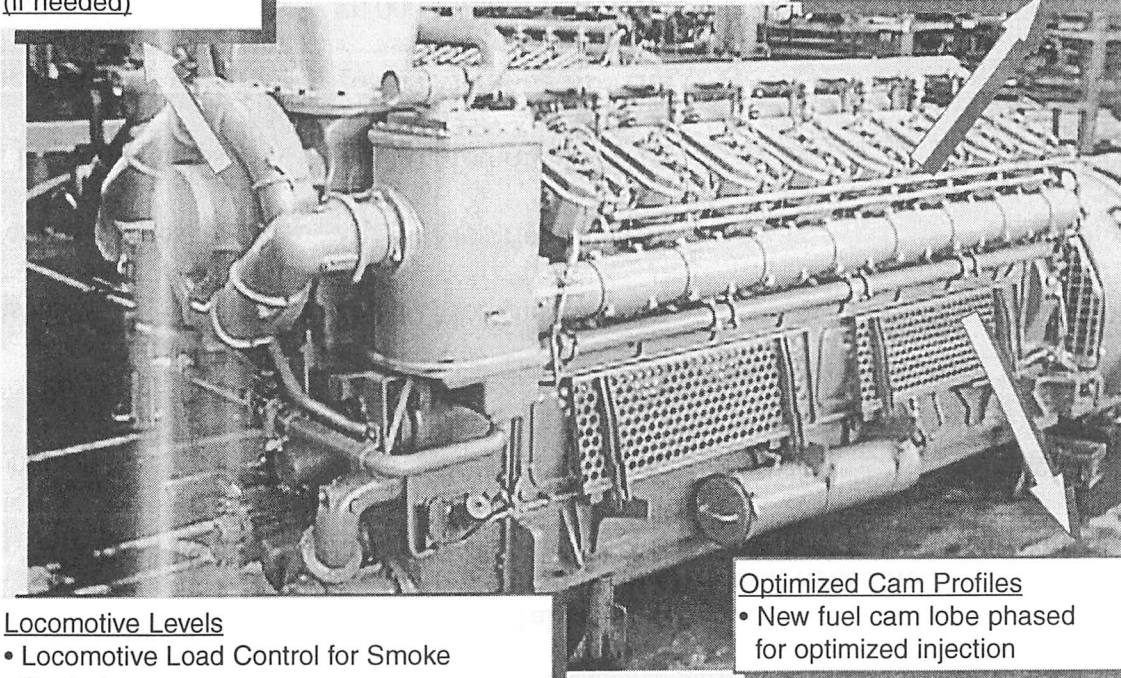
**Table 1**  
**NOx vs. Fuel Efficiency Improvement**

| Baseline           | NOx<br>(g/BHP-hr) | HC   | CO   | PM   | AAR BSFC<br>% Change (lb/BHP-hr) |
|--------------------|-------------------|------|------|------|----------------------------------|
| Baseline<br>Dash 8 | 13.62             | 0.41 | 2.19 | 0.19 | Reference                        |
| Tier 0<br>Dash 8   | 7.7               | 0.42 | 1.11 | 0.19 | -4.5%                            |

## Tier 0 Solution

1716 Turbocharger  
(if needed)

Mechanical Injection  
• Retard Mechanical Timing



Locomotive Levels

- Locomotive Load Control for Smoke Control
- Altitude Deration

Optimized Cam Profiles

- New fuel cam lobe phased for optimized injection

**Table 2**  
**Emissions - Related Component Overhaul Schedule**

| <u>Component</u>     | <u>Overhaul or Qualify</u> | <u>Reference</u>   |
|----------------------|----------------------------|--------------------|
| Diesel Engine        |                            |                    |
| Camshaft             | 26,000 Motoring MWHrs      | 91216 Maint. Inst. |
| Power Assemblies     | 30,000 Motoring MWHrs      | 93104 Maint. Inst. |
| Fuel Injection Pumps | 13,000 Motoring MWHrs      | 93298 Maint. Inst. |
| Intercooler          | 26,000 Motoring MWHrs      | 95100 Maint. Inst. |
| Turbocharger         | 26,000 Motoring MWHrs      | 94316 Maint. Inst. |

**Table 3**  
**Emissions - Related Inspection and Lubrication**

| Item            | Recommendation |          |          |            |                             |
|-----------------|----------------|----------|----------|------------|-----------------------------|
|                 | 92 Days        | 184 Days | 1 Year   | 1.5 Years  | 2 Years                     |
| Air Filters     | Replace        | Replace  | Replace  | Replace    | Replace                     |
| Radiator        | N/A            | N/A      | Heat Run | N/A        | Heat Run                    |
| Fuel Nozzles    | N/A            | N/A      | N/A      | Change Out | N/A/                        |
| Cyl Inlet Ports | N/A            | N/A      | N/A      | N/A        | Check for<br>Carbon Buildup |

#### IV. LOCOMOTIVE INSPECTION TRAINING

##### A PREVIEW OF CFR 229/238

*Presented by Art Mallette, MetroLink  
Southern California Regional Rail  
Authority, SCRRRA*

##### CFR Title 49 Part 238 Locomotive Training

In September 1994 the Secretary of Transportation convened a meeting of representatives from all sectors of the rail industry with the goal of enhancing rail safety. As one of the initiatives arising from this Rail Safety Summit, the Secretary announced that DOT would begin developing safety standards for rail passenger equipment over a five-year period. In November 1994, Congress adopted the Secretary's schedule for implementing rail passenger equipment regulations and included it in the Federal Railroad Safety Authorization Act of 1994.

The Federal Railroad safety Act of 1994 includes minimum standards for

- 1) The crashworthiness of the cars;
- 2) interior features that may affect passenger safety;
- 3) maintenance and inspection of the cars;
- 4) emergency response procedures and equipment; and
- 5) any operating rules and conditions that directly affect safety not otherwise governed by regulations.

The Secretary of Transportation delegated these rules to the FRA. Consistent with the intent of Congress, the FRA invited various organizations from the railroad

industry to participate in a working group to focus on the issues related to railroad passenger equipment safety and assist FRA in developing Federal safety standards. The Passenger Equipment Safety Standards Working Group first met on June 7, 1995 and has assisted FRA throughout the rulemaking process.

The rule making effort has resulted, in part, in CFR 49 Part 238. Part 238.109 requires a training, qualification and designation program. We will review a portion of the training that was developed to qualify SCRRRA's contractor employees performing the locomotive daily inspection (part 229). Training is divided into three parts including classroom, written test, and hands on demonstration. Minimum qualifying grades are 70% on the written, 80% on the hands on demonstration with a combined average of 80%.

Following is a brief overview of the training provided for locomotive daily inspection certification.

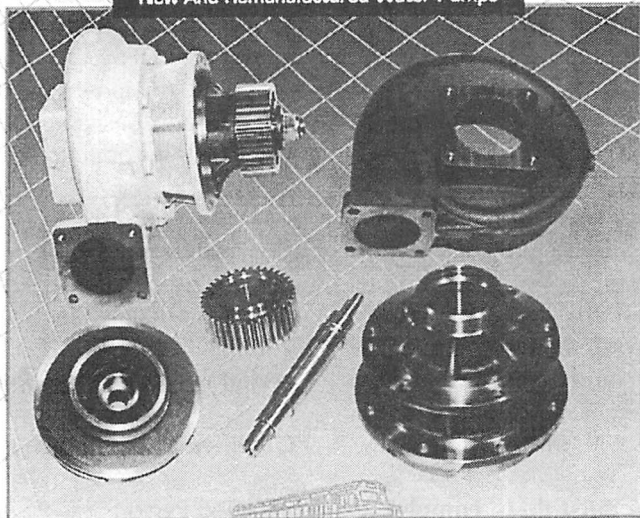
##### **Purpose**

The purpose of CFR Title 49 Part 238 is to prevent collisions, derailments, and other occurrences involving railroad passenger equipment that cause injury or death to railroad employees, railroad passengers or the general public. The regulation prescribes minimum Federal safety standards for railroad passenger equipment. 238.1(a)

CFR Title 49 Part 238, effective September 2000 is a new regulation governing Passenger Equipment Safety Standards. The general

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provisions of this document provide that:

The railroad must be able to provide the FRA a detailed inspection, testing and maintenance plan consistent with the requirements of Part 238.

The plan must include:

- Inspection procedures, intervals and criteria;
- Test procedures and intervals;
- Scheduled preventive maintenance intervals;
- Maintenance procedures; and
- Special testing equipment or measuring devices required to perform inspections and tests.

Beginning on January 1, 2002, the railroad shall have adopted a training, qualification, and designation program for employees and contractors that perform any of the inspections, tests, or maintenance required by this part and shall have trained such employees and contractors in accordance with this program.

### **What we must do to comply?**

As a minimum, the railroad must:

- Identify the tasks related to inspection, testing, and maintenance;
- Develop written procedures for the performance of these tasks;
- Identify skills and knowledge necessary to perform each task;
- Adopt a training curriculum that includes classroom and "hands-on" lessons;
- Require all employees and contractors to successfully complete the training course that covers the equipment and tasks for which they are responsible;
- Require all employees and

contractors to pass a written exam for the tasks;

- Require all employees and contractor to individually demonstrate "hands-on" capabilities in performing the tasks;
- Require periodic refresher training at an interval not to exceed three years; and
- Require supervisors to complete the program that covers the employees they supervise including refresher training.
- Add new equipment to the qualification and designation program prior to its introduction to revenue service.
- Maintain records to distinguish the qualifications of an employee as a "qualified person" or a "qualified maintenance person."

### **What is a "Qualified Person" and a "Qualified Maintenance Person?"**

#### **• Qualified Person**

A qualified person is an employee who has received the instruction and training necessary and can demonstrate the knowledge and skills necessary to perform one or more functions required by CFR 238 in the employee's area of responsibility.

#### **• Qualified Maintenance Person**

A qualified maintenance person is an employee who has received the instruction and training necessary including "hands on" experience in one or more of the following functions: troubleshooting, inspection, testing, maintenance or repair of the specific train brake and other components and systems for which the

person is assigned responsibility.

This paper will cover the items in the regulation that pertain to the inspection, testing, maintenance and repair of locomotives.

### **Inspecting the Front of the Locomotive**

- Ensure all windows permit good visibility, are clean and not broken, damaged or missing.
- Ensure all window seals are in place and will prohibit the entry of water or residue.
- Ensure all window wipers are in place and the blades make continuous contact with the window.
- Ensure the headlights are clean, properly secured, and work as intended - ensure the headlights have operational dim/bright function.
- Ensure all auxiliary lights are clean, properly secured, and work as intended.
- Ensure all marker lights are clean, properly secured, and work as intended.
- Ensure all strobe lights are clean, properly secured, and work as intended.
- Inspect the snow plow/pilot and ensure it is 3"-6" above the top rail.
- Jumpers and cable connections may not hang with the end free.
- Ensure that receptacles are properly marked and secured to the locomotive. High voltage cables must be marked "Danger High Voltage" or with the actual voltage in the cable.
- Ensure receptacles and MU covers are not missing, broken or cracked and are functioning properly.
- Check for broken, flashed or partially missing receptacle pins.
- Check for cracked receptacle pin retaining plate and loose or missing plate mounting bolts (Figure 1).
- Inspect for dirt/moisture contamination of receptacle interior and retaining plate.
- Make all necessary repairs and clean receptacle interior.
- If the coupler appears to be drooping, check the height of the coupler from the top rail. It must be a minimum of 31-1/2" and a maximum of 34-1/2" above the top of rail.
- The couplers may not have a crack or break in the side wall or pin bearing bosses or the pulling face of the knuckle. Cracks are allowable in certain areas (Figure 2).
- Couplers must have anticreep protections.
- Ensure PH locomotives have a cotter key in the top of the knuckle pin and a retaining pin and cotter key properly installed in the bottom. PHI locomotives have only a cotter pin in the bottom end of the knuckle pin.
- Coupler carriers must not be broken or cracked.
- Ensure wear plates on couplers and coupler carriers are not cracked, broken or missing and are properly secured.

## **Inspecting the Sides of the Locomotive Safety Appliances**

### **Vertical Handholds**

- Ensure the vertical handholds are not missing, bent or cracked and are secured with 1/2" diameter bolts or larger (rivets).
- Ensure the vertical handholds are painting a contrasting color (yellow).
- Ensure the vertical handholds provide at least 2-1/2" of usable hand clearance throughout their entire length.
- Ensure there are no obstructions preventing the use of the vertical handholds.

### **Steps**

- Ensure the steps are not missing, bent or cracked and are secured and not loose.
- Ensure the outer edge of the steps are painted a contrasting color (yellow).
- Ensure the backstop is a minimum of 6" above the top of the step.
- Ensure stanchions and handrails are not missing, bent or cracked and are secured and not loose.
- Ensure crossover chains are in place and secured.

### **Overriding Brake Shoes**

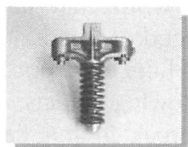
- Brake shoes shall be fastened with a brake shoe key and aligned in relation to the wheel to prevent localized thermal stress in the edge of the rim or the flange.
- Visually inspect brake shoes to ensure the brake shoe is not missing or damaged.

- The brake shoe may not protrude beyond the rim of the wheel.

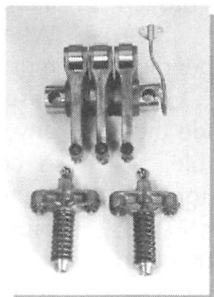
### **Wheels**

- Ensure each wheel does not have the following defects:  
A single flat spot that is 2-1/2" in length, or two adjoining spots that are each two or more inches in length. To measure a flat spot place the back edge of the Go-No Go gauge firmly on the flat spot and confirm that it is at least 2-1/2" in length. Attempt to rock the gauge on the flat spot. If the gauge rocks, the flat spot is not condemnable.
- Ensure each wheel does not have any of the following defects:  
A gouge or chip in the flange that is more than 1-1/2" in length and 1/2" in width.  
A broken rim, if the tread, measured from the flange at a point 5/8 of an inch above the tread, is less than 3-3/4" in width.
- Take the following steps when measuring for a broken rim:  
Measure 5/8" above tread. Measure 3-3/4" out from point on flange 5/8" above tread.  
If broken rim falls within that area, the wheel is not usable.
- Ensure each wheel does not have the following defects:  
A shelled out spot 2-1/2" or more in length, or two adjoining spots that are each two or more inches in length.
- Take the following steps to measure for a shelled out wheel:  
Lay the Go-No Go gauge beside the shelled out area.  
Check the shelled out area

## ROCKER ASSEMBLIES & VALVE BRIDGES



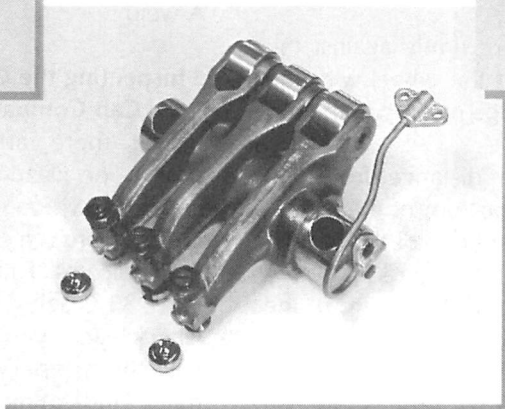
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against the gauge to see if it exceeds 2-1/2".

- Ensure each wheel does not have the following defect:

A seam running lengthwise that is within 3-3/4 inches of the flange.

- Using the Go-No Go gauge to inspect for seams and broken rim:

Place gauge on tread perpendicular to the flange.

A seam or broken rim inside the 3-3/4" area is not acceptable.

- Ensure each wheel does not have the following defect:

A tread worn hollow 5/16 of an inch or more.

- How to measure a tread worn hollow:

Place a square firmly against the inside face of the wheel with the measuring edge resting on the top of the flange.

Measure the distance from the tread to the bottom of the square near the outer edge of the tread – measurement A (Figure 3).

Measure the distance from the tread to the bottom of the square near the center of the tread – measurement B.

Subtract measurement "A" from measurement "B". If the result is 5/16" or more the wheel is condemnable.

- Ensure each wheel does not have the following defect:

A flange worn to a 7/8 thickness or less, gauged at a point 3/8 of an inch above the tread.

- When inspecting wheels for this flange on the service & inspection tracks, the Go-No Go gauge should be used.

Use Go-No Go gauge for measuring flange thickness.

Edge "A" must be parallel to the inside edge of the wheel (Figure 4).

If any portion of the edge "B" contacts the wheel tread, the flange is worn thin.

Wheels with worn thin flanges must be replaced or trued.

- Ensure each wheel does not have any of the following defects:

A crack or break in the flange, tread, rim, plate or hub. (A broken rim is allowable if it meets the criteria mentioned earlier).

A loose wheel - look for rust where the axle meets the hub.

A weld.

### **Inspecting the Cab Interior Cab Compartments**

- Insure there are no cracked, broken or glazed windows that impair the vision of the operator.
- Ensure there is a stencil in the cab that indicates "Fully Equipped FRA Part 233 Glazing."
- Check each window to ensure it has the proper manufacturer's mark indicating the type of glazing.  
All front windows should have Type I glazing.  
All side windows should have Type II glazing.
- Check all windshield wipers and ensure they operate as intended.
- Ensure the side windows will open and close easily and will latch properly.
- Inspect the seats in the cab to ensure they are not damaged, fabric torn or loose.

- Ensure the seats operate as intended,  
Armrests not loose and can be adjusted.  
Front of seat tilts.  
Seat moves back and forth easily.  
Knobs and handles are not missing.  
Seat swivels.  
Seat back not loose and can be adjusted.  
Back of seat tilts.  
Entire seat moves up and down.  
Seat is properly secured to the floor.

### **Inspecting the Engine Compartment**

#### **Equipment Covers and Shields**

- Check the following areas:  
Auxiliary general guard  
Flywheel cover  
Lube oil cooler pipe insulation  
Engine to compressor drive shaft  
Starter motor cover.  
Fan openings, exposed gears and pinions, exposed moving parts of mechanisms, pipes carrying hot gases or liquids, shall be in non-hazardous locations or equipped with guards to prevent personal injury.
- Check the following areas for exhaust leaks:  
Exhaust stack base bolts  
Transition section  
Parts catcher  
Exhaust manifold  
Flash cock  
Muffler.

Products of combustion shall be released outside the cab and other compartments. If fumes are present in the car body, look for carbon

streaks that might indicate an exhaust leak. While the engine accelerates, look for signs of black smoke. Ensure the stack base bolts are not missing or loose. Ensure the exhaust manifold heat shields are not cracked and are properly secured.

### **Inspecting the Engine Compartment Check Fluid Levels**

- Check the engine oil level.  
Check the engine oil level when the engine is hot and idling.  
Oil level should be between the "Low" and "Full" marks.
- Check the engine water level.  
The level can be checked if the engine is dead or running.  
Check the rattlesnake coupling to confirm it is not damaged.  
Ensure the vent cap is in place and secured.

### **Inspecting the Air Compressor**

- Check for oil and water leaks.  
Check the oil level of the air compressor.  
Check the air compressor for water leaks at all water piping flanges and connections and at the intercooler.  
Check the air compressor for oil leaks at low and high pressure heads, oil level gauge and the spin on oil filter.  
Ensure pressure relief valves are safety wired or sealed.

Figure 1

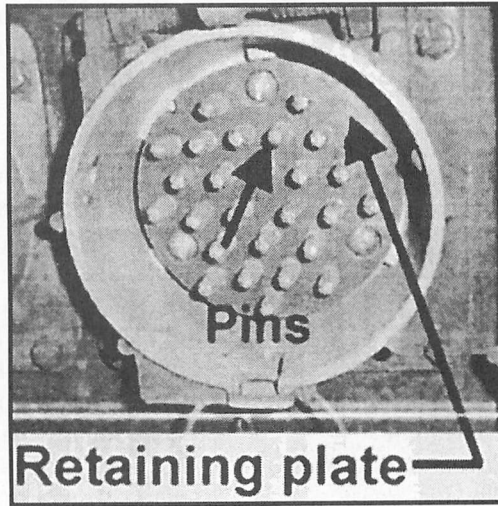


Figure 2

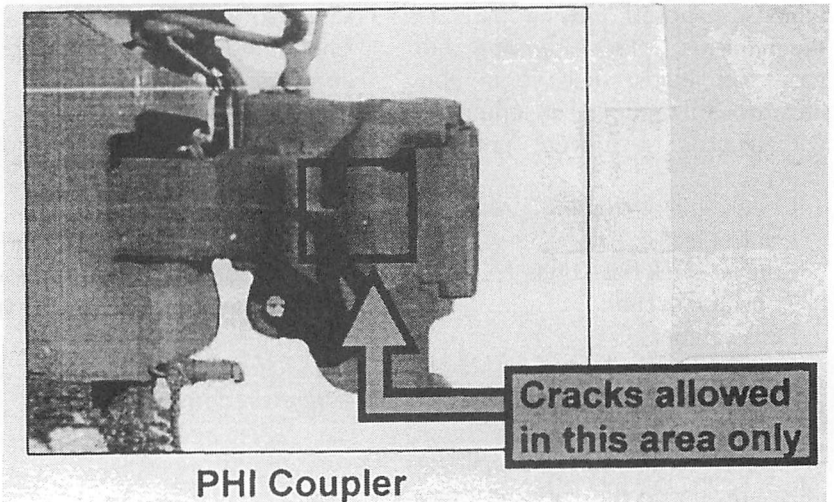
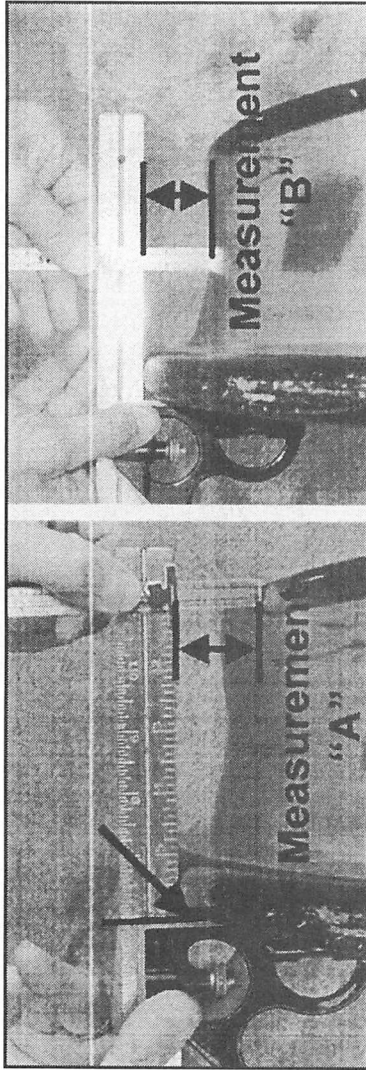
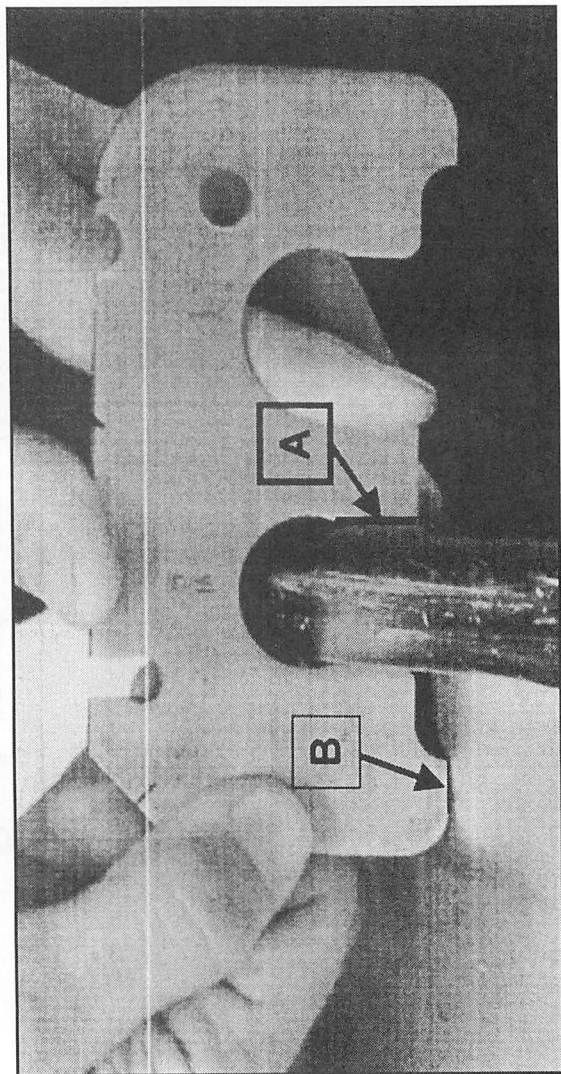


Figure 3

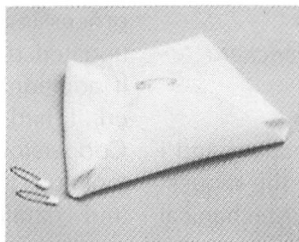


**B - A must = less than 5/16"**

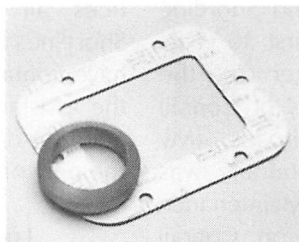
Figure 4



Go-No Go Style Gauge



STOPS LEAKS.



STOPS LEAKS.

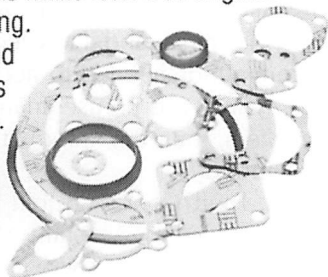
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## V. COMPUTERIZED RECORD KEEPING TO IMPROVE PERFORMANCE AND REDUCE MAINTENANCE EXPENSE FOR SHORTLINE AND REGIONAL RAILROADS

*Prepared by: Dick Blanchard*

### Introduction

My name is Dick Blanchard and I am writing this paper at the request of the LMOA Diesel Mechanical Committee. The topic addresses the need for Computerized Record Keeping on Regional and Shortline Railroads. I spent the first 30 years of my railroad career in the Mechanical departments of Conrail and its predecessor railroads. My last position on Conrail was Manager Locomotive Maintenance and Training. It was on Conrail where I became spoiled by the abundance of information available on the locomotive fleet. Virtually everything you wanted or needed to know was available through the Conrail LIS - Locomotive Information System. All that was required was a computer terminal and knowledge of the commands needed to access the data. There was no user-friendly menu system, but the information could be found.

In 1996, I left Conrail to join the NYS&W Railway as Assistant Vice President - Mechanical. There it was obvious that the information I had taken for granted on Conrail was no longer readily available to me.

At the NYS&W I had a very competent assistant. He had spent over 20 years with the NYS&W and had much of the information needed to

run a mechanical department. Unfortunately, this information was filed away in file cabinets, his desk, or the log books that he kept. Daily locomotive status was kept in a word processing program which was updated daily; a cumbersome task. If additional information was needed, I had to call headquarters in Cooperstown, consult with vendors, look up the information in books and catalogs, or talk with the mechanics on the shop floor. Since then, I have found these same practices all too common on the Shortline and Regional railroads I have contacted or worked with. As the assistant vice president, I had a need for data, but managers are not the only ones with this need.

### Locomotive History

Let us look at how the locomotive maintainer benefits from a database (Figure 1). A benefit to the maintainer is the availability of a locomotive repair history. It tells the mechanic what repairs have to be performed, when they were performed and where they were performed. It also gives you the next inspection dates as well as any comments from the Locomotive Status Screen. It prevents duplication of efforts and eliminates defect possibilities for troublesome locomotives. Often a failed component is the result of a locomotive failure, not the cause of it.

The Locomotive History database will also allow you to identify failure trends, repeat failures, and possible maintenance issues. This is done with the Locomotive History -

Variable Input Screen (not shown). A data range is selected and any combination of variables selected. These variables include Locomotive Number, Locomotive Class, Symptoms, Defects, Actions, Repair Location, and/or Failure or Scheduled shopping. The History Database is searched and a report is generated with all locomotives matching your search criteria.

A second benefit for the locomotive mechanic is customized Periodic Maintenance work packets. The computer can generate a work packet for any periodic maintenance that is specific for that locomotive and the type of inspection that is being performed. No more lost time for the mechanic trying to perform maintenance that is not required or for the supervisor reviewing the work packet trying to determine if in fact the work should have been done.

### **PM Work Items**

The PM Work Items screen is where you would input the work to be performed (Figure 2). The Work Item Number determines the type of inspection when the work is to be performed. The Work Scope is what is printed. The Loco Select Table determines the locomotives, for which the work scopes will print, while the Loco Exception Table determines which locomotive will be ignored. Seasonal work items such as winterization can be marked when they no longer need to be performed and they will not print. Simply unmark the item to make them print again. No need to

re-enter the work scope. The above work item will print out any inspection performed on all EMD locomotives except locomotives with turbochargers.

On the right side of the screen we find two buttons which take us to the Inbound Inspection and Load Box screens where we can customize these work sheets to specific locomotives.

Another benefit is the ability to identify warranty material. Many high cost items such as traction motors may sit around the shop for months before they are applied to the locomotive. The warranty should not begin until they are actually applied. The component tracking system tracks the components by serial number and reflects when the component was applied, and the locomotive position it was applied to. You may want to check with your suppliers, but I would think a component history coupled with a locomotive history provides a good basis for a warranty claim even if the component is out of warranty based upon receipt date or serial number.

### **Component Tracking System**

From Figure 3 you can check your inventory of tracked components. If you enter the component data when the component arrives, you can print a report of those components that have not been applied. You can even check the history of a specific component. A component that repeatedly fails might indicate the re-builder could be missing something.

Yet another benefit to the mechanic is the ability to quickly find loco-

motive specific part numbers (Figure 4). The Locomotive Material Tab of the Locomotive Data screen provides locomotive specific material information. Whether you need to know what air brake is required for an air brake change-out, the material required to perform periodic maintenance or the part number for an injector - the information is readily available.

### **Locomotive Data**

Figure 5 shows us the Loco Material tab of the Locomotive Data Screen. Note, there are six other tabs available on this screen. The purpose of these tabs is to readily provide important information. The first tab is the Loco Status tab.

### **Locomotive Status**

The Locomotive Status tab gives the current status of the locomotive. The status could be "IN" (In service) as shown in Figure 6, "SPM" (shopped - periodic maintenance), "SHR" (Shopped heavy repair), "SLR" (shopped light repair), "XSS" (Stored serviceable) or any of up to 22 status states. These states are customized to the users needs. When you change the status of a locomotive, you are required to enter a date and time for the status change. This date and time is used to compute the Locomotive Performance statistics.

### **Daily Status**

The Daily Status Notes appear on the Fleet Status Reports. They also appear as comments on the locomotive history report. The Shop

Notes appear on the Shop Notes Report and are for the use of the Mechanical Department. They also print on the 3-month Locomotive History Report that prints out as part of the periodic maintenance work packet. The next inspection dates are also on this screen as well as the locomotive fueling information. If you use vendors for fueling and regularly schedule their fueling, here is where you would enter the fuel cycle days. The other fueling information comes from the Fueling Input Screen.

### **Locomotive Information Tab**

The Locomotive Information Tab is used for information you may want to know at a glance (Figure 7). This may include various overhaul dates, and equipment types and locations. Some of this information is used on the FRA Cab Forms and is carried over to the printing of that form. This screen is customized to what the user needs to see.

### **Locomotive Date Tab**

The Loco Date tab is where the Periodic Inspection dates and various mechanical maintenance dates are kept (Figure 8). You simply check the appropriate box for the Air Brake change out period and input the last inspection dates and locations. The next inspection dates are automatically calculated for you.

The mechanical tests portion of this screen also allows you to set up locomotive specific maintenance items to be performed at scheduled times.

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### **Out-of-Service tab**

I am sure you all have had to calculate the out-of-service time for a locomotive. First you need a calendar and a full complement of fingers and toes. Then you need to determine which dates are effected by the out-of-service time and then calculate the new dates. A time consuming and frustrating experience. This screen takes the out-of-service time and adds it to the appropriate date for both the air brake and mechanical inspections. The Out-of-Service screen (Figure 9) will not allow you to enter less than 30 days nor can you enter data prior to the last air brake change.

### **Locomotive Reports**

The Locomotive Reports tab allow quick access to some of the more common reports (Figure 10). We provide other ways to access these reports and will try to cover them later, but for now let us look at a few of the reports that are available here.

### **Locomotive Inspection Forecast**

The Locomotive Inspection Forecast provides you with a listing of your locomotive fleet in the order, which they are due for inspection (Figure 11). It provides the current status of the locomotive, the daily status notes, and the type of inspection that is due. If the locomotive is due for another type of inspection within 92 days of the initial inspection, that information is also provided.

The Locomotive Inspection Dates by 2/3 Year Dates (not shown) provides a listing of your locomotive

fleet in the order that they are due for air brake change-out. This is very handy when you have to forecast your air brake material needs or budget your air brake expenses for the next year.

### **FRA Cab Form Data**

The FRA Cab Form Data is especially useful at the beginning of each year when we are required to apply new cab forms to all our locomotives. Most of the data required to fill out the form is already in our database. Only the blocks 1,2,6,7,8, and 9 are required to be input on this form and this data will only have to be input one time. The other information has been input on other screens and is carried over to the Cab Form Data Screen. Remember - data, no matter where it is used, should only have to be input once.

When we press the "Print FRA Form" Button, error checking is performed against the data and if any exceptions are taken, the "Missing Data" screen appears (not shown). The Missing Data screen will tell us if any of the required fields are blank or, in some instances, if the data is incorrect. This program prints both the front and back of "Form FRA F6188-49A (3-85)." (Figure 12) All you need is the blue paper.

### **Locomotive Fleet Status by Loco Number**

The "Fleet Locomotive Status Report" gives us the current status of all the locomotives in our fleet. The report shown in Figure 13 is by Locomotive Number. It also can be printed out by Inspection Due date.

This report provides a fleet summary and is often sent to other interested departments. Included are the last fueled dates, the next inspection dates, type of inspection the locomotive will be due for, current status, the daily status notes, the out-of-service date, out-of-service days, and forecast in-service date. The current fleet availability is at the bottom.

If you have set Locomotives up with Fuel Cycle Days under the Locomotives Status Tab, the Locomotive Service Forecast Report (not shown) tells you when these locomotives are due for fueling.

### **Locomotive Component Tab**

The Locomotive Components Tab (Figure 14) gives us locomotive specific information about the components applied to the locomotive. Components still under warranty have a green date in the warranty expiration column. If further information is desired about a specific component, you simply double click the component and the Component Tracking screen for that component will open.

### **Main Menu**

There is other information available from the Main Menu (Figure 15) that you would want to share with your mechanical forces. Information about Lead Readings, Wheel Sizes, and Locomotive Train Failures can be found there.

Depending upon your railroad, responsibilities of the mechanics and supervisors will vary. The screens shown benefit supervisors as well as the mechanics, while the following

screens and reports designed for management, may be useful to mechanics.

The maintenance manager has to answer to a higher being and correct information is essential. Often this information is needed "Yesterday," so having the information quickly available is a high priority. Reliability, labor expense, fuel costs, and budgets are areas where the manager is consistently under the gun.

Reliability reflects the performance of the Mechanical Department and ultimately the supervisor. We strive to improve the locomotives, but all too often the "Atta-boys" are forgotten and the "Ah-shits" continue to pile up. A proper measurement of the fleet needs to be based upon actual performance and availability, not the last failure.

### **Locomotive Performance Reports**

You remember the "Status" field from the Locomotive Data Screen where the status change was input by date and time. Here is where that data is compiled and reported. The Locomotive Performance Reports provide the real picture (Figure 16). A date range is input at the top of the screen, then the appropriate reports are selected and printed.

Although these reports are available by individual locomotives and the locomotive model, this reports reflects the Locomotive Fleet Summary.

### **Locomotive Performance - Railroad Summary**

This Report (Figure 17) shows the

fleet total of 16 locomotives had 23 shoppings for the input date range (14 scheduled shoppings and 9 unscheduled shoppings). The scheduled shoppings accounted for 32.8 days of out of service time - 3.4 scheduled days and 29.3 Periodic Inspection days. The unscheduled shoppings accounted for 73.1 days out of service - 13.9 days for light repairs, 5.8 days enroute for repairs, 23.1 days for road failure shoppings and 29.8 days for otherwise unclassified unscheduled shoppings. The report also tells us that we had locomotives stored serviceable for 12.3 days and that we had locomotives leased off line for 72 days.

- Our mean time between shoppings was 55.73 days.
- Our mean time between scheduled shoppings was 84.68 days.
- Our mean time between scheduled shoppings was 82.16 Days plus. The plus indicates 1 or more locomotives did not have any unscheduled shoppings.
- Our availability percentage was 92.37%.

### **Locomotive Performance - Railroad Statistics**

A lot of information in a summary report - printing the locomotive detail will identify the bad actors as well as the good locomotives.

The Statistics report provides us another way of looking at the same data. Although the 14 scheduled shoppings accounted for 60.87% of the total shoppings, the 32.79 days out of service accounted for only 30.97% of the total out of service days. Unscheduled shoppings were

fewer but accounted for over twice as much out of service time. This report (Figure 18) is especially useful when comparing individual locomotives or classes of locomotives.

### **Labor Expense Reports**

I'll bet no one has ever asked you, "Where has all the money gone?" or "How come we're over budget?" Because no one ever gets asked these questions, these reports probably won't mean much. But I'll show you anyway.

These reports (Figure 19) are available in detailed format that would print out by location for the Shop Order Summary and Pay Code Summary. For now we will look at the system totals.

### **Labor Expenses by Shop Order - System Total**

How much did we spend on periodic maintenance? Combining shop orders 120 and 130 we spent roughly \$13,600 or a little over 10% of our total labor expense. Divide this by the number of locomotives receiving periodic maintenance and you have a good idea what a PM costs (Figure 20).

Over \$2,000 for shop cleaning. I'll bet that's a line item on everyone's budget. Derailments and re-railing - does the boss really want to know what that costs? Seriously, Shop Orders provide the Manager with the information needed to identify areas of expense for budgeting purposes or cost reduction.

Labor Expense by Pay Code (not shown) breaks down the labor costs by Regular Pay, Overtime Pay,

Vacation Pay, Sick Pay, Holiday Pay, and any other Pay Codes you choose to set up.

The Work Order Summary Report (not shown) gives us time and expenses for each work order.

The Overtime Location Summary (not shown) gives us the total hours and expenses for overtime by location. The detail report will give us the employee and the work order for the overtime.

### **Fuel and Lube Oil Tracking Reports**

Fuel oil and lube oil usually equate to one of the greatest expenses of any railroad. Therefore, it is important that we know where this expense is going and utilize all the information available to reduce expense.

The Fuel and Lube Oil Reports screen (Figure 21) provides us with many ways to see how and where our fuel budget is going. Fuel usage could be a measurement of locomotive utilization. A railroad had four locomotives assigned to a certain location. After reviewing the fueling reports it was obvious that only three locomotives were ever being fueled. The trainmaster at that location liked the security of having an extra locomotive "Just in case..." Needless to say; the extra locomotive was reassigned.

The System Location Summary (Figure 22) gives us a synopsis of the fueling activity for each fueling location on the railroad.

This report illustrates how fuel expenses can be reduced with some planning. You will note the average

cost for fuel at Binghamton is .65¢ per gallon while the cost for fuel at Norwich is \$1.25 per gallon. Three locomotives were fueled at Norwich using a vendor who delivered 4,734.0 gallons of fuel at \$1.25 per gallon. Had the locomotives been moved 60 miles to Binghamton for fuel, over \$2,800 would have been saved.

Foreign locomotives are identified, by the program, as locomotives that are not part of the equipment table. If you share power or have occasion to fuel locomotives for other railroads, are you paying your share? Are they paying you what they should? Fuel prices can vary daily; this program takes the daily fuel price when figuring the costs.

This report (Figure 23) also gives you a summary of the fuel and lube oil activity for every locomotive in your fleet. Do you have a locomotive using excessive lube oil? Maybe you should shop that locomotive and fix the problem. Lube oil is approaching \$4.00 per gallon. Can anyone afford to blow that out the stack or leak it on the ground?

The Fuel and Lube Oil Summary (Figure 24) is just that - a summary of the fuel oil and lube oil put into locomotives. When was the last time you compared what went into the locomotives with what you are purchasing?

Budget time - everyone's favorite time of the year. No matter how hard you try, the boss always thinks there is more fat to be cut from your budget. A root canal is less painful and the IRS more reasonable. My crystal ball broke, therefore I have to

depend upon historical data, anticipated transportation demands, fleet condition and over 35 years of experience when preparing a budget. Some of the reports presented provide historical data to assist us. Now lets look at what else is available.

### **Fleet Component Dates Report**

This report (Figure 25) tells you the applied dates for all the traction motors and power assemblies on the locomotives in your fleet. The information used in this report comes from the Component Input Screen. This report is useful for selecting candidates for overhaul or components for change-out based upon age.

### **Fleet Locomotive Wheel Replacement Forecast Summary**

This report (Figure 26) tells us that we should have seven locomotive wheels to change by the end of the year. It even tells us which locomotives and what positions the wheels are in. This is useful when ordering the wheel sets. The information used to generate this report comes from the wheel sizes taken at the time of inspection. Because the forecast is based upon average wear, the more data input, the more accurate the forecast.

### **Employee Profile**

A database can be used for more than just locomotive records.

Information about your employees is kept here. This screen has general information about the employee including an emergency contact. This screen would usually be available to someone who needs information with a lower security level.

Figure 27 illustrates the information that could be readily available to a person with higher level of security.

Figure 28 has confidential information about the employee. The Emergency Info tab includes medical information that can be provided to paramedics in the event of a serious emergency. This includes medications the employee is currently taking, any allergies the employee may have, any special medical problems the employee may have like high blood pressure, diabetes, etc. Information that could save an employee's life.

There is also a tab for Salary Info. This provides access to the employee's salary history and performance reviews.

Employee Training, Safety, and Discipline tabs provide information in these areas. Everything you might want to know about an employee on one screen, available at the touch of a button. This type of information should be customizable to the railroad's operation and current practices.

### **Material Order Input**

You can use the database to order material and generate Purchase Orders (Figure 29). In this way you can track material costs by locomotive or work order or cost center.

### **Conclusion**

There are many more things we can do with a database. The only limitation is being your imagination. I have shown you some of what this database is capable of doing but there is more. Unfortunately, I think

I have already exceeded my space allowed in this book.

There are other data base products available and I encourage you to look at them all. I find a database to be indispensable and recommend its use to everyone with a locomotive fleet to maintain. There should be several factors considered when selecting your database:

1. Can you set up various levels of access? I have demonstrated this database with the highest security level. A lower security level would not have allowed access to some of the screens and reports shown. Most of your employees will need access at some level. Make sure you can protect sensitive information.

2. Usability - The screens should be intuitive and easy to navigate. Related information should be kept together. The reports should be meaningful. The database should be there to enhance your operation; you should not have to change how you do things to accommodate the database. Will the vendor work with you and customize the screens and reports to what you are used to and want to see? Does the vendor speak "Railroad?"

3. Data Input - A database is only as good as the input. Be prepared to spend some time inputting the data. The initial data load could be tremendous, depending on the information you have accumulated and how it has been kept. See if the vendor will work with you on the initial data load. Select a relational database. Data, no matter how many places and ways it is used, should only have to be input once.

Everything I have shown you, whether it was component information, fueling information, labor costs, you name it - was only input once. Reports and screens requiring information stored in other tables got the information from those tables. I did not have to re-input the data.

### Disclaimer

The information presented in the various reports and shown on the screens is not real data. Although I have taken some liberties using NYS&W locomotive numbers and locations, the information is not a reflection of the NYS&W or any other railroad. The information shown is a product of my imagination and experience and was created for the purpose of demonstrating the benefits of a database.

Due to space limitations I was only able to present a taste of what this database is capable of doing for you. The database currently has over 100 input/data screens and about 150 reports. The program continues to grow with new ideas from you, railroaders with a need for data. I can be contacted for further information at [rrrdickb@adelphia.net](mailto:rrrdickb@adelphia.net) or (315) 732-7431.

I appreciate the LMOA Mechanical Committee inviting me to provide my input on this topic. Thank you for your time.

# LMOA Locomotive History

**LOCOMOTIVE NUMBER: 1800**

**COMMENTS** Locomotive must be shopped at Utica for next PM

Next PM 05/17/2002

Next 1 Year 12/09/2002

Next 2/3 Year 01/23/2003

**Location:** ROCHESTER                      **Date OOS:** 05/10/2002                      **Date IS:** 05/12/2002                      **F /S:** F

**Notes:** This Locomotive has history of wheel slip problems. Repaired burnt wiring in bundle above S24 Contactor.  
116

| SYMPTOM                         | DEFECT                 | POSITION | ACTION   |
|---------------------------------|------------------------|----------|----------|
| WHEEL SLIP                      | WS WIRING              |          | REPAIRED |
| CONTROL GROUND - LOW VOLTAGE GF | CONTROL CIRCUIT WIRING |          | REPAIRED |

**Location:** BINGHAMTON                      **Date OOS:** 04/01/2002                      **Date IS:** 04/03/2002                      **F /S:** S

**Notes:**  
113

| SYMPTOM    | DEFECT      | POSITION | ACTION  |
|------------|-------------|----------|---------|
| WHEEL SLIP | TM ARM OPEN | #3       | RENEWED |

**Location:** UTICA                                      **Date OOS:** 02/18/2002                      **Date IS:** 02/19/2002                      **F /S:** S

**Notes:**  
115

| SYMPTOM            | DEFECT            | POSITION | ACTION   |
|--------------------|-------------------|----------|----------|
| SCHEDULED SHOPPING | WHEEL HIGH FLANGE | 3        | WHL TRUE |
| SCHEDULED SHOPPING | WHEEL HIGH FLANGE | 4        | WHL TRUE |

**Location:** NORWICH                                      **Date OOS:** 02/13/2002                      **Date IS:** 02/15/2002                      **F /S:** S

**Notes:** Sent to Utica for wheel true  
114

| SYMPTOM              | DEFECT                  | POSITION | ACTION    |
|----------------------|-------------------------|----------|-----------|
| PERIODIC MAINTENANCE | 92 DAY INSPECTION       |          | PERFORMED |
| EXHAUST LEAKS        | EXHAUST MANIFOLD GASKET | 2        | RENEWED   |
| BELL NOT WORKING     | BELL CARTRIDGE          |          | RENEWED   |
| WHEEL DEFECTS        | WHEEL HIGH FLANGE       | 3        | E-F-R     |
| WHEEL DEFECTS        | WHEEL HIGH FLANGE       | 4        | E-F-R     |
| WHEEL SLIP           | CONTACTOR "P"           | P4       | RENEWED   |


Locomotive History

RRR-05-15-00


1800 Page 1 of 1

Figure 1

Load/Save Records, Print the Maintenance Plan



# PM Work Items



Work Item Number  (100 to 699 for 45 Day Luba, 500 to 999 special items like wastelanding, 1000 to 2499 for 92 Day, 2500 to 3999 for 184 Day, 3000 to 3999 for 1 Year, 4000 to 6999 for Air Brakes, 5000 to 5999 for 2 Year, 6000 to 6999 for 3 Year, and 7000 to 7999 for 4 Year)

Work Scope:

Loco Select Table

Loco Encyden Table

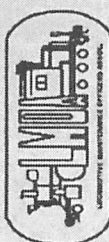
Record 20

Table Pm Work Items Query on Records 131


NUM

Figure 2

Full Screen Records (Component Tracking Form)



# Component Tracking System



COMPONENT  MODEL/GE  SERIAL #  WARRANTY  YR

MANUFACTURER OR REBUILDER  ABC MOTOR REPAIRS  CONDITION

SOURCE  COST

RECEIVED DATE  APPLIED DATE  LOCO #  POSITION

WARRANTY EXPIRATION DATE  REMOVED DATE  REASON REMOVED

DISPOSITION:  WHEEL AXLE SIZE  WHEEL RIM (1/16 INCREMENTS)  TM or WHEEL GEAR

Record: 1

Table: Component History

Figure 3

# LMOA

## Component History

| MANUFACTURER      |  | SOURCE            |  | CONDITION | APP. DATE  | LOCC# | POS. | REML DATE  | REASON            | DISPOSITION                  |
|-------------------|--|-------------------|--|-----------|------------|-------|------|------------|-------------------|------------------------------|
| ABC MOTOR REPAIRS |  | ABC MOTOR REPAIRS |  | REBUILT   | 03/12/2002 | 4002  | 1    |            |                   |                              |
| ABC MOTOR REPAIRS |  | ABC MOTOR REPAIRS |  | REBUILT   | 12/21/1997 | 4006  | 3    | 01/15/2001 | GROUNDED ARMATURE | SENT TO ABC MOTOR FOR REPAIR |
| ABC MOTOR REPAIR  |  | ABC MOTOR REPAIR  |  | REBUILT   | 06-08/1997 | 4008  | 3    | 09/01/1997 | GROUNDED FIELDS   | RETURNED FOR WARRANTY        |

Component History  
Page 1 of 1

Figure 4

RRR-01-28-00

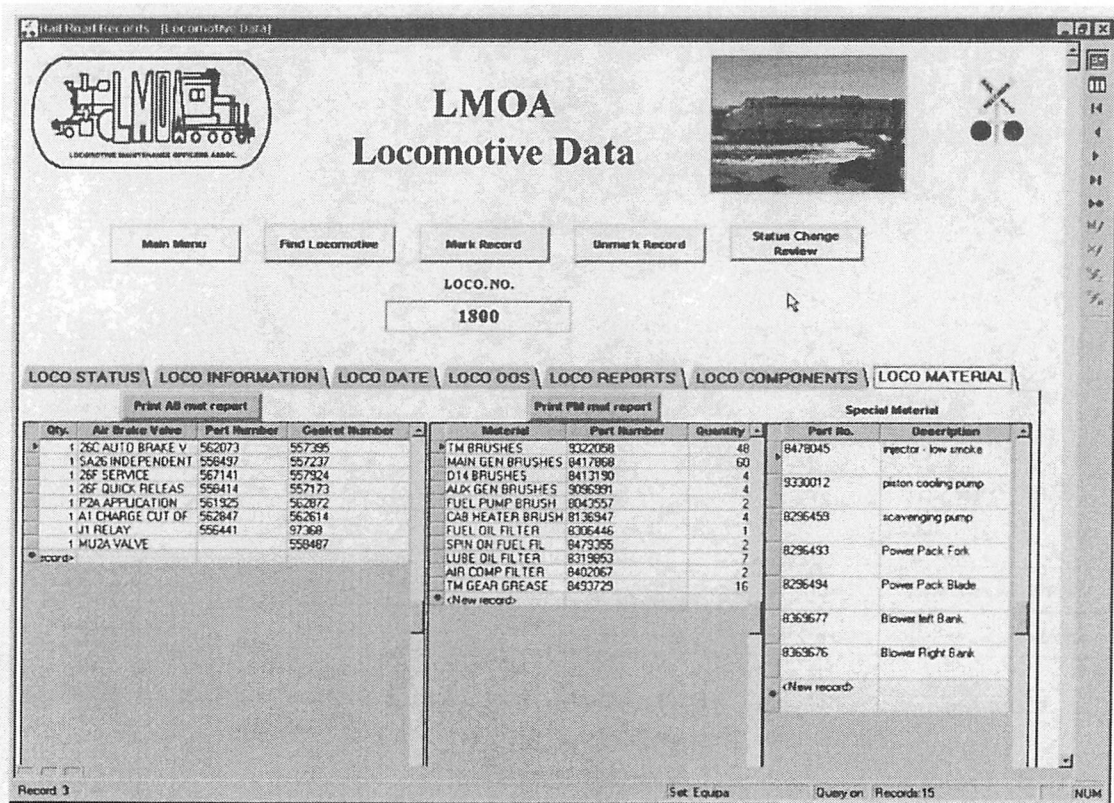



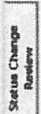
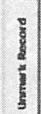
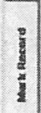
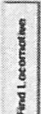
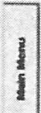
Figure 5

Read Board Files on this PC or on another PC (not a)



# LMOA

## Locomotive Data

LOCO NO.

LOCO STATUS
LOCO INFORMATION
LOCO DATE
LOCO OOS
LOCO REPORTS
LOCO COMPONENTS
LOCO MATERIAL

ASSIGNED REGION  STATUS  FORECAST IS DATE

CALL DATE  ER DAYS  OS DAYS

DAILY STATUS NOTES  
Locomotive must be shipped at Uta for next PM

SHOP NOTES  
Class send hours at next shipping

|              |   |                   |   |                 |   |
|--------------|---|-------------------|---|-----------------|---|
| NEXT LUBE    | <input type="text" value="05/17/2002"/> | NEXT 1 YR.        | <input type="text" value="12/09/2002"/> | NEXT 2.5 YR.    | <input type="text" value="01/23/2003"/> |
| LAST FUELED: | <input type="text" value="03/06/2002"/> | GALLONS ADDED:    | <input type="text" value="1500.0"/>     | FUEL CYCLE DAYS | <input type="text" value="6"/>          |
|              |   | NEXT FUELING DUE: | <input type="text" value="04/03/2002"/> |                 |   |

Record: 3
Set Equip
Query on: Records 15
NUM

Figure 6

Head Report Records (Locomotive Data)

**LMOA**  
Locomotive Data

Locomotive Data

Main Menu Find Locomotive Mark Record Locomotive Record Status Change Review

LOCO. NO. 1800

LOCO STATUS | LOCO INFORMATION | LOCO DATE | LOCO GOS | LOCO REPORTS | LOCO COMPONENTS | LOCO MATERIAL


MFG. EMD MODEL CP12 YR. BILT. 1962 # of CYLINDERS 16

|                            |            |                      |               |
|----------------------------|------------|----------------------|---------------|
| AIR BRAKE TYPE             | 26L        | MAX. PISTON TRAVEL   |               |
| EVENT REC. MFG.            | QUANTUM    | EVENT REC. TYPE      | FRA-SS        |
| EOT MFG.                   | NONE       | EOT TYPE             | 1 WAY         |
| DITCHROAD CROSS LIGHT MFG. | QUANTUM    | DITCHROAD CROSS TYPE | ROAD CROSSING |
|                            |            | LOCATIONS            | BOTH          |
| LAST OVERHAUL TYPE         | PAC        | GEAR RATIO           | 6215          |
| LAST OVERHAUL DATE         | 03/15/1994 | FUEL TANK            | 2300          |
| REVERSE DATE               | 02/21/1982 |                      |               |
| GENERATOR DATE             | 02/21/1982 |                      |               |
| ENGINE DATE                | 07/24/1989 |                      |               |
| TRUCKS DATE                | 07/24/1989 |                      |               |


Record 3 Sk Equip Quality on Records 15 NUM

Figure 7

East Penn Records - Locomotive Data



# LMOA Locomotive Data



Main Menu
Find Locomotive
Mark Record
Unmark Record
Status Change Review

LOCO.NO.  
**1800**

LOCO STATUS
LOCO INFORMATION
LOCO DATE
LOCO OOS
LOCO REPORTS
LOCO COMPONENTS
LOCO MATERIAL

Air Brake Type:

2 Year Air Brake Change

3 Year Air Brake Change

4 Year Air Brake Change (Canada - TOC Extension only)

**Air Brake Tests**

|                          | Date       | Inspection Location |
|--------------------------|------------|---------------------|
| Last 2/3/4 yr. Air Brake | 08/21/1999 | UTICA, NY           |
| Last 1 yr. Air Brake     | 11/04/2001 | UTICA, NY           |
| Last 92 Day Insp.        | 02/15/2002 | NORWICH, NY         |

**Mechanical Tests:**  
Check the appropriate tests for this locomotion

|  | Current OOS | Carry-over OOS | Last Inspection | Next Inspection |
|--|-------------|----------------|-----------------|-----------------|
| <input checked="" type="checkbox"/> 45 Day Lube        |             |                |                 |                 |
| <input checked="" type="checkbox"/> 184 Day Mechanical |             |                |                 |                 |
| <input checked="" type="checkbox"/> 1 Year Mechanical  | 33          |                | 11/04/2001      | 12/09/2002      |
| <input checked="" type="checkbox"/> 2 Year Mechanical  | 33          |                | 11/04/2001      | 12/12/2003      |
| <input checked="" type="checkbox"/> 3 Year Mechanical  | 148         |                | 08/21/1999      | 01/23/2003      |
| <input checked="" type="checkbox"/> 4 Year Mechanical  | 148         | 205            | 10/12/1996      | 10/10/2001      |

Computed Information:

Total out-of-service days:

Next 2/3/4 yr Air Brake:

Next 1 yr. Air Brake:

Next 92 Day Insp.:

Record 3
Set Equipa
Query on Records 15
NUM

Figure 8



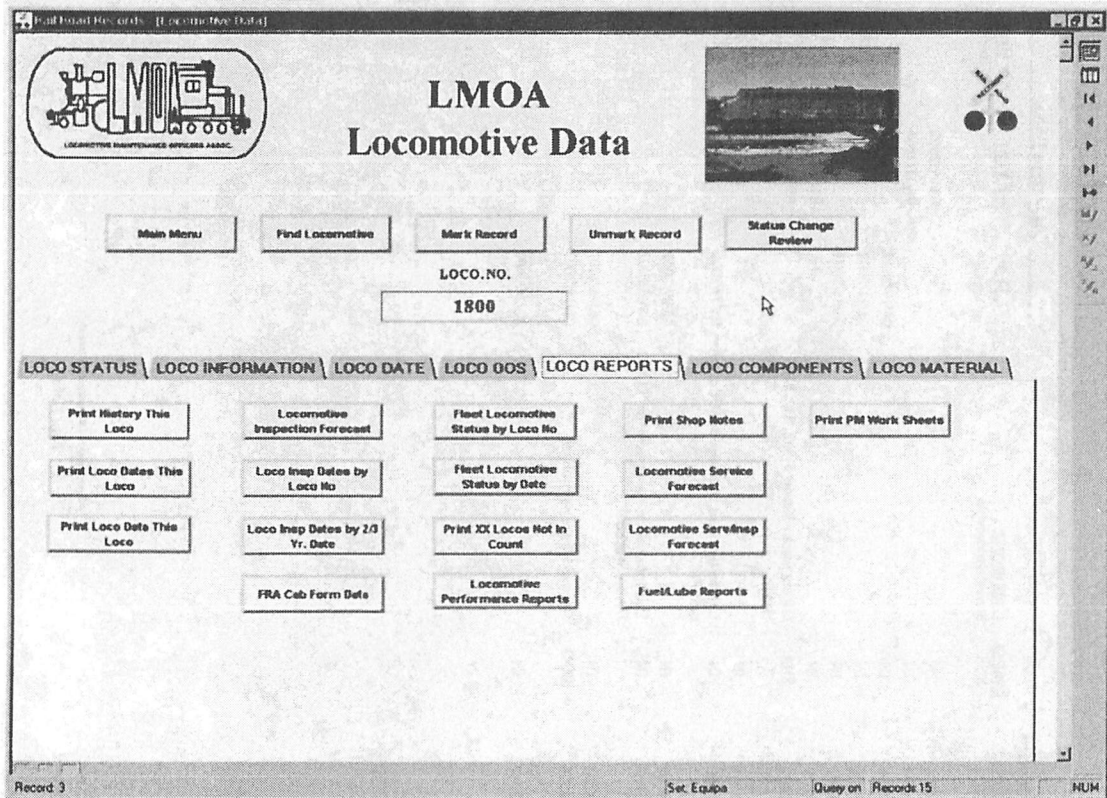


Figure 10

# LMOA

## Locomotive Inspection Forecast

DATE: 06/24/2002

| <u>Locomotive Number</u> | <u>Status</u> | <u>Comments</u>                                    | <u>Inspection Dates</u> |               |                  |
|--------------------------|---------------|--|-------------------------|---------------|------------------|
|                          |               |  | <u>92 Day</u>           | <u>1 Year</u> | <u>Air Brake</u> |
| 3634                     | XSS           | Stored Serviceable                                 |                         |               | 04/26/2001       |
| 2064                     | IN            |  |                         | 04/09/2002    |                  |
| 4004                     | IN            |  |                         | 04/11/2002    |                  |
| 3618                     | IN            |  | 04/17/2002              |               |                  |
| 4008                     | IN            |  | 04/21/2002              |               | 06/27/2002       |
| 2062                     | IN            |  | 04/21/2002              |               |                  |
| 3612                     | IN            |  |                         | 04/26/2002    |                  |
| 1802                     | SHR           | Oil out Stack - Renew #1, #3, #12, #15 Heads       |                         | 05/01/2002    |                  |
| 3614                     | IN            |  |                         |               | 05/03/2002       |
| 1800                     | IN            | Locomotive must be shopped at Utica for next PM    | 05/17/2002              |               |                  |
| 4002                     | IN            |  | 05/29/2002              |               |                  |
| 1804                     | IN            | This Information comes from the "LOCO DATA SCREEN" | 06/06/2002              |               |                  |
| 4006                     | IN            |  | 06/06/2002              |               |                  |
| 2066                     | SRFS          | Dynamic Brake not working                          | 06/19/2002              |               |                  |
| 2012                     | IN            |  | 06/24/2002              |               |                  |

Locomotive Inspection Forecast

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Figure 11

| REPORTING YEAR                   | 1 OPERATED BY          | 2 OWNED BY (Railroad) | RR CODE                | RR CODE         |
|----------------------------------|------------------------|-----------------------|------------------------|-----------------|
| 1992                             | CP18                   | 1800                  | NE                     | 1800            |
| 3 MODEL NO.                      | 4 LOCO NO.             | 5 YR. BUILT           | 6 BY                   | 7 DE            |
| 1800                             | 1800                   | 1962                  | 1800                   | 1800            |
| 8 STEAM GEN                      | 9 GEN #1               | 10 WORKING PRESSURE   | 11 GEN #2              | 12 NE           |
| WORKING PRESSURE                 | TYPE OF AIR BRAKE      | 20L                   | 11. OUT OF USE CREDIT  | 148 Days        |
| 13 LAST PERIODIC INSPECTION DATE | 16 H & H TEST PRESSURE | 19                    | 15 WAIVER PART 229     | 20              |
| 02/15/2002                       | DISABLED               | 21 PERSON CONDUCTING  | 22 TEST DATE AND PLACE | 23 CERTIFIED BY |
|                                  |                        |                       |                        |                 |
| 24 PREVIOUS TEST DATE AND PLACE  | 25                     | 26                    | 27                     | 28              |
| 11/8/2001                        | UTICA, NY              | N/A                   | N/A                    | UTICA, NY       |
| 11/8/2001                        | UTICA, NY              |                       |                        |                 |
| 08/21/1999                       | UTICA, NY              |                       |                        |                 |

| TESTS            |                   | INTERVAL NOT MORE THAN | NUMBER OF CALENDAR DAYS |
|------------------|-------------------|------------------------|-------------------------|
| METER            | 360 calendar days | 41                     | 41                      |
| PUMP AND HYDRO   | 736 calendar days | 32                     | 32                      |
| AIR BRAKE 229.27 | 368 calendar days | 42                     | 42                      |
| Filters Only     | 368 calendar days | 33                     | 33                      |
| ABSORBER 229.25  | 1184              | 8                      | 8                       |

Equipped with Event Recorder per CFR 229.135 - Check appropriate box.

| Out of service from | to         | Days | Out of service from | to | Days |
|---------------------|------------|------|---------------------|----|------|
| 18/21/1999          | 12/01/1999 | 41   | Out of service from |    | 0    |
| 02/12/2000          | 01/16/2000 | 32   | Out of service from |    | 0    |
| 04/01/2001          | 05/12/2001 | 42   | Out of service from |    | 0    |
| 12/01/2001          | 01/03/2002 | 33   | Out of service from |    | 0    |
|                     |            | 8    | Out of service from |    | 0    |

Equipped     Not Equipped

**INFORMATION ON BACK SIDE OF FORM**

Figure 12

# LMOA

## Locomotive Fleet Status by Loco Number

20:28:16  
06-24-2002

| Loco#                        | Last<br>Est | Loco<br>Date | Next<br>PM | Type           | Status                      | Comment  | OS Days  | ER Days      | OS Days | Forecast ER<br>Date |
|------------------------------|-------------|--------------|------------|----------------|-----------------------------|--|----------|--------------|---------|---------------------|
| 2634                         | 03-29-01    | 05-12-01     | 04-26-01   | 2/3 Yr.        | XSS                         | Stored Serviceable                                 | 10-15-01 | 0            | 252     |                     |
| 1802                         | 03-20-02    |              | 05-01-02   | 1 Yr.          | SHR                         | Oil out Stack - Renew #1, #5, #12, #15 Heads       | 02-25-02 | 0            | 119     |                     |
| 2066                         | 03-29-01    |              | 06-19-02   | 3 Mo.          | SRFS                        | Dynamic Brake not working                          | 03-26-02 | 0            | 90      |                     |
| Loco#                        | Last<br>Est | Loco<br>Date | Next<br>PM | Type           | Status                      |  | ER Days  |              |         |                     |
| 1800                         | 03-30-02    |              | 05-17-02   | 3 Mo.          | IN                          | Locomotive must be shipped at Union for next PM    |          |              |         |                     |
| 1804                         | 03-30-02    |              | 06-06-02   | 3 Mo.          | IN                          | This information comes from the "LOCO DATA SCREEN" |          |              |         |                     |
| 2012                         | 03-20-02    |              | 06-24-02   | 3 Mo.          | IN                          |  |          |              |         |                     |
| 2062                         | 03-29-01    |              | 04-21-02   | 3 Mo.          | IN                          |  |          |              |         |                     |
| 2064                         | 03-29-01    |              | 04-09-02   | 1 Yr.          | IN                          |  |          |              |         |                     |
| 3612                         | 03-29-01    | 03-31-02     | 04-26-02   | 1 Yr.          | IN                          |  |          |              |         |                     |
| 3614                         | 03-29-01    | 04-05-01     | 05-03-02   | 2/3 Yr.        | IN                          |  |          |              |         |                     |
| 3618                         | 03-29-01    | 04-18-02     | 04-17-02   | 3 Mo.          | IN                          |  |          |              |         |                     |
| 4002                         | 03-29-01    | 04-14-01     | 05-29-02   | 3 Mo.          | IN                          |  |          |              |         |                     |
| 4004                         | 03-28-01    | 03-21-02     | 04-11-02   | 1 Yr.          | IN                          |  |          |              |         |                     |
| 4006                         | 03-28-01    | 04-22-01     | 06-06-02   | 3 Mo.          | IN                          |  |          |              |         |                     |
| 4008                         | 03-28-01    | 04-21-02     | 04-21-02   | 2/3 Yr.        | IN                          |  |          |              |         |                     |
| <b>Units In service</b>      |             |              | <b>12</b>  | <b>80.00 %</b> | <b>Average Days Enroute</b> |  |          | <b>0.0</b>   |         |                     |
| <b>Units Out of Service</b>  |             |              | <b>2</b>   | <b>13.33 %</b> | <b>Average Days OOS</b>     |  |          | <b>104.5</b> |         |                     |
| <b>Units Stored</b>          |             |              | <b>1</b>   | <b>6.67 %</b>  | <b>Average Days Stored</b>  |  |          | <b>252.0</b> |         |                     |
| <b>Units Leased OFF Line</b> |             |              | <b>0</b>   |                | <b>Total Leased Days</b>    |  |          | <b>0</b>     |         |                     |

Locomotive Daily Status by Loco Number

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RR:10-21-01

Figure 13

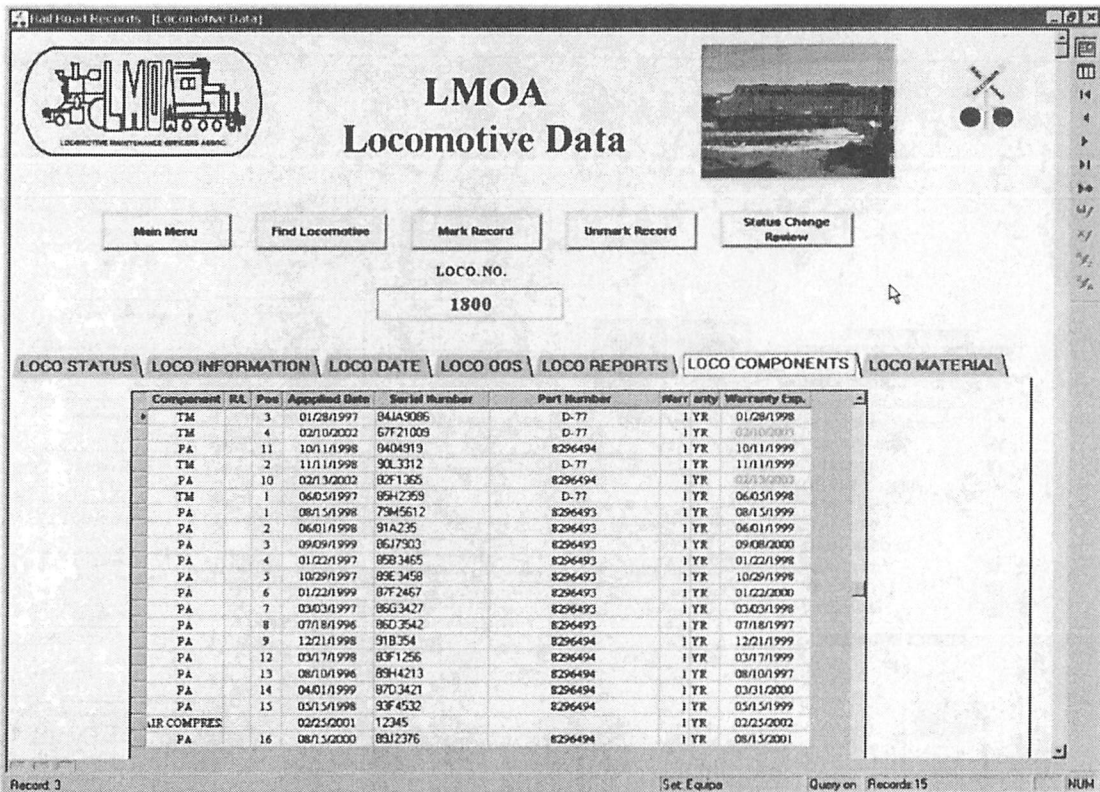


Figure 14



## Locomotive Performance Reports

Reports START Date: 10/01/2000      Reports END Date: 12/31/2000

|   |   |
|---|---|
| <input checked="" type="checkbox"/> Locomotive Detail Report      | Requires Start Date, End Date, and Locomotive Number. Prints detailed Locomotive Performance Report for the requested locomotive between the dates input. |
| <input checked="" type="checkbox"/> Loco Fleet Detail Report      | Requires Start Date and End Date. Prints Detailed Report of Locomotive Performance with all status changes between the dates input.                       |
| <input checked="" type="checkbox"/> Loco Fleet Summary Report     | Requires Start Date and End Date. Prints Summary Report of Locomotive Performance (no status change detail) between the dates input.                      |
| <input checked="" type="checkbox"/> Fleet Model Summary Report    | Requires Start Date and End Date. Prints Summary Report of Locomotive Performance by Models between the dates input.                                      |
| <input checked="" type="checkbox"/> Fleet Summary Report          | Requires Start Date and End Date. Prints Summary Report of Locomotive Performance for fleet between the dates input.                                      |
| <input checked="" type="checkbox"/> Loco Fleet Statistics Report  | Requires Start Date and End Date. Prints Statistics Report, by locomotive, of Locomotive Performance between the dates input.                             |
| <input checked="" type="checkbox"/> Fleet Model Statistics Report | Requires Start Date and End Date. Prints Statistics Report, by locomotive model, of Locomotive Performance between the dates input.                       |
| <input checked="" type="checkbox"/> Fleet Statistics Report       | Requires Start Date and End Date. Prints Fleet Statistics Report of Locomotive Performance between the dates input.                                       |

Record 1      Table Status Change      NUM

Figure 16

# Locomotive Performance - Railroad Summary

Report Date Range: From 10/01/2008 To 12/31/2008

## LMOA

IFS = In Service - Field Service  
 INCALL = In Service - Called to shop  
 IN = In Service  
 SF-184 = Shopped - Called to shop  
 SF-184 = Shopped Field Inspection - 184 Day  
 SF-92 = Shopped Field Inspection - 92 Day  
 SPM = Shopped - Periodic Maintenance  
 S EFR = Shopped Earwax for Repair  
 S AM = Shopped Awaiting Material  
 SHR = Shopped - Heavy Repair  
 SLR = Shopped - Light Repair  
 SFCAL = OOS - Called to shop  
 SRRFS = Shopped - Road Failure Shopping  
 SRRP = Shopped - Road Running Repair  
 SUN = Unscheduled Shopping  
 LWM = Locomotive Lensed Off Line With Maintenance  
 LOK = Locomotive Lensed Off Line  
 XSWD = Stored Waiting Deposition  
 XKS = Stored Serviceable  
 XSL = Stored - Light Repair  
 XSH = Stored - Heavy Repair  
 XSL = Stored - Light Repair  
 XSS = Stored Serviceable  
 XSWD = Stored Waiting Deposition  
 XKX = Locomotive Removed from court

### Railroad Total - 16 Locomotives

NOTE: - All Times are in Days

| Total Shopings                             | 23         | Scheduled Shopings | 14   | Unscheduled Shopings | 9            | Days in Report | 1472         | Period = 1472 | Days in Report | 1387.71 | Report Period = |
|--|------------|--------------------|--|----------------------|--------------|----------------|--------------|---------------|----------------|---------|-----------------|
| Total In                                   | IFS        | IN                 | INCALL   | S EFR                | S AM         | SHR            | SLR          | SRRFS         | SRRP           | SUN     | LWM             |
| Service Days                               | = Days     | + Days             | + Days   | + Days               | + Days       | + Days         | + Days       | + Days        | + Days         | + Days  | + Days          |
| 1281.8                                     | 1271.8     | 9.2                | SF-92  | SF-184               | SF-92        | SPM            | 0.0          | 29.3          | 0.0            | 0.0     | 72.0            |
| Total Scheduled                            | SCH        | SF-184             | SF-92  | S EFR                | S AM         | SHR            | SLR          | SRRFS         | SRRP           | SUN     | LWM             |
| Shop Days                                  | = Days     | + Days             | + Days   | + Days               | + Days       | + Days         | + Days       | + Days        | + Days         | + Days  | + Days          |
| 32.8                                       | 0.0        | 0.0                | 29.3   | 0.0                  | 0.0          | 0.0            | 0.0          | 0.0           | 0.0            | 0.0     | 72.0            |
| Total Unscheduled                          | S EFR      | S AM               | SHR  | SLR                  | SRRFS        | SRRP           | SUN          | LWM           | XKX            | XSWD    | XKS             |
| Shop Days                                  | = Days     | + Days             | + Days   | + Days               | + Days       | + Days         | + Days       | + Days        | + Days         | + Days  | + Days          |
| 73.1                                       | 0.0        | 0.0                | 13.9   | 5.8                  | 23.1         | 0.5            | 29.8         | 0.0           | 0.0            | 0.0     | 72.0            |
| Average Time Between ANY Shopings:         | 55.73 Days | 84.68 Days         | 82.16 Days + (1 or more Locomotives no Unscheduled Shopings) | 92.37%               | Percentage = | 92.37%         | Percentage = | 92.37%        | 92.37%         | 92.37%  | 92.37%          |
| Average Time Between Scheduled Shopings:   | 55.73 Days | 84.68 Days         | 82.16 Days + (1 or more Locomotives no Unscheduled Shopings) | 92.37%               | Percentage = | 92.37%         | Percentage = | 92.37%        | 92.37%         | 92.37%  | 92.37%          |
| Average Time Between Unscheduled Shopings: | 55.73 Days | 84.68 Days         | 82.16 Days + (1 or more Locomotives no Unscheduled Shopings) | 92.37%               | Percentage = | 92.37%         | Percentage = | 92.37%        | 92.37%         | 92.37%  | 92.37%          |

Locomotive Performance - Railroad Summary

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Figure 17

RR-03-26-01

# LMOA

## Locomotive Performance - Railroad Statistics

Report Date Range: From 10/01/2000 To 12/31/2000

### Railroad Total - 16 Locomotives


|  | # of<br>Shoppings | % of Fleet<br>Shoppings                                       | # of<br>OOS Days | % of Fleet<br>OOS Days    |
|--|-------------------|---|------------------|---------------------------|
| Scheduled Shoppings                                | 14                | 60.87%  | 32.79            | 30.97%                    |
| Unscheduled Shoppings                              | 9                 | 39.13%  | 73.08            | 69.03%                    |
| <b>Totals</b>                                      | <b>23</b>         | <b>100.00%</b>  | <b>105.87</b>    | <b>100.00%</b>            |
| <b>Days in Report Period</b>                       | <b>1472.00</b>    |   |                  |                           |
| -Locomotive Leased Days                            | 72.00             |   |                  | In Service<br>Days        |
| -Locomotive Stored Days                            | 12.29             |   |                  | Percent Days<br>Available |
| <b>Loco Days in Report Period</b>                  | <b>1387.71</b>    |   | <b>1281.8</b>    | <b>92.37%</b>             |
| <b>Average Time Between ANY Shoppings:</b>         |                   | 55.73 Days  |                  |                           |
| <b>Average Time Between Scheduled Shoppings:</b>   |                   | 84.68 Days  |                  |                           |
| <b>Average Time Between Unscheduled Shoppings:</b> |                   | 82.16 Days + (1 or more Locomotives no Unscheduled Shoppings) |                  |                           |

Locomotive Performance - Railroad Statistics

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Figure 18


X

## Labor Expense Reports

Reports START Date: 
                         
 Reports END Date:

Shop Order Range  
 To

|   |   |
|---|---|
| <input checked="" type="checkbox"/> Shop Order Summary - System | Requires Start Date and End Date. Prints Labor Hours and Total Labor Costs, by Shop Order Number, between the dates input. System Total.                    |
| <input type="checkbox"/> Shop Order Summary - Location          | Requires Start Date and End Date. Prints Labor Hours and Total Labor Costs, by Shop Order Number, between the dates input. Location Totals.                 |
| <input type="checkbox"/> Pay Code Summary - System              | Requires Start Date and End Date. Prints Labor Hours and Total Labor Costs, by Pay Code, between the dates input. System Total.                             |
| <input type="checkbox"/> Pay Code Summary - Location            | Requires Start Date and End Date. Prints Labor Hours and Total Labor Costs, by Pay Code, between the dates input. Location Totals.                          |
| <input type="checkbox"/> Work Order Summary - System            | Requires Start Date and End Date. Prints Summary Report of Labor Hours and Total Labor Costs, by Work Order Number, between the dates input. System Total.  |
| <input type="checkbox"/> Work Order Detail - System             | Requires Start Date and End Date. Prints Detailed Report of Labor Hours and Total Labor Costs, by Work Order Number, between the dates input. System Total. |
| <input type="checkbox"/> Overtime Summary                       | Requires Start Date and End Date. Prints Summary of Overtime Labor Hours and Total Overtime Labor Costs, between the dates input, by Location.              |
| <input type="checkbox"/> Overtime Detail                        | Requires Start Date and End Date. Prints Detail of Overtime Labor Hours and Total Overtime Labor Costs, between the dates input, by Location.               |

Record 1 Table Form NUM

Figure 19

# LMOA

## Labor Expense by Shop Orders - System Total

FROM 10/01/2000 TO 12/31/2000

Shop Orders 100 to 999


| <u>Shop Order No.</u> | <u>Shop Order Description</u> | <u>Average Rate</u> | <u>Order Hours</u> | <u>Percent Total Hours</u> | <u>Percent Total Wages</u> | <u>Order Total Wages</u> |
|-----------------------|-------------------------------|---------------------|--------------------|----------------------------|----------------------------|--------------------------|
| 100                   | LOCO. MAINT. GENERAL          | \$17.49             | 144.00             | 1.74%                      | 1.88%                      | \$2,518.46               |
| 120                   | PER INSP - MECH               | \$15.37             | 594.50             | 7.20%                      | 6.81%                      | \$9,139.06               |
| 130                   | PER INSP - ELECT              | \$14.75             | 304.00             | 3.68%                      | 3.34%                      | \$4,485.39               |
| 140                   | RR - MECH                     | \$15.37             | 1,157.50           | 14.01%                     | 13.26%                     | \$17,787.88              |
| 150                   | RR - ELEC                     | \$16.02             | 856.50             | 10.37%                     | 10.23%                     | \$13,716.88              |
| 160                   | HR - MECH                     | \$16.58             | 722.50             | 8.74%                      | 8.93%                      | \$11,975.89              |
| 170                   | HR - ELEC                     | \$18.09             | 132.50             | 1.60%                      | 1.79%                      | \$2,396.46               |
| 180                   | CONTRACT REP - MECH           | \$21.58             | 226.00             | 2.74%                      | 3.64%                      | \$4,877.34               |
| 190                   | CONTRACT REP - ELEC           | \$19.31             | 64.00              | 0.77%                      | 0.92%                      | \$1,235.84               |
| 200                   | LOCO SERV                     | \$15.01             | 657.00             | 7.95%                      | 7.35%                      | \$9,861.14               |
| 210                   | LOCO CLEAN                    | \$15.48             | 8.00               | 0.10%                      | 0.09%                      | \$123.84                 |
| 300                   | SHOP CLEANING                 | \$17.86             | 127.00             | 1.54%                      | 1.69%                      | \$2,267.81               |
| 310                   | SHOP MAINT                    | \$16.79             | 242.50             | 2.94%                      | 3.03%                      | \$4,070.46               |
| 330                   | SHOP EQUIP REP                | \$16.81             | 97.50              | 1.18%                      | 1.22%                      | \$1,639.18               |
| 400                   | CAPITAL WORK                  | \$15.79             | 257.50             | 3.12%                      | 3.03%                      | \$4,066.11               |
| 410                   | REIMBURSABLE                  | \$15.02             | 525.50             | 6.36%                      | 5.89%                      | \$7,893.89               |
| 500                   | SAFETY MEETING                | \$14.46             | 21.00              | 0.25%                      | 0.23%                      | \$303.61                 |
| 700                   | VACATION                      | \$16.90             | 632.00             | 7.65%                      | 7.96%                      | \$10,679.44              |
| 705                   | SAFETY DAY                    | \$15.36             | 40.00              | 0.48%                      | 0.46%                      | \$614.56                 |
| 710                   | HOLIDAY                       | \$15.94             | 368.00             | 4.45%                      | 4.37%                      | \$5,864.24               |
| 715                   | NOT PAID - ABSENT             | \$0.00              | 0.00               | 0.00%                      | 0.00%                      | \$0.00                   |
| 720                   | SICK PAY                      | \$20.84             | 48.00              | 0.58%                      | 0.75%                      | \$1,000.40               |
| 900                   | FREIGHT CAR REPAIR            | \$16.79             | 696.00             | 8.42%                      | 8.71%                      | \$11,683.68              |
| 910                   | FREIGHT CAR INSP, AIR TES     | \$16.73             | 58.00              | 0.70%                      | 0.72%                      | \$970.24                 |
| 920                   | CAR REPAIR - DERAILMENTS      | \$17.16             | 30.00              | 0.36%                      | 0.38%                      | \$514.80                 |
| 930                   | LABOR - RERAILING             | \$17.48             | 212.50             | 2.57%                      | 2.77%                      | \$3,715.14               |
| 999                   | SPECIAL DUTY - RATE INCRE     | \$18.06             | 40.00              | 0.48%                      | 0.54%                      | \$722.56                 |
|                       |                               | <u>Average Rate</u> | <u>Total Hours</u> |                            |                            | <u>Total Wages</u>       |
|                       |                               | \$16.23             | 8,262.00           |                            |                            | \$134,124.29             |

Labor Expense by Shop Orders - System Total

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Figure 20


**Fuel and Lube Oil Tracking Reports**

Reports START Date: [00/1/2000]      Reports END Date: [12/31/2000]

Requires Start Date, End Date, and Locomotive Number. Prints Fuel/Lube History for the requested locomotives between the dates input.

Requires Start Date, End Date, and Location. Prints Detailed Report of fuel/lube activity (with locomotive numbers) at that location between the dates input.

Requires Start Date, End Date, and Location. Prints Daily Summary Report of fuel/lube activity (on locomotive numbers) at that location between the dates input.

Requires Start Date, End Date, and Location. Prints Summary Report of fuel/lube activity at that location between the dates input.

Requires Start Date and End Date. Prints Detailed Report of fueling activity (with locomotive numbers) for ALL Locomotives between the dates input.

Requires Start Date and End Date. Prints Summary Report of fuel/lube activity for all locomotives between the dates input.

Requires Start Date and End Date. Prints Detailed Report of fuel/lube history for all locomotives, by locomotive number, between the dates input.

Requires Start Date and End Date. Prints Summary Report of fuel/lube history for all locomotives, by locomotive Model, between the dates input.

Requires Start Date and End Date. Prints Summary Report of fuel/lube history for all locomotives between the dates input.

Record 1      5 of 5 Records

Figure 21

# LMOA

## Fuel/Lube Report -System/Location Summary

10/01/2000 TO 12/31/2000

### BINGHAMTON

#### LOCATION SUMMARY

|                            |           |                                |              |                            |        |
|----------------------------|-----------|--------------------------------|--------------|----------------------------|--------|
| Total Fueling Days:        | 43        | Total Locomotives Fueled:      | 211          | Avg. Locomotive Per Day:   | 4.9    |
| Total Gal. of Fuel:        | 241,774.0 | Total Fuel Cost:               | \$156,257.64 | Avg. Fuel Cost/Gallon:     | \$0.65 |
| Avg. Gal. Fuel/Locomotive: | 1,145.8   | Avg. Fuel Cost/Locomotive:     | \$740.56     |                            |        |
| Total Gal. Lube Oil:       | 4,121.0   | Total Lube Oil Cost:           | \$12,198.16  | Avg. Lube Oil Cost/Gallon: | \$2.96 |
| Avg. Gal. Lube/Locomotive: | 19.5      | Avg. Lube Oil Cost/Locomotive: | \$57.81      |                            |        |

### BUFFALO

#### LOCATION SUMMARY

|                            |         |                                |            |                            |        |
|----------------------------|---------|--------------------------------|------------|----------------------------|--------|
| Total Fueling Days:        | 3       | Total Locomotives Fueled:      | 5          | Avg. Locomotive Per Day:   | 1.7    |
| Total Gal. of Fuel:        | 4,103.1 | Total Fuel Cost:               | \$3,487.63 | Avg. Fuel Cost/Gallon:     | \$0.85 |
| Avg. Gal. Fuel/Locomotive: | 820.6   | Avg. Fuel Cost/Locomotive:     | \$697.53   |                            |        |
| Total Gal. Lube Oil:       | 0.0     | Total Lube Oil Cost:           | \$0.00     | Avg. Lube Oil Cost/Gallon: | \$0.00 |
| Avg. Gal. Lube/Locomotive: | 0.0     | Avg. Lube Oil Cost/Locomotive: | \$0.00     |                            |        |

### NORWICH

#### LOCATION SUMMARY

|                            |         |                                |            |                            |        |
|----------------------------|---------|--------------------------------|------------|----------------------------|--------|
| Total Fueling Days:        | 3       | Total Locomotives Fueled:      | 3          | Avg. Locomotive Per Day:   | 1.0    |
| Total Gal. of Fuel:        | 4,734.0 | Total Fuel Cost:               | \$5,917.50 | Avg. Fuel Cost/Gallon:     | \$1.25 |
| Avg. Gal. Fuel/Locomotive: | 1,578.0 | Avg. Fuel Cost/Locomotive:     | \$1,972.50 |                            |        |
| Total Gal. Lube Oil:       | 0.0     | Total Lube Oil Cost:           | \$0.00     | Avg. Lube Oil Cost/Gallon: | \$0.00 |
| Avg. Gal. Lube/Locomotive: | 0.0     | Avg. Lube Oil Cost/Locomotive: | \$0.00     |                            |        |

Figure 22

# LMOA

## Locomotive Fuel/Lube Summary

### Locomotive Detail

From: 10/01/2000 To: 12/31/2000

#### Foreign Locomotives

| Loco No.          | Times  | Total Fuel        | Avg./day             | Tot Fuel Cost        | Fuel Cost/Day        | Total Lube        | Avg./day             | Tot Lube Cost        | Lube Cost/day        |
|-------------------|--------|-------------------|----------------------|----------------------|----------------------|-------------------|----------------------|----------------------|----------------------|
|                   | Fueled |                   |                      |                      |                      |                   |                      |                      |                      |
| 3000              | 14     | 14,228.7          | 154.7                | \$9,904.05           | \$107.63             | 156.0             | 1.7                  | \$461.76             | \$3.02               |
| 3006              | 7      | 10,913.0          | 118.6                | \$7,433.15           | \$80.80              | 260.0             | 2.8                  | \$769.60             | \$8.37               |
| 3040              | 11     | 12,374.0          | 134.5                | \$8,040.08           | \$87.39              | 135.0             | 1.5                  | \$399.60             | \$4.34               |
| 4050              | 9      | 11,798.0          | 128.2                | \$7,581.56           | \$82.41              | 210.0             | 2.3                  | \$621.60             | \$6.76               |
| 4052              | 10     | 12,199.0          | 132.6                | \$7,971.63           | \$86.63              | 120.0             | 1.3                  | \$355.20             | \$3.86               |
| 4054              | 11     | 16,184.0          | 175.9                | \$11,000.61          | \$119.57             | 155.0             | 1.7                  | \$458.80             | \$4.99               |
| CSXT 3106         | 2      | 1,662.0           | 18.1                 | \$1,201.94           | \$13.06              | 40.0              | 0.4                  | \$118.40             | \$1.29               |
| CSXT 85           | 1      | 1,150.0           | 12.5                 | \$701.50             | \$7.63               | 0.0               | 0.0                  | \$0.00               | \$0.00               |
| NS 6145           | 1      | 1,443.0           | 15.7                 | \$880.23             | \$9.57               | 75.0              | 0.8                  | \$222.00             | \$2.41               |
|                   |        | <b>Total Fuel</b> | <b>Avg./day</b>      | <b>Tot Fuel Cost</b> | <b>Fuel Cost/Day</b> | <b>Total Lube</b> | <b>Avg./day</b>      | <b>Tot Lube Cost</b> | <b>Lube Cost/day</b> |
|                   |        | 81,951.7          | 890.8                | \$54,714.77          | \$594.73             | 1151.0            | 12.5                 | \$3,406.96           | \$37.03              |
| <b>Locomotive</b> |        | <b>Avg. Fuel</b>  | <b>Avg. Fuel</b>     | <b>Avg. Fuel per</b> | <b>Avg. Fuel</b>     | <b>Avg. Lube</b>  | <b>Avg. Lube</b>     | <b>Avg. Lube per</b> | <b>Avg. Lube</b>     |
| <b>Costal</b>     |        | <b>per Loco</b>   | <b>Cost per Gal.</b> | <b>Loco per Day</b>  | <b>Cost per Loco</b> | <b>per Loco</b>   | <b>Cost per Gal.</b> | <b>Loco per Day</b>  | <b>Cost per Loco</b> |
| 9                 |        | 9,105.7           | \$0.67               | 99.0                 | \$6,079.42           | 127.9             | \$2.96               | 1.39                 | \$378.55             |

#### B40-8

| Loco No. | Times  | Total Fuel | Avg./day | Tot Fuel Cost | Fuel Cost/Day | Total Lube | Avg./day | Tot Lube Cost | Lube Cost/day |
|----------|--------|------------|----------|---------------|---------------|------------|----------|---------------|---------------|
|          | Fueled |            |          |               |               |            |          |               |               |
| 4002     | 12     | 17,348.0   | 188.6    | \$12,026.74   | \$130.73      | 220.0      | 2.4      | \$651.20      | \$7.68        |
| 4004     | 11     | 14,569.0   | 158.4    | \$9,140.47    | \$99.35       | 232.0      | 2.5      | \$686.72      | \$7.46        |
| 4006     | 10     | 15,472.0   | 168.2    | \$10,089.04   | \$109.66      | 100.0      | 1.1      | \$296.00      | \$3.22        |
| 4008     | 10     | 12,157.0   | 132.1    | \$9,617.01    | \$104.53      | 185.0      | 2.0      | \$547.60      | \$5.95        |

Locomotive Fuel/Lube Summary

Page 1 of 4

RRR-02-23-01

# LMOA

## Locomotive Fuel/Lube Summary

### System Summary

From: 10/01/2000 To: 12/31/2000

| <u>Total Facilities</u> | <u>Total Fuel</u>     | <u>Avg./day</u>          | <u>Tot Fuel Cost</u>       | <u>Fuel Cost/Day</u> | <u>Total Lube</u>     | <u>Avg./day</u>          | <u>Tot Lube Cost</u>       | <u>Lube Cost/day</u> |
|-------------------------|-----------------------|--------------------------|----------------------------|----------------------|-----------------------|--------------------------|----------------------------|----------------------|
| 253                     | 287,347.8             | 3,123.3                  | \$199,183.86               | \$2,164.17           | 4,346.8               | 45.1                     | \$12,272.16                | \$133.39             |
| <u>Locomotive Count</u> | <u>Avg. Fuel/Loce</u> | <u>Avg. Fuel \$/Gal.</u> | <u>Avg. Fuel Cost/Loce</u> |                      | <u>Avg. Lube/Loce</u> | <u>Avg. Lube \$/Gal.</u> | <u>Avg. Lube Cost/Loce</u> |                      |
| 25                      | 11,493.91             | \$0.69                   | \$7,964.15                 |                      | 165.8                 | \$2.96                   | \$490.89                   |                      |
| <u>Foreign Loco's</u>   |                       |                          |                            |                      |                       |                          |                            |                      |
| 9                       | 9,105.7               |                          | \$6,079.42                 |                      | 127.9                 |                          | \$378.55                   |                      |
| <u>Assigned Loco's</u>  |                       |                          |                            |                      |                       |                          |                            |                      |
| 16                      | 12,837.3              |                          | \$9,024.32                 |                      | 187.2                 |                          | \$554.07                   |                      |

Locomotive Fuel/Lube Summary

Page 1 of 1

RRR-02-06-01

Figure 24

# LMOA

## Fleet Component Dates Report

06/25/2002

### Locomotive No. 1800

| <u>TM1</u>   | <u>TM2</u>    | <u>TM3</u>    | <u>TM4</u>    |               |               |               |               |
|--------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| 06/05/1997   | 11/11/1998    | 01/28/1997    | 02/10/2002    |               |               |               |               |
| <u>#1 PA</u> | <u>#2 PA</u>  | <u>#3 PA</u>  | <u>#4 PA</u>  | <u>#5 PA</u>  | <u>#6 PA</u>  | <u>#7 PA</u>  | <u>#8 PA</u>  |
| 08/15/1998   | 06/01/1998    | 09/09/1999    | 01/22/1997    | 10/29/1997    | 01/22/1999    | 03/03/1997    | 07/18/1996    |
| <u>#9 PA</u> | <u>#10 PA</u> | <u>#11 PA</u> | <u>#12 PA</u> | <u>#13 PA</u> | <u>#14 PA</u> | <u>#15 PA</u> | <u>#16 PA</u> |
| 12/21/1998   | 02/13/2002    | 10/11/1998    | 03/17/1998    | 08/10/1996    | 04/01/1999    | 05/15/1998    | 08/15/2000    |

### Locomotive No. 1802

| <u>TM1</u>   | <u>TM2</u>    | <u>TM3</u>    | <u>TM4</u>    |               |               |               |               |
|--------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| 11/10/1996   | 03/18/1997    | 11/17/1998    | 06/22/1998    |               |               |               |               |
| <u>#1 PA</u> | <u>#2 PA</u>  | <u>#3 PA</u>  | <u>#4 PA</u>  | <u>#5 PA</u>  | <u>#6 PA</u>  | <u>#7 PA</u>  | <u>#8 PA</u>  |
| 06/18/1998   | 02/12/1998    | 03/15/1998    | 04/15/1998    | 05/30/1998    | 10/05/1998    | 07/09/1997    | 01/12/1998    |
| <u>#9 PA</u> | <u>#10 PA</u> | <u>#11 PA</u> | <u>#12 PA</u> | <u>#13 PA</u> | <u>#14 PA</u> | <u>#15 PA</u> | <u>#16 PA</u> |
| 02/16/1997   | 06/08/1998    | 04/15/1998    | 12/11/1999    | 03/04/1998    | 04/04/1999    | 05/03/1999    | 03/04/1999    |

### Locomotive No. 1804

| <u>TM1</u>   | <u>TM2</u>    | <u>TM3</u>    | <u>TM4</u>    |               |               |               |               |
|--------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| 07/26/1997   | 12/12/1999    | 03/27/1998    | 11/16/1994    |               |               |               |               |
| <u>#1 PA</u> | <u>#2 PA</u>  | <u>#3 PA</u>  | <u>#4 PA</u>  | <u>#5 PA</u>  | <u>#6 PA</u>  | <u>#7 PA</u>  | <u>#8 PA</u>  |
| 11/11/1996   | 09/17/1995    | 09/24/1996    | 03/09/1997    | 06/29/1998    | 12/03/1997    | 05/15/1997    | 04/15/1997    |
| <u>#9 PA</u> | <u>#10 PA</u> | <u>#11 PA</u> | <u>#12 PA</u> | <u>#13 PA</u> | <u>#14 PA</u> | <u>#15 PA</u> | <u>#16 PA</u> |
| 09/15/1998   | 06/29/1998    | 09/21/1998    | 11/27/1996    | 05/29/1998    | 05/06/1998    | 08/28/1998    | 06/28/1997    |

### Locomotive No. 2012

| <u>TM1</u>   | <u>TM2</u>    | <u>TM3</u>    | <u>TM4</u>    |               |               |               |               |
|--------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| 05/19/1998   | 03/17/1995    | 12/12/1999    | 07/09/1996    |               |               |               |               |
| <u>#1 PA</u> | <u>#2 PA</u>  | <u>#3 PA</u>  | <u>#4 PA</u>  | <u>#5 PA</u>  | <u>#6 PA</u>  | <u>#7 PA</u>  | <u>#8 PA</u>  |
| 04/06/1998   | 09/17/1998    | 12/05/1994    | 05/16/1997    | 06/17/1998    | 06/12/1995    | 09/07/1998    | 06/06/1997    |
| <u>#9 PA</u> | <u>#10 PA</u> | <u>#11 PA</u> | <u>#12 PA</u> | <u>#13 PA</u> | <u>#14 PA</u> | <u>#15 PA</u> | <u>#16 PA</u> |
| 02/03/1995   | 03/27/1998    | 06/12/1994    | 12/15/1996    | 12/15/1994    | 12/09/1998    | 01/05/2000    | 02/04/1994    |

Fleet Component Dates Report

RRR-05-14-00

Page 1 of 3

## Figure 25

## LMOA

### Fleet Locomotive Wheel Replacement Forecast Summary - Wheels Worn To 1 Inch, by 12/31/2002.

06/26/2002

**120**

|                 |            |               |            |            |         |                  |                  |
|-----------------|------------|---------------|------------|------------|---------|------------------|------------------|
| #1 Big Whl date | 03/02/2001 | #1 Last Meas. | 09/13/2001 | Days       | 195     | Avg wear per day | 0.00240512820513 |
| #1 Big Wheel    | 1.9690     | #1 Last Size  | 1.5000     | Difference | 0.46900 | 1 inch date      | 04/08/2002       |
| #2 Big Whl date | 03/02/2001 | #2 Last Meas. | 09/13/2001 | Days       | 195     | Avg wear per day | 0.00176151846154 |
| #2 Big Wheel    | 1.8750     | #2 Last Size  | 1.5315     | Difference | 0.34350 | 1 inch date      | 07/11/2002       |

**1800**

|                 |            |               |            |            |         |                  |                  |
|-----------------|------------|---------------|------------|------------|---------|------------------|------------------|
| #1 Big Whl date | 03/17/2001 | #1 Last Meas. | 06/20/2001 | Days       | 95      | Avg wear per day | 0.00033157894737 |
| #1 Big Wheel    | 1.0630     | #1 Last Size  | 1.0315     | Difference | 0.03150 | 1 inch date      | 09/23/2001       |

**1802**

|                 |            |               |            |            |         |                  |                  |
|-----------------|------------|---------------|------------|------------|---------|------------------|------------------|
| #2 Big Whl date | 03/26/2001 | #2 Last Meas. | 09/09/2001 | Days       | 106     | Avg wear per day | 0.00029245283019 |
| #2 Big Wheel    | 1.0940     | #2 Last Size  | 1.0630     | Difference | 0.03100 | 1 inch date      | 04/12/2002       |

**1804**

|                 |            |               |            |            |         |                  |                  |
|-----------------|------------|---------------|------------|------------|---------|------------------|------------------|
| #2 Big Whl date | 04/19/2001 | #2 Last Meas. | 10/26/2001 | Days       | 190     | Avg wear per day | 0.00082368421053 |
| #2 Big Wheel    | 1.4065     | #2 Last Size  | 1.2500     | Difference | 0.15650 | 1 inch date      | 08/25/2002       |

**2012**

|                 |            |               |            |            |         |                  |                  |
|-----------------|------------|---------------|------------|------------|---------|------------------|------------------|
| #1 Big Whl date | 08/16/2001 | #1 Last Meas. | 12/05/2001 | Days       | 111     | Avg wear per day | 0.00422072072072 |
| #1 Big Wheel    | 2.1875     | #1 Last Size  | 1.7190     | Difference | 0.46850 | 1 inch date      | 05/24/2002       |
| #4 Big Whl date | 08/16/2001 | #4 Last Meas. | 12/05/2001 | Days       | 111     | Avg wear per day | 0.00591441441441 |
| #4 Big Wheel    | 2.1255     | #4 Last Size  | 1.4690     | Difference | 0.65650 | 1 inch date      | 02/22/2002       |

**SYSTEM SUMMARY**

|                                       |   |
|---------------------------------------|---|
| Wheels to change by 12/31/2002        | 7 |
| Wheels to change next 6 months        | 7 |
| Wheels to change next 6 to 12 months  | 3 |
| Wheels to change next 12 to 24 months | 7 |

Fleet Locomotive Wheel Replacement Forecast  
Summary

RRR 01-31-01

Page 1 of 1

Figure 26

Print Emergency Info


Employee Time Reports

Print This Record

# EMPLOYEE PROFILE

Main Menu

Print Emergency Info



NAME: GERALD K BLACK

ADD 1: 103 WEST GATES ST

ADD 2:

CITY: SYRACUSE

STATE: NY 13027

COUNTRY:

HIRE DATE: 02/15/1997

EMP. NO.: 1015

DEPT: MCL

STATUS: WORKING

LOCATION: SYRACUSE

POSITION: MECHANIC

HOME PHONE: (315) 555-1234

CELL PHONE: (888) 555-7923

PAGER NUMBER: (888) 555-8769

PIN:

RELATION TO EMPLOYEE: Mother

CONTACT PERSON: JOAN BLACK

FIRST PHONE: (315) 555-2345

EXT.:

| Last Name | F. Name |
|-----------|---------|
| BAKER     | DANAL   |
| BOADO     | MARK    |
| BOYCE     | ROCKY   |
| BOYD      | ROCKY   |
| BROOKS    | TIM     |
| BERGER    | WILLIAM |
| BERG      | DAVID   |


Show All

Table Employee Query on Records 8

Record 15

Figure 27

Real-Board Records - Employees - FormView (employeeinfo.cfm)



## EMPLOYEE CONFIDENTIAL INFORMATION

Close

Emp. Info  Salary Info  Training  Sales  Discipline

BLAOK  OGRALD  K

Sec. Sec. No. 123-45-6789

Date of Birth 11/23/1969

Marital Status S \*M\* Married or "S" Single

Dependents 0

| A | M | F | name     |
|---|---|---|----------|
| B | A | K | DANAL    |
| B | O | K | MARK     |
| C | P | O | DOYCE    |
| D | Q | O | BROOKS   |
| E | R | O | BURGER   |
| F | S | O | BURNS    |
| G | T | O | DAVID    |
| H | U | O | CONWAY   |
| I | V | O | LARRY    |
| J | W | O | MAYNE    |
| K | X | O | EDWARDS  |
| L | Y | O | MARK     |
| M | Z | O | GARROWAY |
|   |   |   | KENNETH  |
|   |   |   | RODMAN   |
|   |   |   | HARRISON |
|   |   |   | HASSEL   |
|   |   |   | HERRICK  |
|   |   |   | HOLMES   |
|   |   |   | RONALD   |
|   |   |   | RANSOM   |
|   |   |   | MALES    |
|   |   |   | SOBCK    |
|   |   |   | EDWARD   |
|   |   |   | SMITH    |
|   |   |   | CHARLES  |

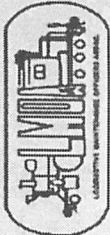

Show All

Record 15

Query on Records: 23

Set Empha

Figure 28

Main Menu    Print Current Record    Find Purchase Order    Print PO    Material Reports

P. O. Number:   
 Request Date:   
 Date Required:   
 Requested By:   
 Approved By:   
 Vendor Name:   
 Vendor Number:

Tax Rate:  %  
 Sub Total:   
 Tax:   
 Shipping:   
 Order Total:   
 Ship VIA:   
 Ship To:   
 Address:   
 Instructions:

| Part Number | Qty | Unit | Description     | Unit Price | Subtotal | Rec. Date | Quant. | Rec. # | Inv. # |
|-------------|-----|------|-----------------|------------|----------|-----------|--------|--------|--------|
| 3033623     | 1   | EA   | U LX CONTROLLER | \$200.00   | \$200.00 | 12-10-00  | 1      |        | 1860   |
| 8478046     | 2   | EA   | U DP INJECTOR   | \$55.00    | \$110.00 | 12-10-00  | 2      |        | 1860   |

Notes:

Record 488    Set Order Set    Query on    Records 543    NUM

Figure 29

## The AMSTED Rail Group Makes It Easy

Now it's easier than ever to work with us for your castings, bearings and wheel needs. We've grouped the sales and marketing functions of our ASF-Keystone, Brenco/QBS and Griffin Wheel divisions under one umbrella organization called the AMSTED Rail Group. System solutions or individual components from all three of our railroad products divisions are presented through a single contact with one of our qualified sales managers. It's as easy as that.



AMSTED Rail Group 312.853.5680  
200 West Monroe Street, Suite 2300, Chicago, Illinois 60606

**REPORT OF THE COMMITTEE  
ON DIESEL MATERIAL CONTROL  
TUESDAY, SEPTEMBER 24, 2002  
9:00 A.M.**



**Benoit Girard, Chairman**  
Manager Procurement-Locomotive  
Canadian Pacific Railway  
Calgary, Alberta

Vice Chairman  
**John Minnie**  
Materials Manager  
BNSF Railway  
West Burlington, IA

**COMMITTEE MEMBERS**

|               |                        |                        |                         |
|---------------|------------------------|------------------------|-------------------------|
| R. Delevan    | Mgr.-Transp. Products  | National Elect. Carbon | Wilkes Barre, PA        |
| J. Fronckoski | Loco. Procurement Mgr. | CSX Transportation     | Jacksonville, FL        |
| J. Hartwell   | VP-Sales               | Progress Rail          | Jacksonville, FL        |
| B. Harvilla   | Sales Manager          | Standard Car Loco.     | Strongsville, OH        |
| G. Sumpter    | Superintendent-Locos.  | Florida East Coast     | New Smyrna<br>Beach, FL |

New Committee Members: Pat Johnson, Norfolk Southern; Kriss Myers, GETS

## PERSONAL HISTORY

### *Benoit Girard*

Benoit Girard is the manager procurement - rolling stock at Canadian Pacific Railway Calgary, Alberta head office, with over 24 years of experience in the rail industry.

He began his career with Canadian Pacific in January 1978 at Angus shop in the Material department in Montreal. In 1992 he became senior material supply specialist when Purchasing and Material merged. During the summer of 1997 he transferred from

Montreal to Calgary when CPR decided to move its head office. Finally, in January 1999, he was appointed to his current position.

He and Sylvie, who have been married for 21 years have one son, Pierre-Olivier.

**I. "MENTORED  
CHAMPION PROCESS"  
CSX SUPPLY & SERVICE  
MANAGEMENT**

*Prepared by: Jim Hartwell,  
Progress Rail Services and  
Jim Fronckoski, CSX Transportation*

**Overview: (see Figures 1, 2 & 3)**

- Procurement Process used by the P&M department that is:
  - Structured
  - Team oriented
  - Proactive
  - Developing lowest possible supply chain to maximize savings in the shortest time possible.
- **Products or services**
  - Expired contracts
  - Problems with products and/or service
  - New products become available new programs or maintenance practices change
  - High cost, high volume goods and services are candidates.
- **Timeline**
  - Start and end dates
  - Schedule
  - Keeps project on track
  - Deviation.
- **Benchmarking**
  - Structure method of comparing
  - Identify companies to benchmark with
  - Look for innovation.
- **Team (Driving force behind the success)**
  - Cross functional team - All applicable parties (P&M, Engineering, Mechanical, etc.)
  - Participants have background and knowledge to make the best decision.
  - Establish consensus goals
  - Finance & QC/QA are always participants
  - P&M usually takes the lead, documents and analyzes.
- **Strategy**
  - Team develops strategy (lower total supply costs, cradle to grave)
  - Type of material-standardization
  - Freight cost, complete freight costs (local vs. national process)
  - Inventory costs, consignment opportunities
  - Manufacturing costs, set up and turnaround time
  - Long term partnership benefits.
  - New vs. reconditioned
  - Make vs. buy
  - Explore warranty options
  - Measurable performance
  - Bundling (Pulling products together to maximize purchasing power).
- **Technical Forums**
  - Meet with potential suppliers and review offerings
  - Solicit feedback and opportunities
  - Review specifications for standardization and cost efficiencies-re-engineer

Fine tune specifications to achieve the lowest total supply cost and highest life cycle costs

“Best of the Best” incorporated into the RFP (request for proposal).

- **Request for Proposal (RFP)**

Standardize format

Re-engineered specification

RFP issued to innovative suppliers who demonstrate commitment to improve CSX’s competitive position during technical forums

Meets established timelines.

- **Proposal Analysis**

Team analyzes proposals on standard forms

Suppliers are eliminated (short list)

Selected suppliers move on to negotiations

Lowest bidders are not always lowest total supply chain cost.

Review all factors.

- **Negotiations**

Negotiate with most promising suppliers

Team prepares strategy that addresses:

Cost and savings

Supplier’s market position

Ability and skills of suppliers

Ability to deliver quality products on time

Ability to attack problems and seek resolution - follow-up

Issues concerning both parties interests

“Win-Win” situation

Important document details and assignments

Follow up.

- **Award**

Based on strategy phase and proposal reviews

Team makes recommendation for the lowest total supply chain cost award

Contract duration length

Summary of costs and savings

Implementation plan

Prepares award using standard agreements.

- **Follow Up**

As important as the entire process

Team follow up, if required, individuals with interests in the process

Schedule periodic meetings with awarded suppliers to review status

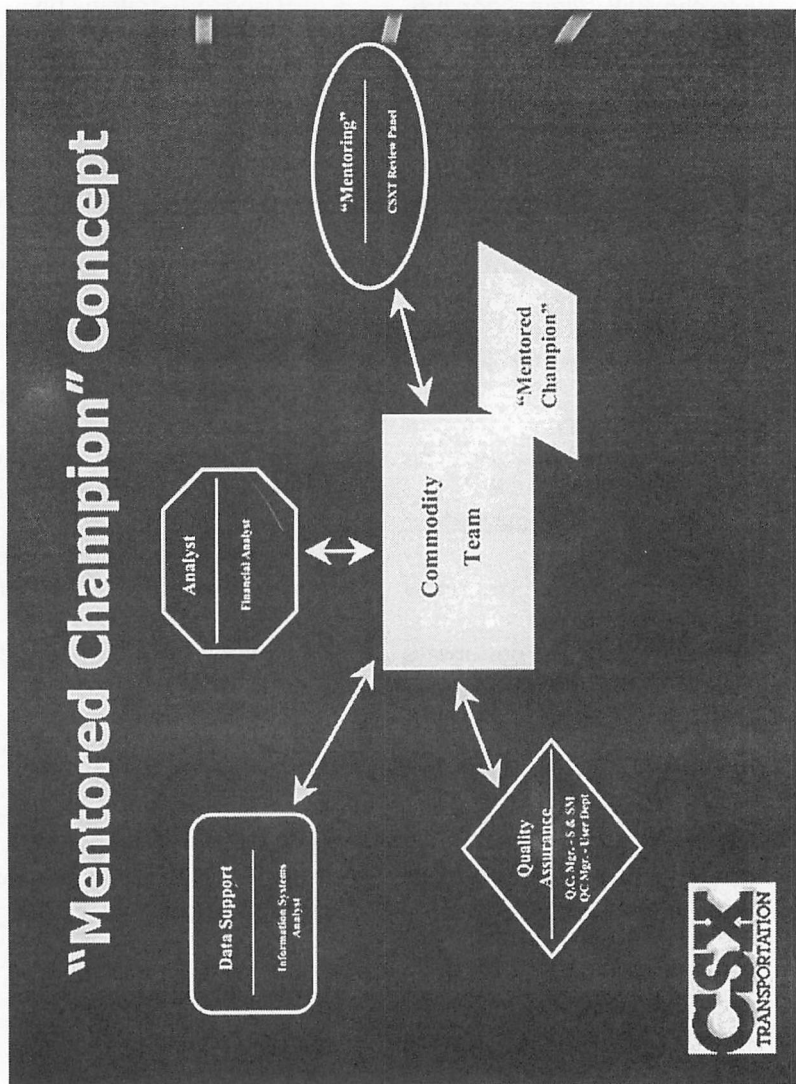
Explore additional opportunities

Resolve problems

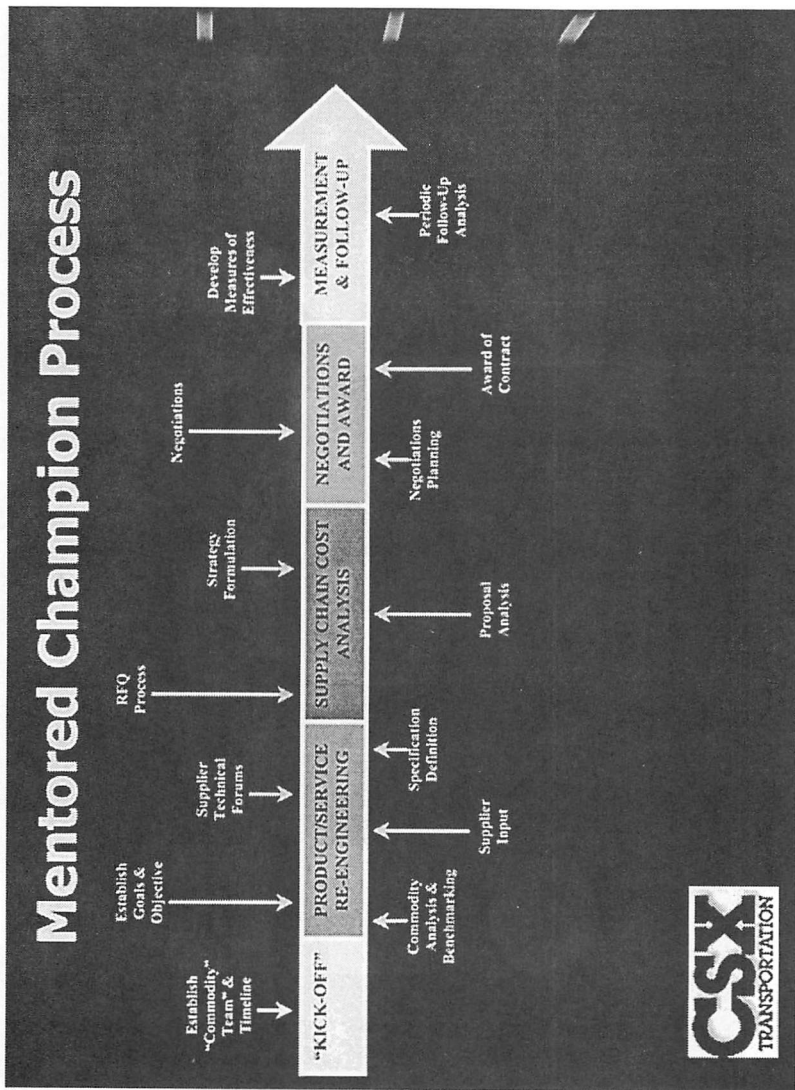
Continue to fine-tune the process.

**Minimize total supply chain costs through a structured process and team approach.**

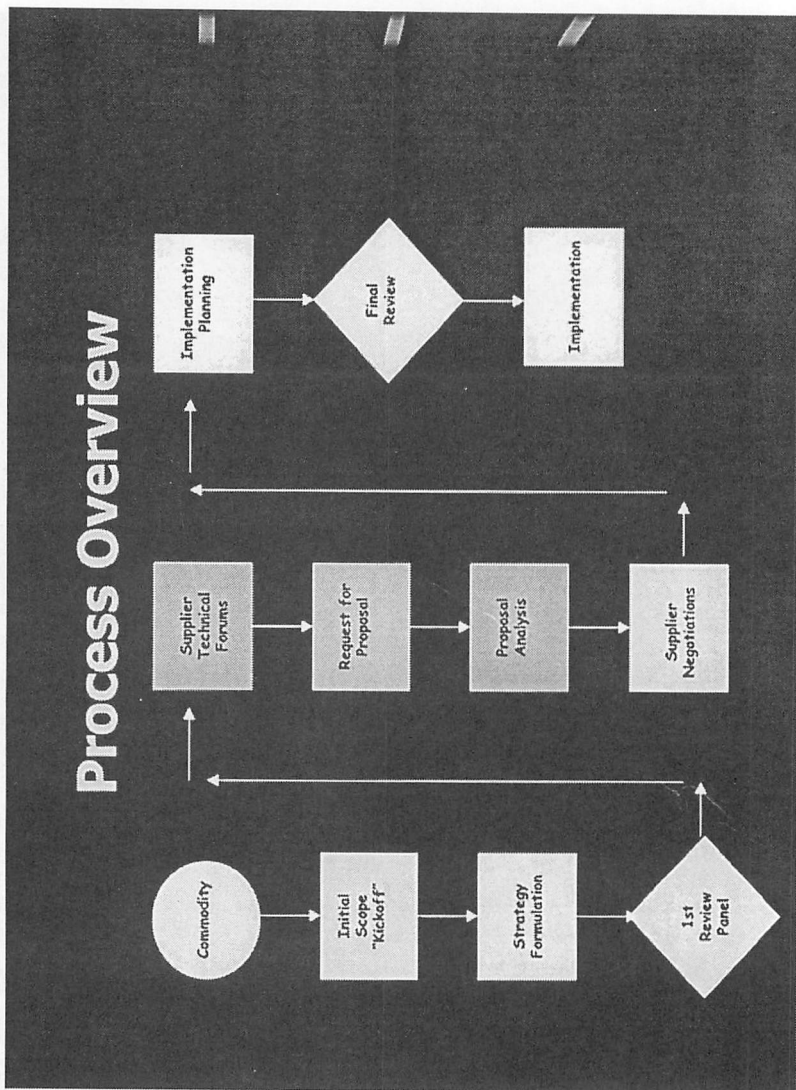
(Figure 1)



(Figure 2)



(Figure 3)



**REPORT OF THE COMMITTEE  
ON FUEL, LUBRICANTS AND ENVIRONMENTAL  
TUESDAY, SEPTEMBER 24, 2002  
10:30 A.M.**



**Ron Lodowski, Chairman**

Superintendent-Locomotives, CSX Transportation  
Selkirk, NY

Vice Chairman

**Robert Dittmeier**

Technical Services Coordinator, Ethyl Petroleum Additives  
Richmond, VA

**COMMITTEE MEMBERS**

|                |                                |                          |                    |
|----------------|--------------------------------|--------------------------|--------------------|
| D. Bachelder   | Manager                        | Caltex Services          | Dallas, TX         |
| G. Bills       | Vice President                 | Searle Petroleum Co.     | Council Bluffs, IA |
| Z. Bolt        | Application Engineer           | Exxon Mobil L&PS         | Houston, TX        |
| D. Campbell    | Technical Engineer             | Electro Motive Divn.     | LaGrange, IL       |
| K. Davis       | Mgr.-Test & Lab Services       | CSX Transportation       | Waycross, GA       |
| D. Doughty     | Director-Springfield Lab       | TSL, Inc.                | Springfield, MO    |
| T. Eitzen      | Staff Engineer                 | Chevron Lubricants       | Richmond, CA       |
| D. Elvin       | Sales Manager                  | Ondeo-Nalco              | Kennett Square, PA |
| S. Fritz, P.E. | Senior Research Engineer       | Southwest Res. Institute | San Antonio, TX    |
| F. Girshick    | Mgr.-Tech. Svcs. Rep.          | Infineum USA, L.P.       | Linden, NJ         |
| L. Haley, Jr.  | Chief Chemist                  | Norfolk Southern Corp.   | Chattanooga, TN    |
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| J. Jackson     | Mgr.-Mech. Engineering         | Amtrak                   | Wilmington, DE     |
| D. McAndrew    | Fuel & Lube Specialist         | GE Transportation        | Erie, PA           |
| M. Melnyk,     |                                |                          |                    |
| Ph.D.          | Systems Integration Eng.       | GE Lubrizol, LLC         | Wickliffe, OH      |
| M. Mulvihill   | Mgr.-Research &<br>Development | Bestolife Corporation    | Dallas, TX         |
| T. Pyziak      | Railroad Acct. Executive       | Safety-Kleen Oil Rec.    | Palatine, IL       |
| C. Tincher     | Product Manager                | Lyondell Lubricants      | Houston, TX        |
| P. Whallon     | Mgr.-OEM Sales                 | Clark Filters            | Lancaster, PA      |

Returning to Committee: Chuck Kunkel, Union Pacific RR, Welcome back, Chuck!

## PERSONAL HISTORY

### *Ron Lodowski*

Mr. Lodowski was born in Buffalo, New York on March 4, 1950. After his elementary and high school education, he scholared at Canisius University in Buffalo and received a Bachelor of Science degree in Chemistry in 1972.

He began his railroad career with the Penn Central as a Freight Carman in 1975. In March 1977, he transferred to the Locomotive Department and was promoted to General Foreman in Buffalo. In July 1984, he was transferred to Selkirk, New York and was promoted to Manager - Environmental Operations. In August of 1989, he was given the additional duty of

Supervisor - Oil Control Labs. In March 2000, Ron was promoted to Superintendent - Locomotives at Selkirk for CSX Transportation.

Ron's hobbies are travel, photography, and he enjoys spectator sports such as hockey and football.

He has been married for 33 years and his wife's name is Susan. They have two children, Michael 32, and Nicole, age 16. Ron and Susan also have two grandchildren.

## I. IMPROVED GENERATION 5 LUBRICANT PROVIDES POTENTIAL FOR EXTENDED LUBE OIL FILTER LIFE

*Prepared by  
Wes Middleton, Chevron*

### Introduction

Cost is a critical issue for modern railroads. In total the top seven North American railroads spend around nine million dollars for the 718,000 oil filters that are consumed yearly. This does not include costly locomotive down time, shop labor for changing the filters or the price of disposal of the used filters, a figure estimated to be equal to or higher than that of a new oil filter.

Engine oil additive research has put significant emphasis on improving the oil's ability to better handle insolubles through improved dispersant technology. This provides the opportunity to extend oil filter life and reduce the costs associated with them. In addition, modern additive technology provides a margin of safety against filter bypass, an operational mode that can accelerate engine wear.

This paper presents the results of four case studies where railroads determined that they could double their oil filter life by using an improved Generation 5 formulation with excellent dispersant characteristics.

Extending oil filter life through the use of dispersancy has been demonstrated while conducting extended oil drains during improved Generation 5 field testing. Results showed that oil filters could take 180

days without plugging despite insoluble levels over 5.5 mass%. Figure 1 compares the oil filter performance of two Generation 5 lubricants, one using improved dispersant technology after 180 days service and the reference using older Generation 5 technology after 92 days. As can be seen, the filter using the improved dispersant technology is much cleaner even though it ran twice as long.

Figure 2 is a macrograph (31X) showing the difference in the filter media of the previous two filters. This is an example of the superior insoluble handling of the newer dispersant technology.

### Running the numbers

In mid 2001 a survey of several class 1 railroads revealed that there were no reported incidents of oil filter plugging during the previous year. Oil filter changes were scheduled to coincide with each locomotive's 92 day maintenance schedule and all roads surveyed expressed an interest in extending oil filter life.

Those who participated reported using filters of 12u or 18u nominal pore diameter for use in EMD locomotives and 28u nominal pore diameter filters for their GE engines.

Depending on the model, a locomotive may have a 7, 8 or 10 element filter tank. Today a large class 1 railroad can expect to save over \$1 million per year in new filter costs; add to that an equal amount in shop labor and disposal charges.

For example, a railroad with a reported 6,000 locomotives would purchase about 192,000 oil filters per year at a cost of approximately

\$2.4 million. An immediate yearly saving of \$1.2 million would be realized by doubling the oil filter change interval. On top of that figure is the cost of locomotive down time and shop labor. Used filter disposal charges are estimated to range between 50% to 100% of that of the new filters, giving a conservative estimate of around \$2 million.

### **180 Day Filters Made Viable by Dispersants**

Modern lubricants are up to the challenge of extending oil filters due to the use of ashless nitrogen succinimide dispersants. A model of a dispersant molecule is shown in Figure 3.

Each molecular is comprised of a nitrogen containing polyamine polar head (which absorbs onto soot particles), a linking group and a solubilizing polybutene tail, which provides a physical barrier to aggregation and keeps the particles suspended in the oil.

Stabilized carbon particles can be represented by ball-and-stick dispersant molecules clustered around a solid particle. Figure 4 is a depiction of the process of stabilizing solid particles.

Nitrogen containing succinimide dispersants are capable of suspending large amounts of insoluble material while maintaining viscosity control and keeping oil filters clean.

An example of the dispersant effect on aggregation is shown in Figure 5.

In addition, it has been demonstrated that formulations which minimize soot aggregation and viscosity

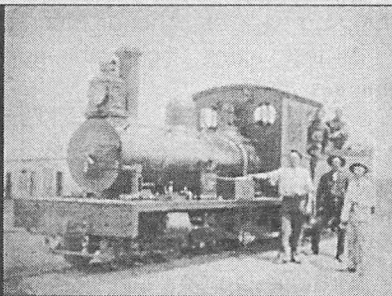
increase also give superior wear performance by reducing soot causing abrasive wear. (1)

A big question has been whether or not the filter media itself is capable of surviving the additional 90 days without excessive wear, tearing or even collapsing. All of the tests outlined in this paper were conducted using the standard OEM approved filters. These results suggest that the media is durable enough for the double change interval.

One filter manufacturer has, however, conducted test work on an extended life media. This media was developed to have greater contaminant holding capacity while maintaining a lower pressure drop under full flow conditions. At the same time, the media was designed for high-strength characteristics necessary to withstand the demands of 180-day service. Media integrity was evaluated and corroborated by means of the following test procedures:

a) Mullen Burst (determines the burst pressure of a simple piece of media by gradually inflating a rubber bladder beneath the media section until point of failure). An independent laboratory performed testing on a group of 16 filter elements removed after 180 days of locomotive service. Three separate media sections from each element were collected, tested and an average Mullen value established for each of the 16 elements. All tests values exceeded the minimum requirement.

## **TRAIN ROBBERY DIDN'T END IN THE 1800s**



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- b) **Fabrication Integrity** (determines integrity of the filter element per ISO 2942 by submerging cartridge in a liquid bath and introducing gradually increased pressurized air to the center of cartridge until bubble leakage is observed). An independent laboratory performed testing on a group of 10 filter elements removed after 180 days of locomotive service. A series of two tests were performed on each of the 10 elements. All test values exceeded the minimum requirement.
- c) **Seal Integrity** (determines integrity of cartridge seal by submerging filter in liquid bath and introducing pressurized air internally to the cartridge and noting any bubble leakage from seal area). An independent laboratory performed testing on a group of 40 filter elements removed after 180 days of locomotive service. A series of two tests were performed on each of the 10 elements. All test values exceeded the minimum requirement.
- d) **Media Bond** (determines the integrity of adhesive bond between filter media and cartridge end cap through application of tensile stress until point of failure). An independent laboratory performed testing on a group of 40 filter elements removed after 180 days of locomotive service. A series of two tests were performed on each of the 10 elements. All test values exceeded the minimum

requirement.

### **Conclusion**

Independent laboratory testing on one filter manufacturer's product developed for 180-day service demonstrated that not only filter media but other critical components such as adhesives, outer wrap, center cores and end caps are capable of extended service.

Recent test work with several railroads has shown that extending the oil filter change interval is an achievable goal.

### **Case Study 1**

In 1998 this railroad was having filter plugging problems with its fleet of older SD45 locomotives. Filters were plugging, necessitating changes every 45 days. A test was initiated to determine if filter extension, in this case back to the normal 92 days, was possible.

A program was set up in which the locomotives would change from their current Generation 5 fleet oil to an improved Generation 5 lubricant containing an updated dispersant. The locomotives would undergo an oil and filter change and then be returned to regular service. Filter samples would be taken from the locomotives and submitted for flow testing at the 92 day interval.

This test consists of cutting three 2 inch by 2 inch sections from one of the oil filters, mounting it in a filter rig and timing how long it takes to filter 100 grams of 150 neutral oil at constant vacuum. The average of the three determinations is reported and the filter is considered plugged if the time was equal to or exceeded

600 seconds. After gaining more experience with this procedure it was determined that the maximum filtration time could be reduced to 400 seconds.

The filter samples would also be visually rated under low magnification using a scale of 1 to 5 with 1 describing the media fibers as clean and 5 being completely plugged with no fibers visible.

Figure 6 compares the Generation 5 fleet oil after 45 days to the improved Generation 5 product after 92 days of service.

As can be seen, of those tested, all were successful in reaching 92 days. Three had, however, reached the 600 second limit. As a result this road switched to the improved Generation 5 product and returned its SD45's to a 92 day oil filter change interval. In addition, the nominal filter pore diameter was returned to the EMD recommended 12u from 18u.

### **Case Study 2**

In November, 1999 a European railroad that had recently purchased a sizable fleet of EMD SD70 type locomotives expressed an interest in oil filter extension. These units were already using an improved Generation 5 lubricant. A short program was set up in which filter sections from five locomotives along with oil samples were evaluated after the normal 92 day service interval.

The results were encouraging and the test was re-run on six different locomotives after they had run a total of six months. Filtration times for the six month filters averaged

about double that of the three month filters but, in either case, filtration times were considered low. This data was encouraging enough for this road to switch its entire EMD fleet over the six month filter changes. Today it is considering expanding again out to one year. The test data for these locomotives is shown in Figure 7.

The new test criteria which define a plugged filter as one which takes 400 seconds or longer to filter 100 grams of 150 neutral oil was used in this study and all subsequent studies in this paper.

### **Case Study 3**

More recently, other North American railroads are showing interest in oil filter extension as a means to help reduce costs. This railroad, already using an improved Generation 5 product, wanted to evaluate a cross section of its fleet at 92 days as a baseline to evaluate the possibility of extending its oil filter change interval. Results were, as can be seen in the charts in Figure 8, very encouraging. The data in Figure 8 covered six different models of GE and seven of EMD. A total of 46 locomotives participated and at 92 days none of the filters was plugged. One GE and two EMD had excessive filtration times, but analysis showed that these were due to minor water leaks.

A few months later, a second look, shown in Figure 9, was just as encouraging. The number of locomotives was reduced to 15, covering three GE models and nine EMD locomotive models. Again, one GE

and one EMD exhibited slowed filtration times due to minor water leaks. Both exercises gave a strong indication that oil filter extension could be successful at this railroad. Subsequent to this study this particular road has decided to move to 180 day oil filter changes.

#### **Case Study 4**

This program was set up to monitor the filter tank pressure on three models of EMD locomotives. For the purposes of this test the filters would be defined as plugged and would be changed if the filter tank pressure reached or exceeded the by-pass pressure 35 psi. Three locomotives each of three EMD models participated in this study.

As of the date of writing, two of the three SD70's had successfully reached 180 days. The third had to be restarted due to fuel contamination of the oil. The SD40's have been the most problematic due to a variety of mechanical problems and had to be re-started. One unit made 180 days with no mechanical problems. Two units experienced water contamination and needed to be restarted. An extra SD40 was put on test at our request to get another data point. So far, this unit is progressing nicely and should make the 180 day target. It should be noted that these units perform nicely with respect to filter plugging unless they experience a water leak. It is our opinion that these units will make 180 day filter changes barring any mechanical problems.

#### **Conclusion**

Four case studies were conducted at four different railroads involving a total of 62 EMD locomotives and 31 GE engine types. These have demonstrated that a modern engine oil formulation with a high quality dispersant can provide 180 day oil filter life provided there are no water leaks.

Testing conducted with an independent laboratory by one filter manufacturer on filters developed for 180 day service demonstrated that not only the media, but other critical filter components such as seals end caps and wrapping are capable of extended service.

With cost reduction as a major goal of today's Class 1 railroads, oil filter extension can make a significant contribution by helping increase locomotive availability while lowering related shop labor costs and reducing expensive hazardous waste.

#### **References**

- (1.) October 1984 SAE "Effect of Oil Formulations in Minimizing Viscosity Increase and Sludge Due to Diesel Engine Soot" J. A. McGeehan, J. D. Rynbrandt, and T. J. Hansel, Chevron Research Co.

#### **APPENDIX**

##### **Railroad engine used filter test rating procedure**

1. Soak filter patch for five minutes in hexane/pentane, slowly wafting filter patch when placing in the solvent and when removing from the solvent.

2. Heat at 150° degree oven for five minutes to evaporate residual hexane/pentane.

3. Place filter patch under microscope with maximum lighting. Center crosshairs of the microscope in the "valley" and take picture at 10x magnification, and 32x magnification.

4. Rate filter patch in the "valley" using the following scale:

1 = Clean. No visible sludge.

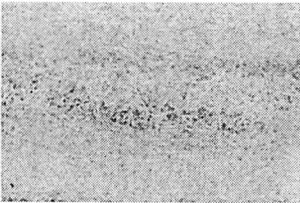
2 = Mild crusting of sludge.

3 = Significant webbing between fibers.

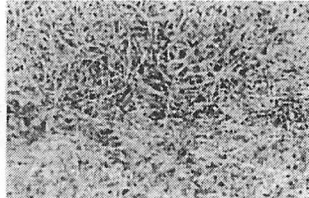
4 = Most fibers covered with sludge. Almost can't see fibers.

5 = No fibers visible.

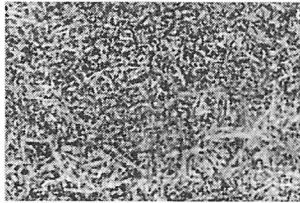
1.



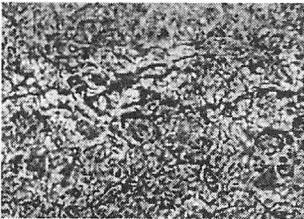
2.



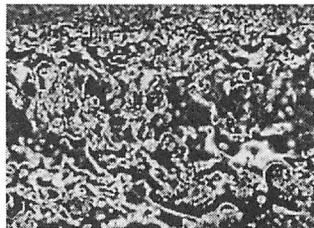
3.



4.

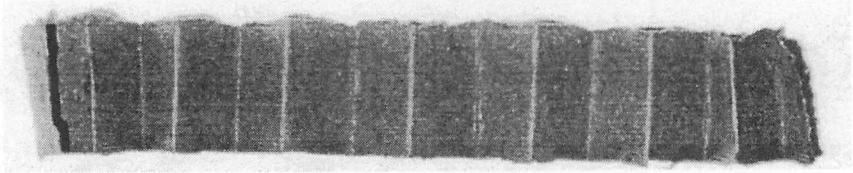


5.

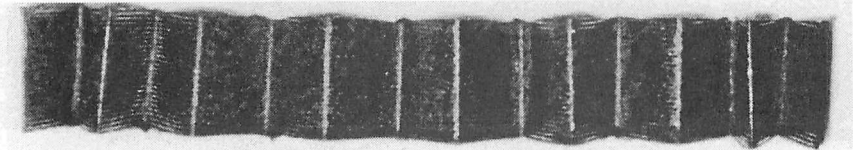


### Figure 1 Generation 5 Approval Field Testing

GE B30-7A



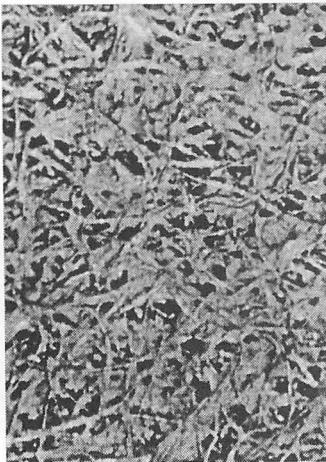
180 day filter using improved Gen. 5 dispersant technology



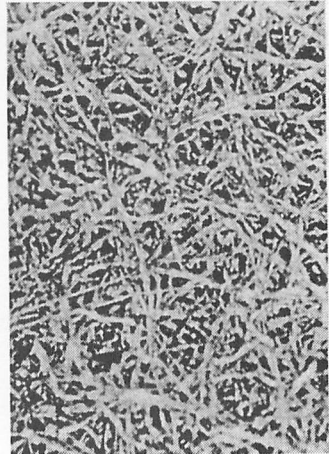
92 day filter using Gen. 5 dispersant technology

### Figure 2 Generation 5 Approval Field Test

(GE B30-7A Filters)



Generation 5 at 92 days



Improved Generation 5  
at 180 days.



Figure 6

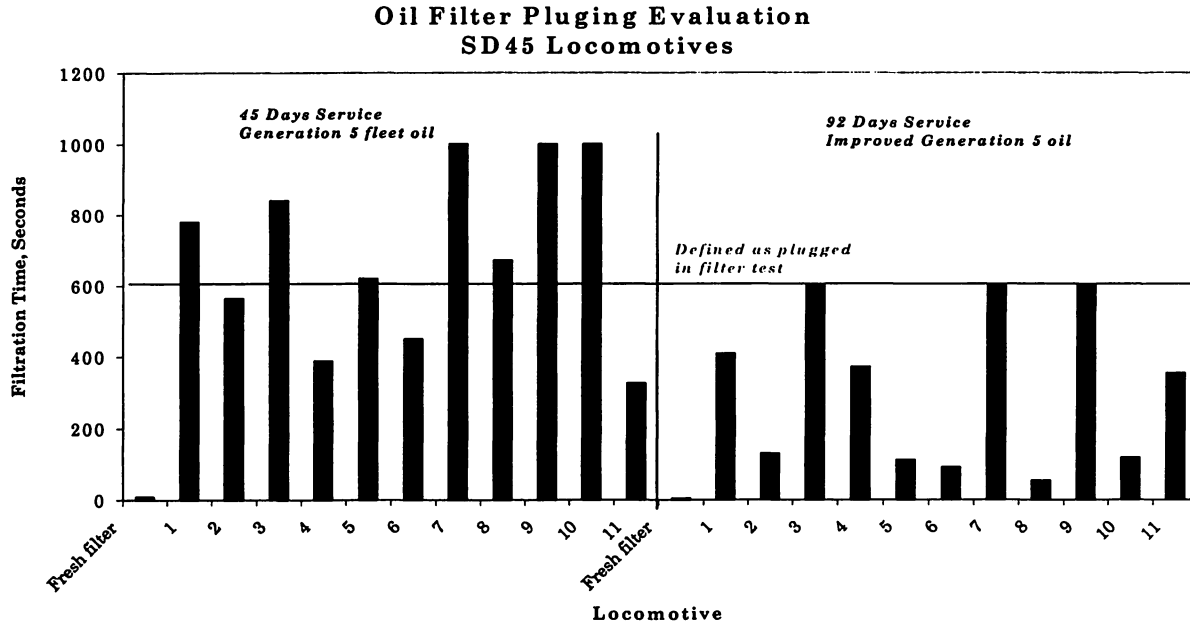
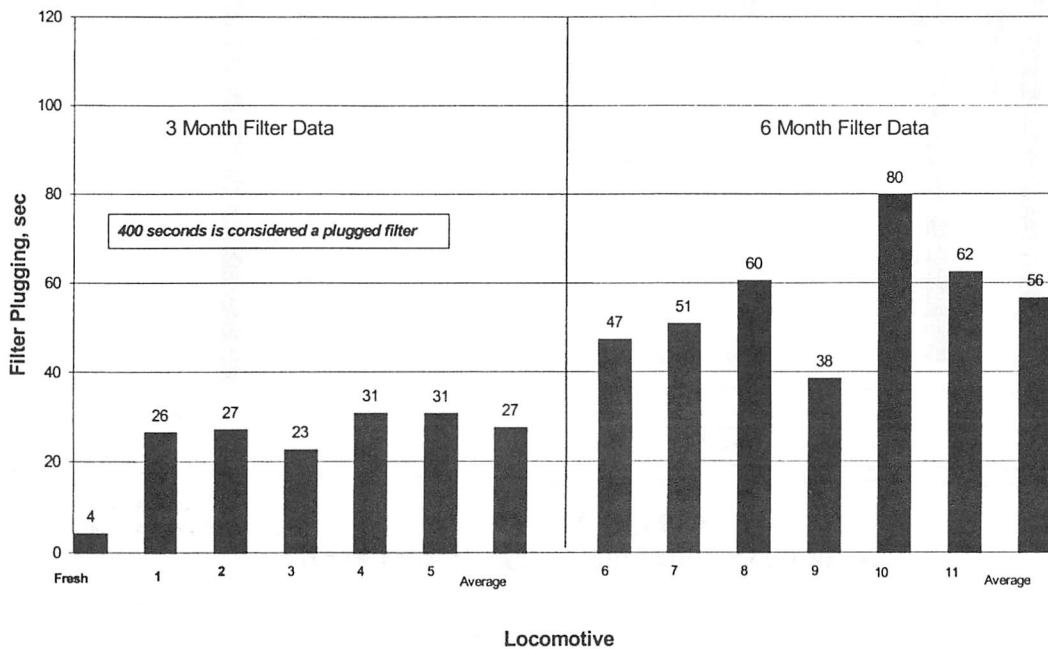


Figure 7

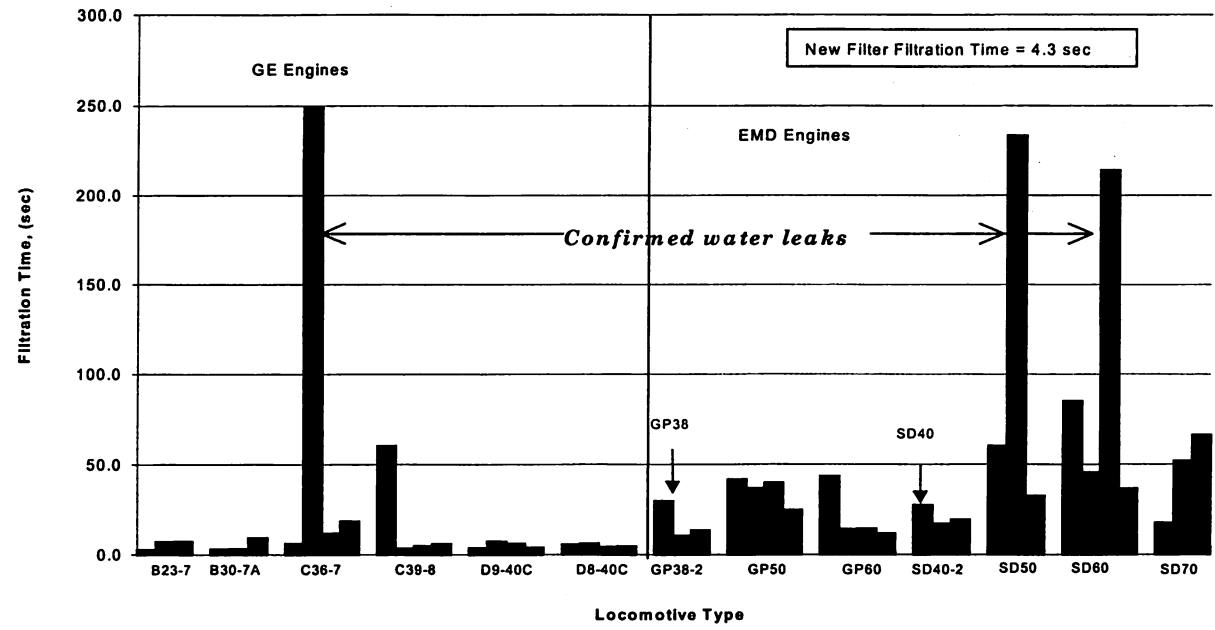
OIL FILTER PLUGGING EVALUATION  
EMD SD70 Locomotives



### Figure 8

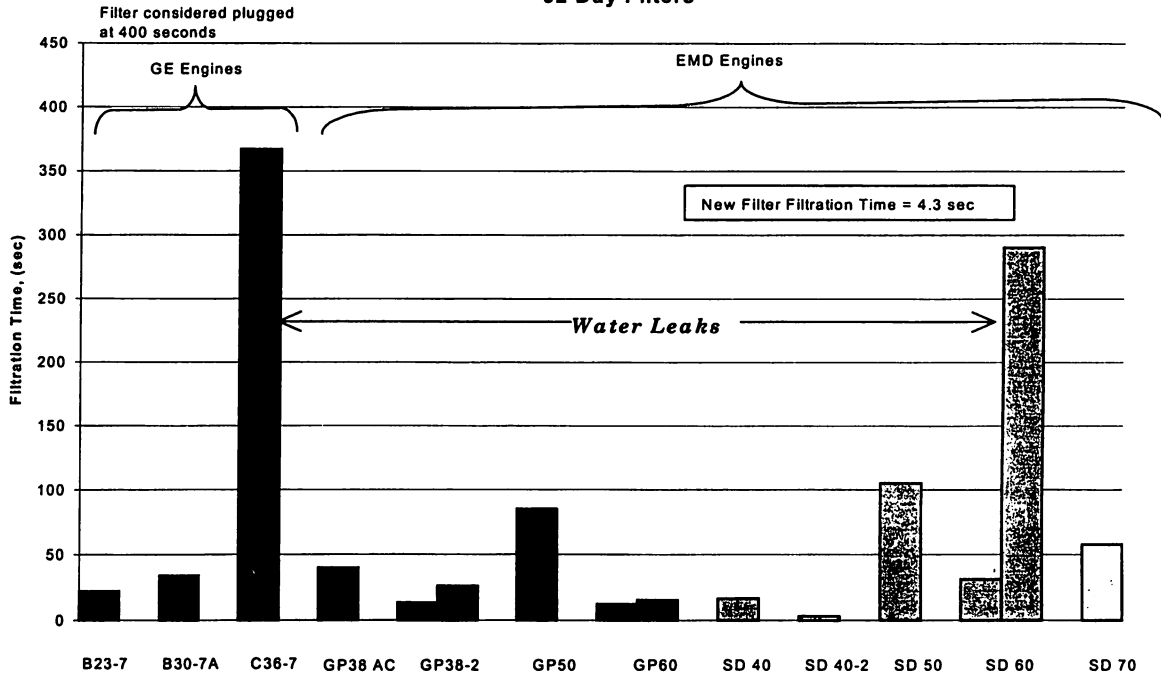
## Base Line Oil Filter Plugging Evaluation 92 Day Filters

Filters considered plugged  
at 400 seconds

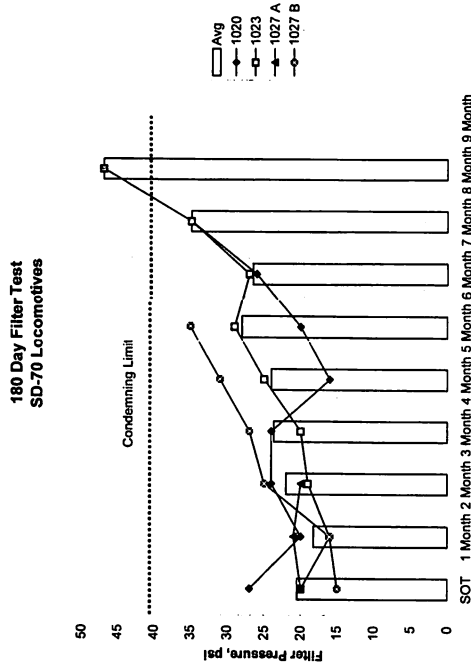


# Figure 9

## Base Line Oil Filter Plugging Evaluation 92 Day Filters



**Figure 10**  
**180 Day Oil Filter Tank Pressure Study**

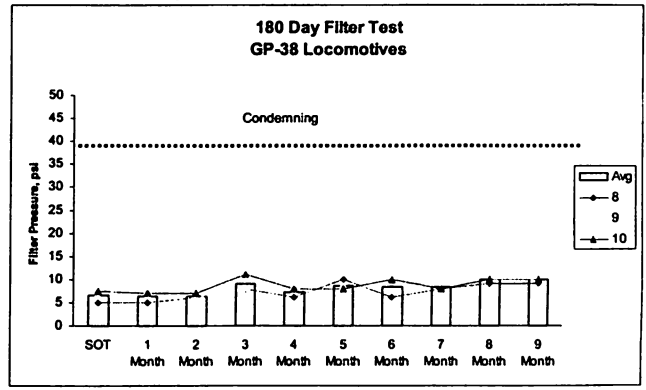
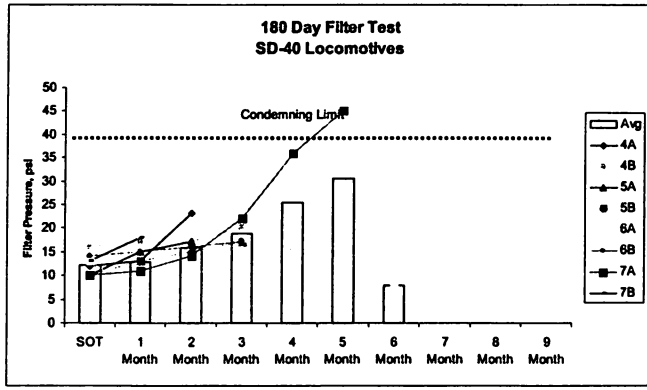


(35 psi max limit)

|            | SOT       | 1 Month   | 2 Month   | 3 Month     | 4 Month      | 5 Month        | 6 Month   | 7 Month   | 8 Month   | 9 Month   |
|------------|-----------|-----------|-----------|-------------|--------------|----------------|-----------|-----------|-----------|-----------|
| 1020       | 27        | 20        | 24        | 24          | 24           | 16             | 20        | 26        | 35        |           |
| 1023       | 20        | 16        | 19        | 20          | 20           | 25             | 29        | 27        | 35        | 47        |
| 1027 A     | 20        | 21        | 20        | 21          | 27           | 31             | 35        |           |           |           |
| 1027 B     | 15        | 16        | 25        | 27          | 24           | 24             | 28        | 27        | 35        | 47        |
| <b>Avg</b> | <b>21</b> | <b>18</b> | <b>22</b> | <b>24</b>   | <b>24</b>    | <b>28</b>      | <b>27</b> | <b>27</b> | <b>35</b> | <b>47</b> |
| 6103 A     | 12        | 13        | 23        | 23          | 48           |                |           |           |           |           |
| 6103 B     | 16        | 17        | 17        | 20          |              |                |           |           |           |           |
| 6103C      | 18        | 20        | 22        |             |              |                |           |           |           |           |
| 6111 A     | 10        | 15        | 17        | 17          |              |                |           |           |           |           |
| 6111 B     | 10        | 13        | 15        | 17          | 22           | 10             | 12        |           |           |           |
| 6125 A     | 13        | 6         | 9         | 18          | 15           | 16             | 8         |           |           |           |
| 6125B      | 14        | 15        | 16        | 17          | 36           | 45             |           |           |           |           |
| 6030A      | 10        | 11        | 14        | 22          | 47           |                |           |           |           |           |
| 6030B      | 13        | 18        | 22        | 47          |              |                |           |           |           |           |
| <b>Avg</b> | <b>13</b> | <b>14</b> | <b>17</b> | <b>18.8</b> | <b>30.25</b> | <b>23.6667</b> | <b>10</b> |           |           |           |
| 5847       | 5         | 5         | 6         | 8           | 6            | 10             | 6         | 8         | 9         | 9         |
| 5822       | 7         | 7         | 6         | 8           | 8            | 8              | 9         | 9         | 11        | 11        |
| 9573       | 7.5       | 7         | 7         | 11          | 8            | 8              | 10        | 8         | 10        | 10        |
| <b>Avg</b> | <b>7</b>  | <b>6</b>  | <b>6</b>  | <b>9</b>    | <b>7</b>     | <b>9</b>       | <b>8</b>  | <b>8</b>  | <b>10</b> | <b>10</b> |

Figure 11

180 Day Oil Filter Tank Pressure Study



## II. CORROSION PROTECTION OF LOCOMOTIVE COOLING SYSTEMS

*By Dave Elvin, Ondeo-Nalco  
Company and  
Leighton Haley, Norfolk Southern  
Corporation*

### Introduction

The locomotive cooling system is a necessary component of engine design, as it removes heat generated by friction and the combustion of fuel. Without the heat removal the internal combustion engine will quickly destroy itself. Most engine components require some maintenance to maintain peak operating condition. The cooling system is no different. If not properly maintained the system can quickly corrode, degrading cooling efficiency and possibly shortening the life of other components.

If the cooling system is not properly maintained, heat exchanger efficiency will soon degrade because of the insulating properties of mineral and corrosion deposits. In addition, a corrosive environment will attack the cooling system itself, resulting in component failure and subsequent shopping to repair the leak(s). Depending on the location and severity of a leak, catastrophic engine failures can result.

No matter how you look at it, improper maintenance of a locomotive cooling system increases maintenance and repair costs and increases out of service time.

### Corrosion - A brief primer:

Corrosion is the electrochemical process in which a metal in its elemental form returns to its native, oxidized state.

In order for corrosion to occur there must be:

1. A corrodible surface - one with electrons to lose,
2. A difference in potential - a driving force for the electrons,
3. An electron acceptor - a place for the electrons to go, and
4. An electrolyte to close the circuit - conditions conducive for electron flow.

The corrosion reaction rate is determined by the reactions at the cathode and is influenced by:

- a. Size of the cathode,
- b. Amount of oxidizer present,
- c. Size of the potential difference,
- d. Temperature,
- e. Velocity of the water,
- f. pH of the water, and
- g. Presence of dissolved solids and gases.

Depending on the conditions and factors present in the system, corrosion can appear as one or a combination of the following types:

1. General etch.
2. Concentration cell.
3. Cracking.
4. Mechanical damage.

General etch is metal loss in which a given area is alternately a cathode and an anode. Metal loss

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occurs uniformly over the surface.

Concentration cell corrosion is a localized attack caused by chemical or surface anomalies and can take the form of crevice corrosion, under deposit corrosion, tuberculation, biologically induced corrosion, acid corrosion, or alkaline corrosion (see Figure 1).

Cracking corrosion failures are caused by the combined effects of corrosion and metal stress. These cracks initiate on the surface exposed to the corrodant, and propagate into the metal in response to the applied stress. The critical factors are the presence of a specific corrodant and sufficient tensile stress (see Figure 2).

Mechanical damage includes cavitation/erosion corrosion, corrosion fatigue, and de-alloying. Cavitation is the creation, growth, and violent collapse of bubbles. The collapse of the bubbles very near the surface causes mechanical deformation of the surface and over time leads to loss of material from the surface - erosion (see Figure 3).

### **How do we protect locomotive cooling systems?**

The overall goal is to protect all of the metals in the cooling system from corrosion and deposits while maintaining efficient heat transfer. This requires consideration of several factors, including, the quality of the water, the metals in the system, the seals that are in contact with the water, the type of inhibitor chemistry employed, and how any chemicals used are introduced into

the system.

### **The importance of water**

Water is the medium used in the cooling system to remove heat from the engine. The quality of the water used can and does play a major role in how the cooling system performs and the maintenance required. Any minerals contained in the water will form scale and deposits as the minerals precipitate from solution. Water added to a system brings oxygen and other dissolved gases that can renew or intensify system corrosion in addition to carrying dissolved and suspended solids that further promote scale and deposit formation.

The equipment manufacturers recognize the importance of water quality and use the following parameters to define good water quality:

Chlorides <40ppm

Sulfates <100ppm

Total dissolved solids <340ppm

Total hardness <170ppm

In areas where the water exceeds these limits, ion exchange softening of the water is preferred to minimize the corrosive / deposit tendency. Otherwise additional chemical treatment will be required. Please refer to the attached water quality graph in Figure 4.

It is important to remember that the quality of the water is a critical factor but that the use of high quality water alone does not eliminate corrosion or deposit formation. It does reduce the demand on any

chemical treatment required.

Non-chemical steps can be taken to minimize corrosion in a cooling system. The basic objective is to operate the system in a manner that eliminates or minimizes water losses. Thus, less fresh makeup water is required and treatment residuals are more easily maintained.

Although beyond the scope of a maintenance shop, the corrosion resistance of a system can be maximized through the selection of corrosion-resistant metals. Economics generally is the deciding factor in materials selection. Ideally, a single metal should be specified throughout a system to avoid any dissimilar metal corrosion. The use of a minimum number of different metals will greatly improve corrosion control. Occasionally, coatings have been applied to metal surfaces in a closed system to reduce corrosion.

### **The meaning of corrosion control**

At this point, it is desirable to decide just what is meant by practical corrosion control in cooling systems. In some systems, this term can be defined by corrosion rates less than a certain value on a specific type of metal. For example, a general etch attack on mild steel of less than 5 mils per year (mpy) or (<70 micrometers/yr) is usually considered satisfactory protection in open recirculating systems. Figures 1 - 3 are examples of cooling systems that have not maintained corrosion control.

On the other hand, practical cor-

rosion control can also be defined in terms of maintenance costs or system operating efficiency. Most frequently, in closed recirculating systems, i.e. locomotive cooling systems, control is considered to be satisfactory as long as the system continues to operate efficiently with a minimal amount of necessary maintenance.

Because of the characteristics of closed systems and the problems that corrosion and its by-products cause, it is extremely important to eliminate all corrosion from the start of the system operation. This can be accomplished by passivating the surfaces with corrosion inhibiting chemicals prior to putting the equipment into service.

### **Corrosion Control - Chemical Techniques**

An effective corrosion control program usually depends on specific inhibitors for stopping the anodic reaction, slowing the cathodic reaction, or both. When inhibitors were first introduced into water systems, they were frequently composed of single active components (e.g., chromate). Chromates have been virtually eliminated from the treatment of engine cooling closed loop systems in the U.S. and Canada due to the links with cancer and long term health concerns associated with exposure to chromates.

Most closed loop systems are now treated with nitrite based blends. These products are referred to as: "borates", "boron", "water treatment", "Nalco" and yes even as

“chromate.” In general these products are corrosion inhibitors for closed loop systems. The majority of these products are not single active components, but rather, a blend of inhibitors designed to protect all of the system’s metallurgy.

The following section discusses how each inhibitor works in reducing system corrosion.

### **Anodic inhibitors**

Anodic inhibitors operate by oxidation or precipitation mechanisms. Knowledge of the positive aspects of these inhibitors and their limitations is essential for establishing controls for cooling water corrosion inhibition programs that use anodic inhibitors.

#### **Oxidizing anodic inhibitors**

##### ***Chromate***

Chromate is a strong oxidizing agent that accelerates the oxidation of ferrous ions to ferric ions so that a thin, almost invisible layer of tightly adherent iron oxide quickly forms. Metal oxides caused by this reaction become passive and are relatively inert to further oxidation or corrosion.

Sufficient levels of chromate must be present in a system to completely oxidize all anodic sites to a more noble potential. Failure to cover all available anodic surface areas with a polarized corrosion product layer results in localized pitting attack. Chromate levels greater than 100 ppm are needed to produce this layer in cooling water with a pH of 6.5-7.5. For this rea-

son, chromate inhibitors are normally formulated with a cathodic inhibitor, such as zinc, for use in the pH range. Lower levels of chromate are required if the pH is greater than 7.5. Chromates may be used alone in high pH systems or in closed systems where high levels may be maintained.

Since chromate is an oxidizing agent, the presence of reducing contaminants, such as H<sub>2</sub>S or oil, will reduce chromate from the hexavalent form to its trivalent state. Trivalent chromic hydroxides are insoluble above pH 8.0 and can be foulants. The trivalent form also lacks worthwhile corrosion inhibition properties.

Chromate has been one of the most widely used of the anodic inhibitors and is very effective; however, as environmental and health concerns have grown, chromates have been replaced by nitrite as the major player.

##### ***Nitrite***

Nitrites oxidize mild steel surfaces to form an extremely thin and highly tenacious corrosion product layer in a manner similar to chromate. Much higher levels of nitrite (2 to 3 times) are required compared to chromate. Inhibitor blends based on nitrate are normally buffered between pH 8 and 11 with borate. The inhibitor is often called borate; however, borate is only the buffering agent.

The concentration of nitrite in the cooling system is critical. If either too much or too little nitrite is

present it can actually promote corrosion of some metals. During use nitrite ( $\text{NO}_2$ ) oxidizes to nitrate ( $\text{NO}_3$ ). The nitrate form is not an effective corrosion inhibitor for mild steel but does provide some protection against pitting corrosion of aluminum and solder. The presence of hydrocarbons and glycols will not affect nitrite performance.

### **Precipitating/Film-Forming Anodic Inhibitors**

#### ***Silicates***

Silicates react with dissolved metal ions at the anode. The resultant metal ion/silicate complex forms a gel that deposits on anodic sites. The gel formed is highly tenacious and lacks pH sensitivity compared with other commonly used inhibitors. The inhibiting properties of silicates increase with increasing temperature and pH. Silicates also have surface-active properties that allow them to penetrate tubercles and inhibit active corrosion. Silicates are mainly used to inhibit general corrosion of aluminum but they do provide some limited protection of all metals.

#### ***Molybdates***

Molybdenum is in Group VI A in the periodic table, along with chromium. It has been studied extensively as an alternative to chromate. It shows inhibitive effects on general and localized corrosion of ferrous and nonferrous metals. Unlike chromate, however, molyb-

date has very little oxidizing ability.

Molybdate is an effective corrosion inhibitor for metal alloys. It is generally accepted that the corrosion inhibition of iron is achieved by adsorption of molybdate onto the porous oxide surface, probably by a process of ion exchange, followed by the formation of an insoluble film reported to be iron molybdate ( $\text{FeMoO}_4$ ). The adsorption produces a layer impermeable to other anions, particularly chlorides and sulfates.

Molybdates are currently used in combination with other inhibitors (nitrite, zinc, BZT, MBT, and others), producing enhanced passivation and improving an otherwise unacceptable cost imbalance when compared to nitrite programs.

### **Combination anodic and cathodic inhibitors/ organic inhibitors**

#### **Soluble and Dispersible Oils (Used when storing locomotives)**

Soluble and dispersible oils are successfully used to inhibit corrosion in closed cooling water systems. A loose emulsion of the oil is fed to the water. The emulsion breaks at the heat transfer surfaces and lays down a thin, protective oil film on the metal. The film prevents water from further contacting the metal and breaks the electrochemical circuit, stopping corrosion. Soluble dispersible oils are primarily used for systems that are being prepared for long-term storage or overseas shipment.

Although effective, these materi-

als must be thoroughly cleaned out prior to putting the locomotive back into service as they can reduce heat transfer efficiency and could possibly affect o-rings and seals.

### ***Mercaptobenzothiazole***

Mercaptobenzothiazole (MBT) provides excellent copper corrosion inhibition. The organic molecule reacts with copper surfaces via the SH group to form an organic film. This copper corrosion inhibitor is the fastest film former of its type. It is useful well above the boiling point of water. Microorganisms degrade the molecule rapidly. The presence of chlorine oxidizes the -SH group and results in two MBT molecules being bound together as MBT-disulfide. MBT is used widely in closed cooling water systems.

### ***Benzotriazole and Tolyltriazole***

Benzotriazole (BZT) and Tolyltriazole (TT) are two copper corrosion inhibitors that adsorb on copper surfaces to break the electrochemical circuit. Although these molecules form a film more slowly than MBT, they are more stable under conditions of high temperatures and in the presence of chlorine. BZT and TT use is increasing in closed recirculating systems. Many formulators blend TT or BZT with MBT to incorporate rapid film-forming properties and stability into a finished product.

### **Metal Passivation**

Start-up is the most critical period for a cooling water treatment

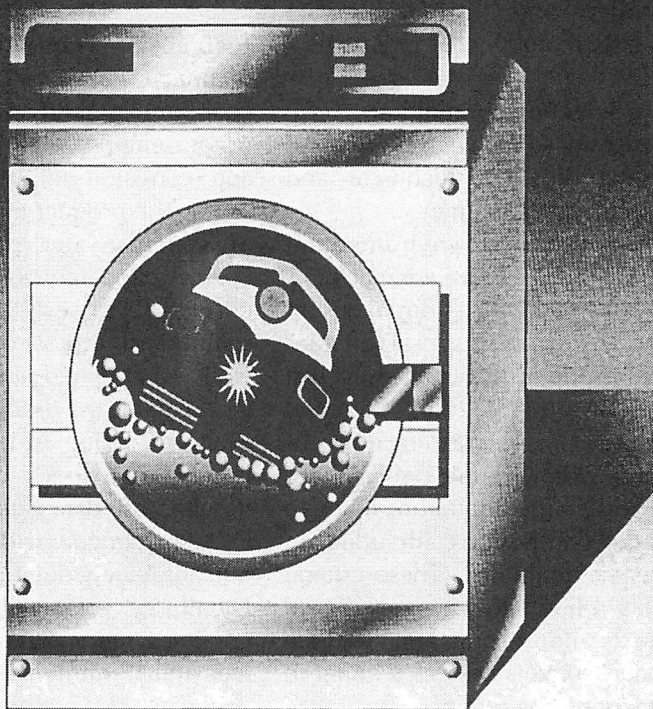
program. Initial metal passivation is the foundation for all effective cooling water programs. Unpassivated or poorly passivated metal surfaces will corrode at high rates when first put into service. This process is frequently called flash corrosion. The resulting corrosion products are usually loose, porous deposits that reduce heat-transfer efficiency. These deposits also interfere with the effectiveness of applied corrosion inhibitors because the inhibitors cannot react at the metal surface where the corrosion is occurring.

The basic concept for effective metal passivation is quite simple. Essentially, the process involves four steps:

1. Prepare the metal surface so that it will be receptive to the formation of a corrosion inhibitor film.
2. Rapidly establish a corrosion inhibitor film before flash corrosion can occur.
3. Complete the metal passivation and repair any breaks in the initial inhibitor film.
4. Maintain the inhibitor film.

Each cooling water system is different, so procedures for achieving clean metal surfaces and then maintaining them free of corrosion require careful planning. Every cooling system, whether new or newly cleaned to remove scale or corrosion, should be thoroughly passivated prior to the introduction of corrosion and scale inhibitors. Systems that require only a change

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of program and that have already been adequately passivated may only require the last two of the four steps.

The techniques used to accomplish the four metal passivation steps must be thoroughly understood so that corrosion is effectively controlled and heat transfer is efficiently maintained.

### **Selecting an inhibitor**

Program selection requires that all environmental, technical and economic needs be met.

**Employee and environmental considerations** - There are many criteria in this category from exposure to employees to disposal of consumed product. Products must first be reviewed for their potential health risks as well as environmental risks. Many municipalities have water discharge limitations that can include compounds included in corrosion inhibitors. These criteria quickly eliminate chromate-based products and in some areas include boron. Borate is used as a buffer in nitrite based programs. Recycling or alternative disposal are the most typical options employed at these locations.

Dye color is another important criteria in the selection of corrosion inhibitor. There are two dyes predominately used, phenolphthalein (red dye) and fluorescein (green dye). Phenolphthalein is pH sensitive dye and is quickly neutralized to a clear color when processed in locomotive wastewater treatment plants or discharged due to cold

weather emergency shutdown. Fluorescein green dyes have been utilized for their leak tracing ability, however the dye is persistent upon discharge. The green dye can cause unnecessary environmental responses due to the green color similarity to glycol based antifreeze.

### **Technical considerations**

Technical criteria will include compatibility / stability with make up water, engine seal compatibility, and corrosion inhibition performance. The product must be tolerant of system water quality levels. Engine seal compatibility is evaluated with OEM seals immersed in a solution of corrosion inhibitor as well as an applied seal compression test. Finally, the products should be evaluated using ASTM D-1384 at the manufacturer's recommended dosage. The data gathered from the D1384 testing should be given significant review due to the variety of metallurgy present in locomotive cooling systems. It is for this reason that straight nitrite inhibitors are not adequate for protection and that today's most effective programs are blended nitrite, azole, silicate, nitrates, and antifoam products.

**Economics** - The most cost-effective treatment programs at the present time are the nitrite based products. Molybdates have been mentioned in this paper as another closed loop inhibitor. They are very effective in corrosion prevention; however, due to product costs, they are typically best applied to systems with mini-

mal make-up water. Therefore molybdate programs are probably not an economically desirable choice for the amount of make up required for locomotives. During the economic review, consideration must be given to the quality of water that will be treated. Lower quality water typically requires use of a higher chemical treat rate.

### **Applying inhibitors and controlling concentrations:**

Cooling water corrosion inhibitors are available in both liquid and dry forms to meet the safe application needs of the industry. The liquid products are available in containers ranging in size from 5-gallon pails to bulk tanker delivery and are applied by either a direct locomotive manual addition or by a variety of metered automated systems. Solid inhibitors are available in several package types and product shapes including dissolvable bags, powders, pellets, and balls.

Dosage is measured in many ways, which include nitrite titration, conductivity or total dissolved solids, and color. Obviously, the nitrite titration provides a direct measurement of the level of protection; however, the time required to perform the tests is not practical for routine inspection in running repair shops. When used, nitrite titration is typically performed in a laboratory in conjunction with oil analysis. Most facilities use conductivity or total dissolved solids (TDS) as the primary measurement of corrosion inhibitor treatment level. This is usually measured with a handheld

conductivity / TDS meter and is a quick test that provides a good indirect measurement of the treatment level. The last method is the fastest but least accurate; this method is the visual color match. This process is a comparison of the color in the cooling water sight glass with a color chart mounted on the locomotive or held next to the sight glass.

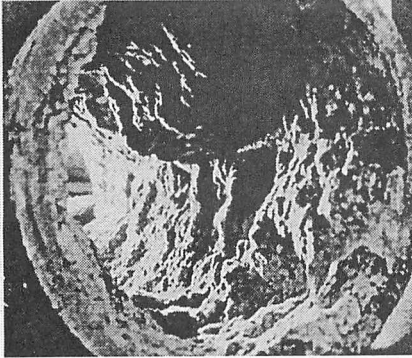
### **Summary**

Locomotive cooling system corrosion protection is a vital part of maintaining your fleet's reliability. In choosing which products to use the key points to consider are:

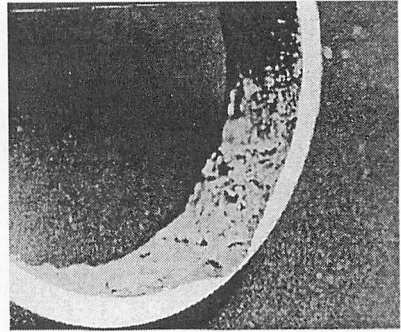
1. Cost associated with uncontrolled corrosion
2. Quality of the make-up water
3. Selection of an appropriate inhibitor for your application employee, environmental, and performance criteria
4. Product application needs
5. Dosage control methods.

Currently there are number of products from various suppliers available to choose from. OEMs can be used as a great source of information on product experience. Using the information contained in this paper can help in maximizing the performance of the locomotive cooling system and minimizing failures and costs associated with an improperly maintained system.

Figure 1



Tubercles in Carbon Steel



Tubercule Corrosion

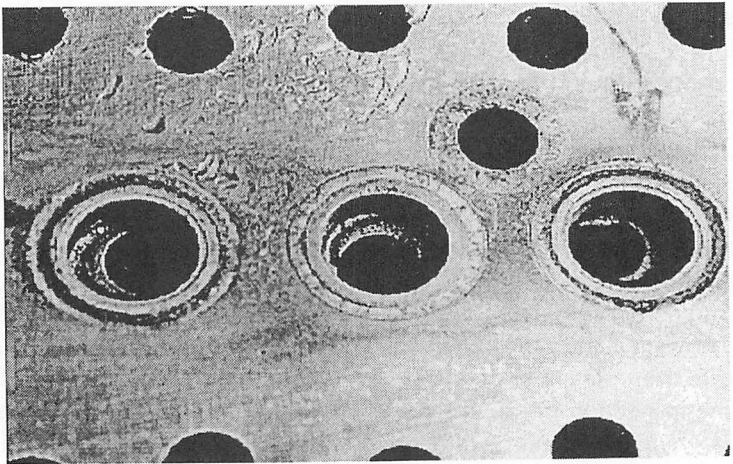
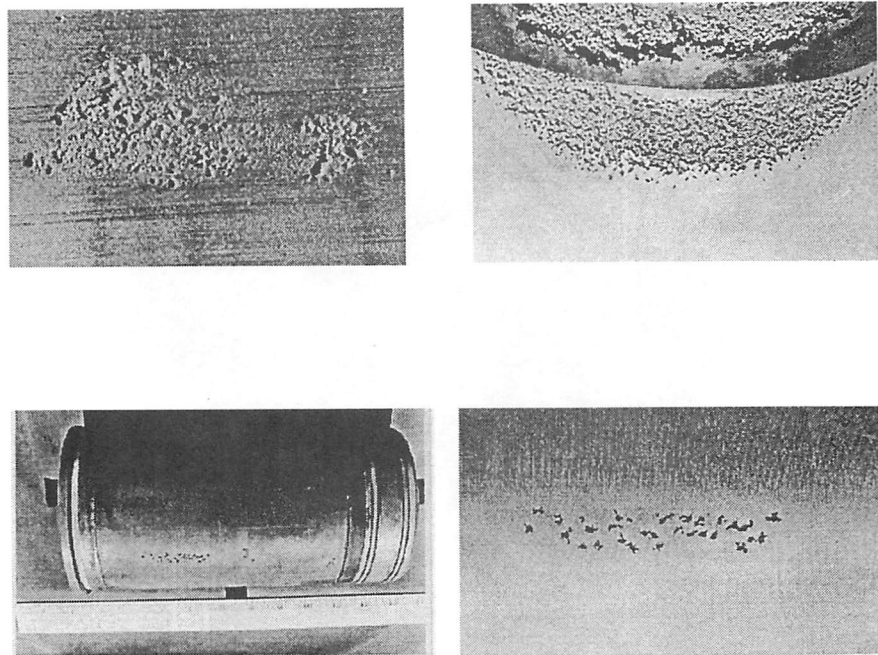


Figure 2

Crevice Corrosion Engine Block



**Figure 3**

**Examples of Cavitation Corrosion**

# Hardness Map

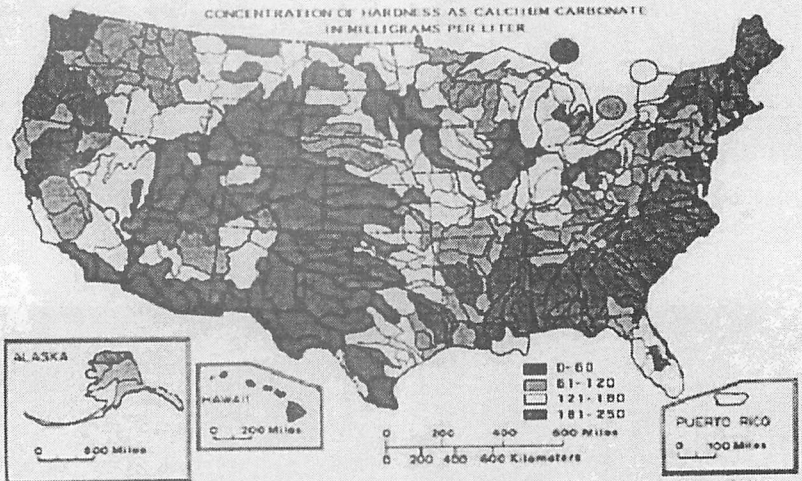


Figure 3.—Mean hardness as calcium carbonate at NASQAN stations during 1973 water year. Map at bottom is colored to show station data representing flow from the accounting unit.

Figure 4

Map showing typical water hardness throughout the United States.

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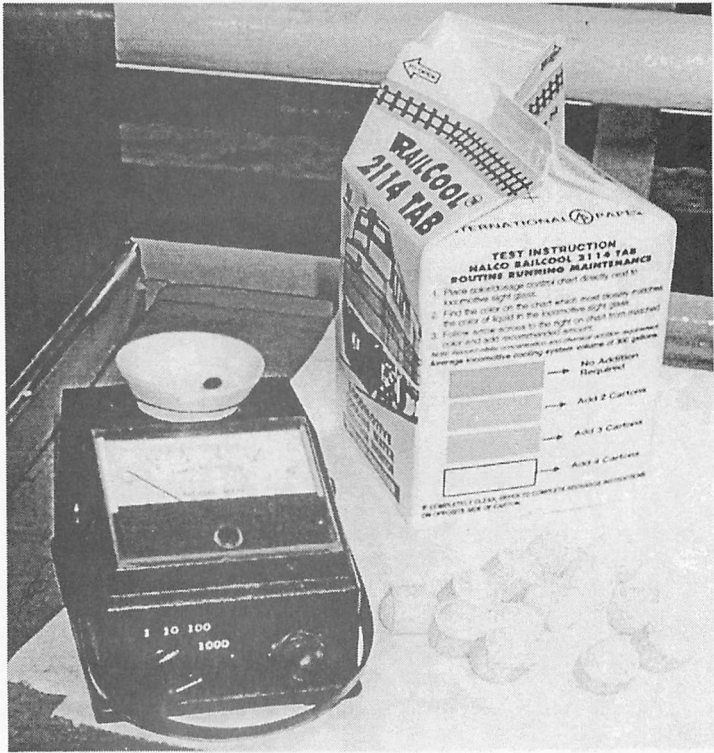


Figure 5

**Solid Corrosion Inhibitor Pellets and Nalcometer.**

REPORT OF THE COMMITTEE  
ON NEW TECHNOLOGIES

TUESDAY, SEPTEMBER 24, 2002  
3:45 P.M.



**Bruce Butts, Chairman**

National Electric Carbon Products, Inc.  
Scottsdale, AZ

Vice Chairman

**TIM BLACK**

Manager-Locomotive Scheduling  
Union Pacific RR  
Omaha, NE

**COMMITTEE MEMBERS**

|                |                            |                     |                  |
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| J. Pedulla     | Technical Writer           | Norfolk Southern    | Atlanta, GA      |
| C. Prudian     | Technical Prop. Manager    | Electro Motive Div. | LaGrange, IL     |
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| D. Robey       | Director-Mech. Engineering | CSX Transp.         | Jacksonville, FL |

New Committee Members: Richard Dalton, Motive Power Industries;  
Gerald Hess, GE Transportation Systems

## PERSONAL HISTORY

*Bruce M. Butts*

Bruce M. Butts received his B.S. degree from the University of Wisconsin in 1970. His background experience includes DC motors, drives and drive systems and industrial pump design.

Bruce joined National Electric

Carbon Products, Inc. in 1988. He and Corinne, who have been married for 29 years, live in Scottsdale, Arizona.

**THE NEW TECHNOLOGIES COMMITTEE  
WOULD LIKE TO THANK  
TIM BLACK  
AND  
THE UNION PACIFIC RAILROAD  
FOR ALLOWING THE COMMITTEE  
TO MEET AT THE  
UP HEADQUARTERS  
IN OMAHA, NE  
IN LATE NOVEMBER 2001.**

## I. ON BOARD RIDER A REMOTE LOCOMOTIVE CONDITION MONITORING SYSTEM

Prepared by: R. Bradley Queen,  
BNSF

### Overview

- Essentials of railroad operation.
- Locomotive fleet performance and utilization.
- Use of remote diagnostics.
- Technologies
- Companies with remote monitoring technology.

### The essentials for railroad operation are:

- Commodities to ship and the rail cars to move them.
  - A large interconnected network of trackage for goods to move from any origin to any destination using reasonably direct routes.
- Personnel to maintain the tight schedules and heavy equipment maintenance.
- Locomotives that exceed mean-time between failures to their next scheduled maintenance. Locomotive fleet performance and locomotive utilization are crucial for overall railroad operations.

### Enroute failures contribute to:

- Having to dispatch a mechanical repair crew to diagnose, troubleshoot, and repair a failed locomotive.
- Allocating time to switch out the failed locomotive causing interchange delays and bottle-

necking.

- Routing a "bad order" locomotive to a qualified mechanical facility for an unscheduled shopping to perform the repairs.

### Using remote diagnostics to monitor the health of the locomotive would:

- Assist a technician to troubleshoot a reoccurring intermittent fault.
- Permit switching remotely to a locomotive's backup mode of a failed component while still maintaining full train operation and handling.
- Provide the ability to know what component has failed on a locomotive in "real time", then have the failed part shipped to meet the locomotive at the closest qualified maintenance facility.
- Keep the locomotive closer to its scheduled route while reducing "waiting material/dwell" time when the unit is shopped for the repair of the failed component.

### An example of locomotive utilization cost and productivity loss, (Figure 1)

This spreadsheet points out 4 occurrence descriptions of a main generator about to fail due to loose electrical connections. Further down the sheet depicts the: Availability cost, which is 7 days out of service for a generator change out compared to 0 days for just cleaning and tightening the connections. Reliability cost, involves a road failure plus the cost

of a main generator.

Many systems have been implemented in the past. So what is new? Increased cell, radio and satellite communication performance and reliability, enabling a networked connection between the locomotive's existing computer system and, desktop personal computer (PC), 2-way pager, cell phone, radio and satellite.

What does a desktop personal computer have to do with remote diagnostics? If your locomotive has a wheel slip alarm, you could monitor the traction motor speed sensor voltage while the unit is still in operation. You could then call a maintenance crew to meet the locomotive and check the #1 speed sensor. Here we found that the #1 speed sensor had come loose and unplugged. We reapplied the speed sensor plug and made sure that it was not loose this time. As the locomotive departed we monitored the #1 speed sensor voltage on our desktop computer to qualify the repair just made (Figure 2).

How could a common cell phone be used to monitor a locomotive? A phone number could be dialed on the cell phone to link to the locomotive's computer. By pressing a specific code on the phone you could shut down the engine and non-vital electrical power. This could be useful when a locomotive is set out waiting disposition to save fuel and battery life.

Along with this technology, we can receive pager notification.

You could receive a pager notification from a locomotive when the engine had just died or is low on fuel in below zero weather.

With this technology, we also have the capability of receiving e-mail notification. You would receive an e-mail for a traction motor disabled, reducing the horsepower per ton ratio but maintaining full train operation.

**Two companies who bring remote monitoring technology to the railroads are: General Electric and EMD.**

**General Electric  
"Expert On-Alert™"**

The Expert On-Alert™ remote monitoring & diagnostics application assesses locomotive health to provide predictive and proactive condition information. The on-board system consistently monitors locomotive conditions, gathering and managing critical data. Recommendations are integrated directly into the customer's system enabling a rapid response. The system can quickly measure estimated repair time and failure urgency as well as identify whether it will be an on train/service track repair or movement to a nearby repair facility. Expert On-Alert™ remote monitoring & diagnostics effectively works to avoid road failures and improve asset utilization.

**Here's how it works:**

An intelligent, on-board system continuously assesses locomotive condition, gathering and managing critical operating data. These data are transmitted from the loco-

tive through satellite and other reliable communications to an off-board system. Automated analysis tools, built on GE knowledge of troubleshooting and problem isolation, “interrogate” the data.

GE service center experts review the data and propose necessary action.

**PinPoint™** locomotive tracking is another way that GE Transportation Systems can improve locomotive utilization by drawing on wireless communication tools that alert the customer if systems are idle or not moving for extended periods of time. Additionally, the system provides fuel status and other on-board reporting data. Through Global Positioning System technology, PinPoint is capable of determining a locomotive’s position within 100 meters.

By logging on to the GE Transportation website and navigating to the Remote Diagnostics Service page (Figure 3), you can enter a unit number and view the health of the locomotive. For example, if you select the box for the 4310 in the view column, you will bring up GE’s recommendation from its Monitoring and Diagnostics Service Center (Figure 4). This page indicates that a case number has been assigned, an urgency/repair time code, and a problem identification with a few recommendations to clear the fault.

The unit number can be entered on-line to receive a remote

download of the locomotive’s on-board fault archive (Figure 5). This information is presently retrieved by physically going to and getting on the locomotive and connecting a laptop to the onboard computer system. With the instructions to read these codes (Figure 6), the picture of why a failure occurred becomes clearer. Now it’s a matter of going after the fault using GE’s troubleshooting guide.

### **EMD “IntelliTrain™ Monitoring Service”**

General Motors Electro-Motive Division can provide unlimited locomotive information through their IntelliTrain remote monitoring services. The Gen2 FIRE (second generation Functionally Integrated Railroad Electronics) cab electronics system collects data making it available through wireless communication channels (including analog cellular, digital cellular, wireless-LAN, with capability for satellite and data radio). For locomotive monitoring, locomotive data is sent to EMD’s Locomotive Management Center. There are several packages of IntelliTrain services, but fundamentally locomotive data is collected, sorted, and made easy to use on a secure website. With proper identification and passwords, locomotive information is available anywhere on a 24/7 basis (Figure7).

EMD’s Locomotive Management Services focuses on improving two factors to reduce road failures and minimizing locomotive shop time.

- Locomotive Availability (percentage of time a locomotive is **available** to be used).
- Asset Utilization (percentage of time a locomotive is **actually** used).

With the health of the locomotive automatically monitored, experts are alerted when problems occur (Figure 8). If a locomotive initiates an alert of a fault or condition, the Central Server receives and stores the information. The Central Server then sends an Alert Notification to a preferred list of people through pager, cell phone, e-mail, or an on-line screen alert. The Locomotive Management Center Personnel perform remote diagnostics accessing additional locomotive information. A work order is sent out to the appropriate party. Maintenance personnel then determine the best repair options using resources accordingly.

There are three fundamental ways EMD IntelliTrain Services can provide value to railroad customers:

1. Reports
2. Alerts
3. Monitoring

### **Reports:**

#### **1. Fleet Summary Status Page - IntelliTrain Website**

This fleet summary status web page is an executive-summary style information page that provides the user their locomotive fleet location and health information. More detail of an individual

locomotive's health is available by selecting various submenus.

#### **2. Locomotive Summary Data Page - IntelliTrain Website**

(Figure 9)

Individual locomotive health and performance information is obtained through this web page including fueling information if the locomotive is equipped with an electronic fuel gauge. This data is collected from the last time and location when the locomotive was sampled.

#### **3. Locomotive Loading Data Page - IntelliTrain Website**

(Figure 10)

Loading performance of individual locomotives is gathered on this web page which includes information about the locomotive direction, setup, power and tractive effort production accumulated over time. The user is able to sort loading information by date.

#### **4. Locomotive Running Total report**

(figure 11)

Gathers data each time the locomotive is sampled sending it to a server. This data is converted to information that includes actual utilization and average speed of the locomotive.

#### **ITEMS THAT WILL BE DISPLAYED UP TO ONE YEAR ARE:**

- Miles per month.
- Kilowatt hours per month.

#### **HOURS, MILES, & KWATT HOUR DATA IS COLLECTED FOR:**

- Throttle position.

- Governor position.
- Dynamic brake position.

THIS DATA IS DISPLAYED BY WEEK, MONTH, QUARTER OR YEARLY INTERVALS.

#### ADDITIONAL MONTHLY DISPLAYS ARE:

- Percent a locomotive is being utilized comparing "idle" versus "not idle" time.
- Locomotive average speed recorded when speed is "not zero."

#### Alerts

An E-mail alert is sent out to the customer contact personnel when a locomotive fault or conditions occur one or more times.

- Alerts can be sent as e-mail to pager or other e-mail-enabled hardware.
- Messages alerts are sent out on a 24/7 basis.

#### Content of Alert

A locomotive alert contains the following information:

- The locomotive road number
- An incident description
- Date, time and location of the incident
- Actual date and time when fault or event occurred.

#### Alert Condition:

Alerts can be configured to the unique needs of each rail customer. Some alerts are specific to locomotive maintenance events, while others can be configured to address the needs of the trans-

portation departments. A sample of possible alerts follows:

- Excessive Time in Idle
- Low Fuel
- Low Horsepower
- Locked Powered Wheel
- Emergency Brake Application
- Air Compressor Failure
- Locomotive Overspeed
- Protective Engine Shutdown
- Ground Relay Lockout
- Hot Engine-Throttle six Limit

#### Locomotive Health Monitoring:

The resources of EMD's Locomotive Management Center are included in IntelliTrain service packages to improve the reliability and availability of locomotives. Highly qualified locomotive technicians, with the full support of EMD's Customer Engineering and Field Service groups, monitor locomotives and can provide advance notice of locomotive problems. Corrective action recommendations can be made to have the proper personnel, tools, and material to meet locomotives and minimize down-time.

#### Optional IntelliTrain Upgrades

Once the IntelliTrain locomotive monitoring system is in place possibilities may vary by locomotive but the future can include:

#### Auxiliary Power Unit Controller and Health Monitor

The Gen2 FIRE computer has the capability to monitor and control a third party system such as an auxiliary power system (APU). The signals received from the APU while monitoring and controlling

its function and output can also be displayed on the Web or trigger alerts to designated contacts when the system is not functioning as desired.

### **Business Applications and other 3rd Party Software**

The combination of IntelliTrain and Gen2 FIRE provides a powerful, connected computing platform that can be used for a wide range of other applications. The platform uses industry-standard hardware and software (an embedded Windows™ operating system). Railroad business software, such as train work orders, can be hosted on the Gen2 FIRE platform and connected with railroad dispatch and other systems to maximize the benefits of such a system for the railroad.

#### ***Remote Event Recorder Download***

- The Gen2 FIRE computer is equipped with an internal event recorder.
- Download data can be stored in a server and viewed on a Website without special playback software.
- The milepost and GPS location could be integrated into the download playback.

#### **Crew Assistance Display**

- Track profile graphic display.
- Train forces calculated and displayed.
- Display train crew work orders.

#### **Additional Options**

Reports offered to the railroad are expandable from data collected from multiple combined sources. Examples of these are:

- Fuel data can be correlated to milepost location using GPS location mapping the track profile. Fuel consumption influence by crew performance between mileposts can be determined and recorded.
- Track condition monitoring data collected from local weather conditions are capable of identifying critical track routes.
- Health monitoring enhanced by combining GPS location, local weather and locomotive data would aid in determining if a fault is real or induced by outside influences.
- An interchange report generated using GP location, time and date stamp, fuel consumption, refuel data and running total information.

Monitoring locomotive performance and reliability is an *old tool*. We now have a *new tool* to link to the locomotive with the technology of cell and satellite communication through the internet. Imagine a potential locomotive failure identified and corrective action scheduled before the repair. Imagine the opportunity to inquire a locomotive's availability while waiting for service instantly.

Imagine the possibilities with On-Board Rider. . .

FIGURE 1

| Cost Benefit Analysis Worksheet                      |   |  |   |                                   |
|--|---|--|---|-----------------------------------|
| Locomotive number: <u>BNSF6380</u>                   |   | Date: <u>2/12/02</u>   |   |                                   |
| Problem detected: <u>OVERHEATED D-14 CONNECTIONS</u> |   |  |   |                                   |
| Problem code (shop. #): _____                        |   | Condition Monitoring Technology: <u>VR</u>   |   |                                   |
| Condition assumption                                 | Critical<br>(Results in equipment failure requiring full replacement. Usually results in a road failure and | Serious<br>(Results in equipment failure requiring parts replacement. May cause a road failure and | Intermediate<br>(Results in reduction of equipment performance level. May cause a road failure) | Actual<br>(Actual cost of outage) |
| Occurrence description                               | GENERATOR FAILS CONNECTIONS BURN AWAY.  | CONNECTIONS BURNT AWAY   | CONNECTIONS OVERHEAT AND BECOME LOOSE AND DROP LOAD   | CLEANED AND TIGHTENED             |
| <b>Maintenance costs</b>                             |   |  |   |                                   |
| Repair description, parts required                   | REPLACE GENERATOR AND LEAD CONNECTIONS  | REPLACE AND REPAIR CONNECTIONS AND LEADS   | REPLACE CONNECTIONS   | CLEANED AND TIGHTENED             |
| Parts cost, \$                                       | \$35,000.00   | \$150.00   | \$100.00  | \$0.00                            |
| Labor hours, hrs                                     | 21  | 12   | 8   | 1                                 |
| Labor rate, \$/hr                                    | \$57.00   | \$57.00  | \$57.00   | \$57.00                           |
| Labor cost, \$                                       | \$1,197.00  | \$684.00   | \$456.00  | \$57.00                           |
| Total Maintenance Cost, \$                           | \$36,197.00   | \$834.00   | \$556.00  | \$57.00                           |
| <b>Availability costs</b>                            |   |  |   |                                   |
| # of days OOS  | 7   | 3  | 3   | 0                                 |
| Cost per day OOS                                     | \$400.00  | \$400.00   | \$400.00  | \$400.00                          |
| Total Availability Cost, \$                          | \$2,800.00  | \$1,200.00   | \$1,200.00  | \$0.00                            |
| <b>Reliability costs</b>                             |   |  |   |                                   |
| Road failure occurs (Yes/No)                         | YES   | YES  | YES   |                                   |
| Average cost of road failure, \$                     | \$1,750.00  | \$1,750.00   | \$1,750.00  |                                   |
| Total Reliability Cost, \$                           | \$1,750.00  | \$1,750.00   | \$1,750.00  |                                   |
| <b>Total weighted benefits</b>                       |   |  |   |                                   |
| Total Costs, \$                                      | \$40,747.00   | \$3,784.00   | \$3,506.00  | \$57.00                           |
| Probability of occurrence, %                         | 10%   | 30%  | 60%   |                                   |
| Weighted Benefits, \$                                | \$4,074.70  | \$1,135.20   | \$2,103.60  |                                   |
| <b>Total Savings</b>                                 |   |  |   |                                   |
| Total Benefits, \$                                   |   |  |   | \$7,313.50                        |
| Total Actual Cost, \$                                |   |  |   | \$57.00                           |
| Net Savings, \$                                      |   |  |   | \$7,256.50                        |

FIGURE 2

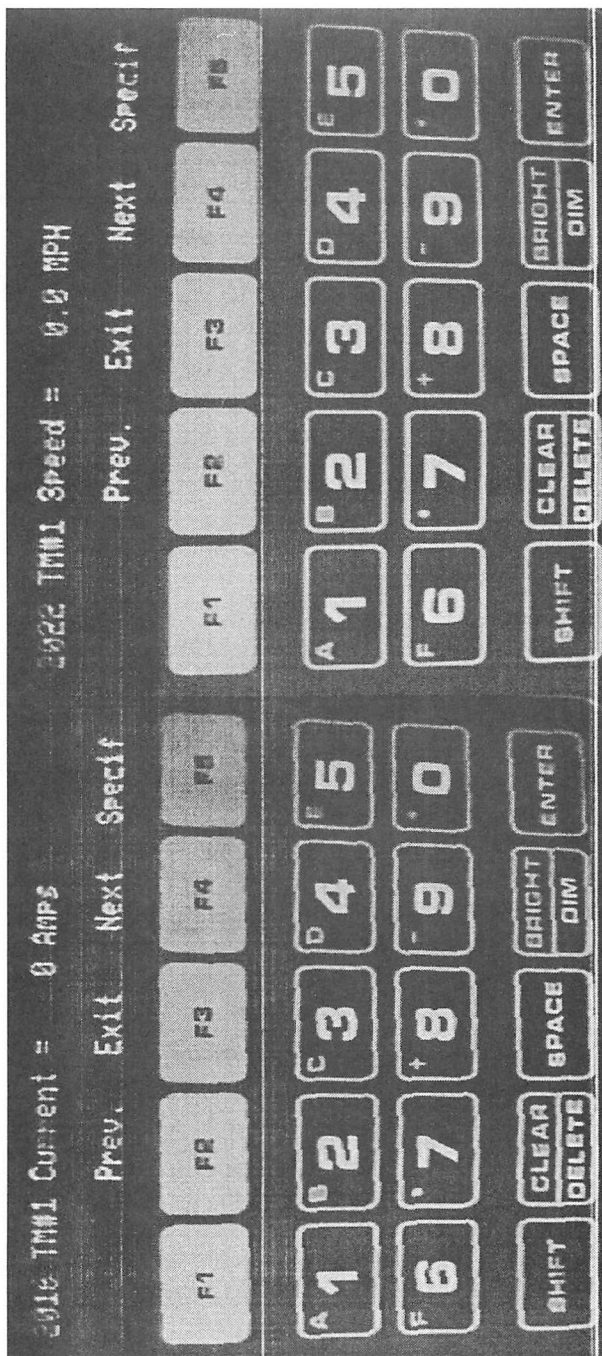


FIGURE 3

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Get a listing of all open recommendations provided by GE experts to keep locomotives with Remote Diagnostics Service coverage up and running. Sort the recommendations by road number and recommendation delivery date.

RR Initials:  To:   
 Road Number:  To:   
 Priority / Repair Time:   
 Recommendation Title:   
 Case Number:  Search

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| No. | Road #   | Case #   | Recommendation Title  | Date       | Pri | View | Fault Log |
|-----|----------|----------|---|------------|-----|------|-----------|
| 1   | BNSF4310 | CA024478 | GELZ - OPM System Issue                                     | 03-20-2002 | W3  |      |           |
| 2   | BNSF4440 | CA014260 | GELZ - Low Engine Oil Level                                 | 02-12-2002 | W3  |      |           |
| 3   | BNSF4454 | BA186914 | GELZ - Low Engine Oil Level                                 | 11-27-2001 | W3  |      |           |
| 4   | BNSF4538 | C001262  | Flashover in Traction Motor 1 (DC)                          | 02-07-2002 | Y2  |      |           |
| 5   | BNSF4540 | C002661  | CMU System - Troubleshooting No Communication (Without PTU) | 03-15-2002 | W3  |      |           |
| 6   | BNSF4555 | CA013122 | GELZ - Low Engine Oil Level                                 | 02-05-2002 | W3  |      |           |
| 7   | BNSF4558 | C002208  | Auto Rec: Low Water Pressure Faults                         | 03-04-2002 | R2  |      |           |
| 8   | BNSF4612 | CA012419 | GELZ - AOC Module System Issue                              | 02-05-2002 | W3  |      |           |
| 9   | BNSF4884 | CA018490 | GELZ - AOC Module System Issue                              | 02-21-2002 | W3  |      |           |
| 10  | BNSF4885 | C002448  | Auto Rec: Crankcase over pressure (COP) Faults              | 03-11-2002 | R2  |      |           |

Page 1 of 2

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FIGURE 4



## MDSC Recommendation

**Customer:** Burlington Northern Sante Fe Railroad  
**Unit Number:** BNSF4310  
**Case Number:** CA024478  
**Date/Time:** Wed 3/20/2002 22:06:09  
**Urgency/Repair Time:** W3  
**Problem Identified:** GELZ - OPM System Issue

**Recommendation:**

1. Inspect all wiring and hose connections to OPM, per the troubleshooting guide. Repair/replace as necessary.
2. If no issues identified, replace OPM.
3. For additional information, call GE Monitoring Diagnostics & Service Center at 888 432 0209.

FIGURE 5

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View the fault logs downloaded from locomotives covered by Remote Diagnostics Service. Get the listing by road number and/or specified time period.

RR Initials

BNSF

Road Number

4538

(Please enter numbers only)

Faults over Last

Custom

24

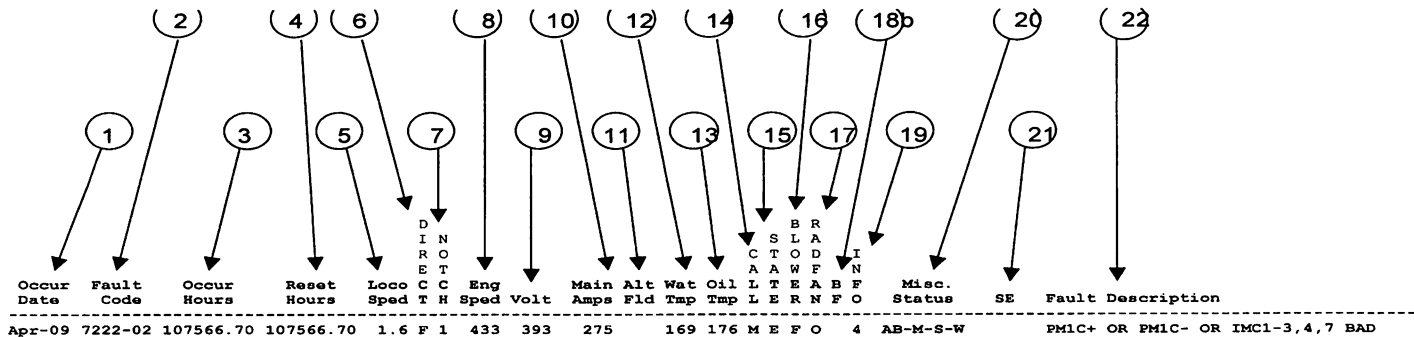
Days

Found 21 Faults

| Road#    | Occur Date | Fault Code | Sub ID | Occur Hours | Reset Hours | Loco Speed | Direction | No tch | Eng Speed | Volts | Main Amp | Alt Fld | Wat Temp | Oil Temp | Ca ll | Sta ta | Bto | RF | BF | In fo | Misc Status | Fault Description             |
|----------|------------|------------|--------|-------------|-------------|------------|-----------|--------|-----------|-------|----------|---------|----------|----------|-------|--------|-----|----|----|-------|-------------|-------------------------------|
| BNSF4538 | 03/07/2002 | H00000     | H00000 | 133,062.33  |             | 45.70      | F         | 3      | 885       |       |          |         | 180      | 194      | M     | E      | 2   | 4  |    | A     |             | HEALTH CHECK DUMMY FAULT CODE |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.17  | 132,886.32  | 0.00       | C         | S      | 0         | 2     | 3        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.15  | 132,886.15  | 0.00       | C         | S      | 0         | 2     | 0        |         | 100      | 133      | R     | E      | O   | O  |    | 1     | B           | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.15  | 132,886.17  | 0.00       | C         | S      | 0         | 2     | 0        |         | 41       | 69       | R     | E      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 422E       | 00     | 132,886.15  | 132,954.45  | 0.00       | C         | S      | 0         | 2     | 1        |         | 104      | 137      | R     | E      | O   | O  |    | 1     | B           | Fault Reset While In Level 1  |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.12  | 132,886.12  | 0.00       | C         | S      | 0         | 3     | 1        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 422E       | 00     | 132,886.12  | 132,886.12  | 0.00       | C         | S      | 0         | 3     | 2        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Fault Reset While In Level 1  |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.12  | 132,886.15  | 0.00       | C         | S      | 0         | 3     | 1        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.10  | 132,886.12  | 0.00       | C         | S      | 0         | 3     | 2        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.08  | 132,886.08  | 0.00       | C         | S      | 0         | 2     | 2        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.08  | 132,886.10  | 0.00       | C         | S      | 0         | 2     | 2        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.07  | 132,886.07  | 0.00       | C         | S      | 0         | 2     | 2        |         | 152      | 185      | R     | E      | O   | O  |    | 1     | B           | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 400A       | 00     | 132,886.07  | 132,886.08  | 0.00       | C         | S      | 0         | 0     | 0        |         | 0        | 0        | C     | S      | O   | O  |    | 1     |             | Auto Water Drain Disabled     |
| BNSF4538 | 02/27/2002 | 422E       | 00     | 132,886.07  | 132,886.08  | 0.00       | C         | S      | 0         | 2     | 2        |         | 41       | 40       | R     | E      | O   | O  |    | 1     |             | Fault Reset While In Level 1  |
| BNSF4538 | 02/25/2002 | H00000     | H00000 | 132,831.00  |             | 0.00       | C         | S      | 0         |       |          |         | 72       | 71       | R     | E      | O   | O  |    | 1     |             | HEALTH CHECK DUMMY FAULT CODE |

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FIGURE 6



1. **Occur date:** The date the fault occurred.
2. **Fault Code:** The fault code number as stored in CAB/CAX including the sub-id.
3. **Occur Hours:** The time in hours since 00:00:00 01-01-1987 that the fault occurred.
4. **Reset Hours:** The time in hours since 00:00:00 01-01-1987 that the fault was reset.
5. **Locomotive Speed:** Speed in miles per hour of axle #2.
6. **Locomotive Direction:** CAX Mode Call (CAB to AUX).
7. **Notch:** CAX Throttle Call.
8. **Engine Speed:** Diesel Engine Speed.
9. **Main Alternator Volts:** Traction Alternator Volts or DC Link Volts.
10. **Main Alternator Amps:** Traction Alternator Amperes or DC Link Current.
11. **Main Alternator Field:** PSC Sub-id on AC4400 locomotives. Main Alternator field amps applies to Dash-9 locomotives.
12. **Engine Water Temperature:** Water temperature measured with the EWT sensor.
13. **Engine Lube Oil Temperature:** Lube Oil temperature measured with the LOT sensor.
14. **Call:** CAX Mode Call.
15. **State:** CAX Mode State.
16. **Blower:** Equipment Blower State.
17. **Radfan:** Radiator Fan State.
18. **BF:** Equipment Blower / Radiator Fan.
19. **INFO:** Idle constraints.
20. **MISC. STATUS:** CAX (EXC) Status.
21. **SE:**
22. **Fault Description:** This is the fault description as defined in the Fault Table.

EMD's IntelliTrain webpage Login (FIGURE 7)

intellitrain

Imagine what happens when we combine the industry expertise in rail transportation and EMD expertise in locomotive design, system integration, and troubleshooting with the power of the Internet and wireless communications... EMD is leading the "intelligent" revolution. About 10,000 of our revolutionizing locomotives are in operation.

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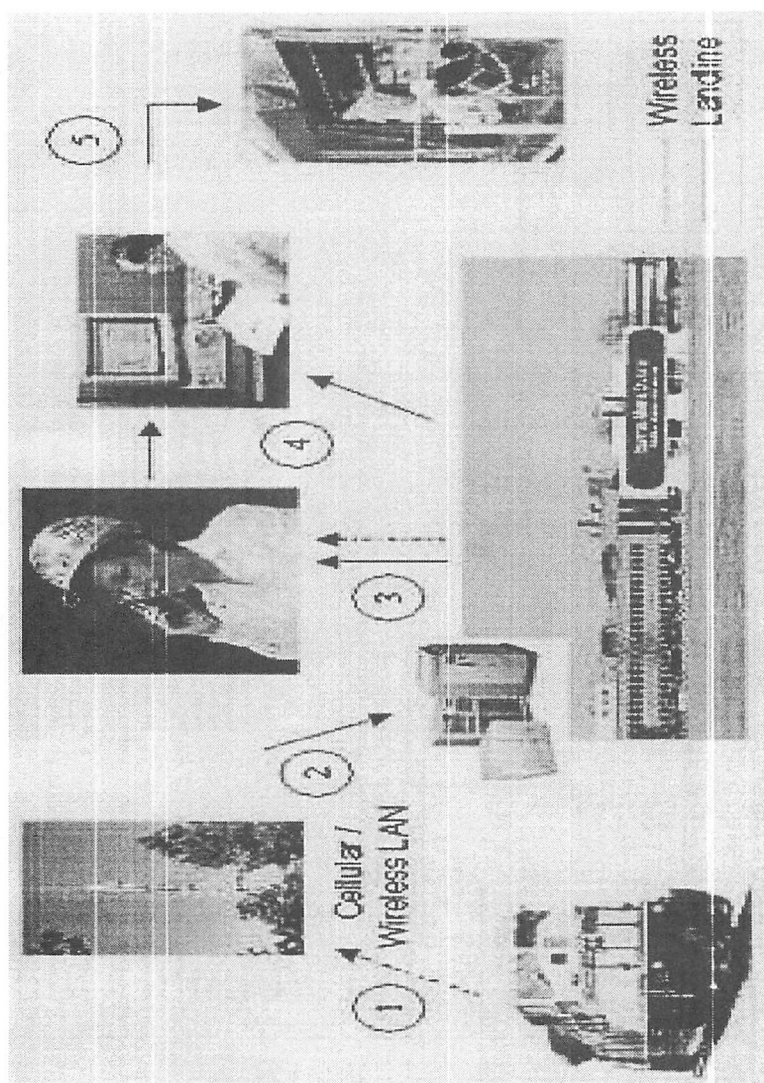
USER NAME:  PASSWORD:

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FIGURE 8



EMD's Locomotive Summary Data Report webpage (FIGURE 9)

Locomotive Summary Data - Netscape

File Edit View Go Communicator Help

Back Reload Home Search Netscape Print Security Shop Stop

Bookmarks Location <https://intellitrain.greend.com/LocomotiveSummary.aspx?LocomotiveID=253> What's Related

Lyons GoTo.com Yellow Pages

**intellitrain** ELECTRO-MOTIVE

Home Locomotives Configuration Mapping Statistics Help Logout FIRE 5:36 PM (GMT-05:00)

Summary for: All Locomotives CDTX 2012

Current Status: OK Locomotive Faults in Last 24 hours: 0

Summary: [Home](#) [Locomotive](#) [VIB](#) [Subsystems](#) [Loading](#) [Fuel](#) [Traction](#) [Roller](#) [Signal System](#)

using: [MapQuest](#)

| Status                             | Loading                  | Subsystems                   |
|------------------------------------|--------------------------|------------------------------|
| Time: 08/18/02 05:31 PM            | Engine State: Running    | Auxiliaries: OK              |
| Fuel: 680 gal                      | Rev Pos: Forward         | Cab Electronics: OK          |
| Health: OK                         | Throttle: T 4            | Dynamic Brake: OK            |
| Location: Cordelia, Solano Co., CA | TE: 218 MLbf             | Electrical Control: OK       |
| Speed: 75 MPH                      | Power: 698 KW            | Engine: OK                   |
| Heading: SSW                       | Unit Config: Trail - Run | Protection System: Attention |
|                                    |                          | Traction System: OK          |

| Refueling                          | HEP                    | Faults                               |
|------------------------------------|------------------------|--------------------------------------|
| Refuel Time: 08/18/02 04:03 AM     | Power: 167 KW          | Fault Active: 08/18/02 09:15:16 AM   |
| Location: Oakland, Alameda Co., CA | Voltage: 490.7 V       | Fault Inactive: 08/18/02 09:15:16 AM |
| Fuel Volume Added: 1,250 gal       | % Engine Load: 32.7 %  | State: Inactive                      |
| Final Fuel Volume: 1,900 gal       | Fuel Rate: 15.7 Gal/Hr | Snapshots: 0                         |
|                                    | Net Power: 87.6 KW     | Fuel Costs: 1.20                     |

Document Done

Start Microsoft Excel - market Microsoft Word - Document Locomotive Summary 5:36 PM

EMD's Locomotive Loading Data Page webpage (FIGURE 10)

Locomotive Loading Data - Mainpage  
 File Edit View Go Commercials Help  
 Back Home Search Helpcase Print Security Shop Stop  
 Bookmarks Locations: /realtime/gmcmd.com/LocomotiveLoading.asp?LocomotiveID=203  
 Loc: 6010.com Yellow Pages

**intellitrain**

Find Locomotives Configure Mapping Statistics  
 Help Logout **FIRE** 5:37 PM (GMT -05:00)

Summary for: All Locomotives | CDIX: 2012  
 Current Status: OK Locomotive Faults in Last 24 hours: 0

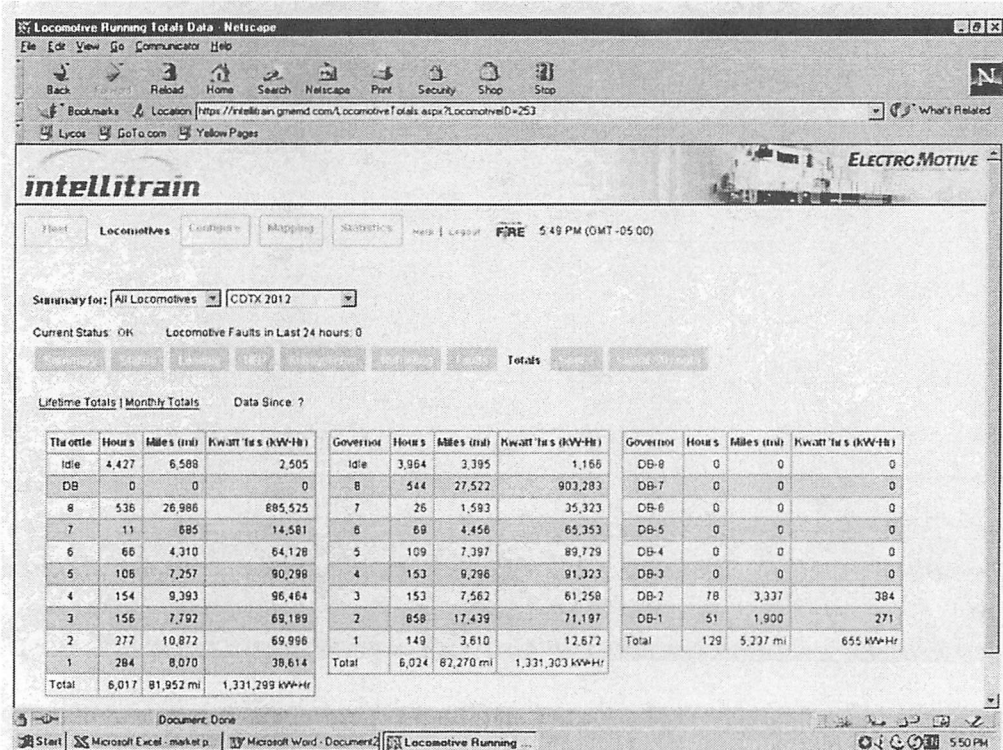
Data Filter  
 From: Immediately To: Immediately Last: Days  
 Apply Filter

▼ Sort columns by clicking headers

| Time              | Health  | Locomotive                     | using | Speed (MPH) | Engine State | Rev Pos | Direction | IE (A/Hz) | Power (kW) | Unit Config     |
|-------------------|---------|--------------------------------|-------|-------------|--------------|---------|-----------|-----------|------------|-----------------|
| 08/19/07 05:31 PM | OK      | Cordelia Solano Co. CA         |       | 75          | Running      | Forward | T 4       | 218       | 698        | Trail - Run     |
| 08/19/07 05:21 PM | OK      | Suisun City, Solano Co., CA    |       | 17          | Running      | Forward | Idle      | -163      | 0          | Trail - Run     |
| 08/19/07 05:11 PM | OK      | Elmira, Solano Co., CA         |       | 77          | Running      | Forward | T 4       | 213       | 697        | Trail - Run     |
| 08/19/07 05:01 PM | OK      | Davis, Solano Co., CA          |       | 73          | Running      | Forward | T 5       | 285       | 934        | Trail - Run     |
| 08/19/07 04:51 PM | OK      | El Matoso, Yolo Co., CA        |       | 74          | Running      | Forward | T 5       | 213       | 679        | Trail - Run     |
| 08/19/07 04:41 PM | OK      | Sacramento, Sacramento Co., CA |       | 12          | Running      | Forward | T 5       | 841       | 978        | Trail - Run     |
| 08/19/07 04:31 PM | Offline | Sacramento, Sacramento Co., CA |       | 0           | Running      | Center  | Idle      | 0         | 0          | Trail - Run     |
| 08/19/07 04:21 PM | Offline | Sacramento, Sacramento Co., CA |       | 0           | Running      | Center  | Idle      | 0         | 0          | Trail - Run     |
| 08/19/07 04:11 PM | Offline | Sacramento, Sacramento Co., CA |       | 0           | Running      | Center  | Idle      | 0         | 0          | Trail - Isolate |
| 08/19/07 04:01 PM | Offline | Sacramento, Sacramento Co., CA |       | 0           | Running      | Center  | Idle      | 0         | 0          | Trail - Isolate |

Document Date: Microsoft Word - Document1  
 Microsoft Excel - make1.p Microsoft Word - Document1 Locomotive Loading ...  
 5:37 PM

EMD's Locomotive Running Totals Report webpage (FIGURE 11)



## II. Cool Your Jets:

### A Low Cost, High Performance Rooftop Air Conditioner

*Prepared by: Robert M. Farar  
Union Pacific Railroad &  
Donald E. Graham, P.E., Ph.D.  
Dayton-Phoenix Group*

#### Abstract

Cost effective air conditioning for older locomotives creates the need for a low-cost, high-performance rooftop air conditioner product. Unitary roof-mounted units have been applied for many years to locomotives not originally designed for air conditioning, but these products exhibit several shortcomings. Those that operate from 74 volts DC may require an expensive upgrade to the auxiliary electrical system of the locomotive, while other types that are powered by the companion alternator (CA) have cooling performance that varies widely with engine speed; cooling performance at low throttle notches is poor. Therefore, engines are often operated in notch 3 or higher at idle to get adequate cooling, resulting in wasted fuel, more noise, more emissions and extra maintenance.

This paper presents a new concept for a low-cost, high-performance air conditioner that provides excellent cooling at all throttle notches and requires no upgrade of other locomotive systems. This product is referred to as the "CA Rooftop Air Conditioner" and is powered by both 74 volts DC and three-phase AC power from the companion alternator. The 74-volt

supply operates an inverter, which provides brushless, adjustable-speed control of the evaporator and condenser fan motors. Three-phase power from the companion alternator directly operates a two-speed compressor motor without an inverter. The frequency of the CA output voltage is measured by control circuitry in the air conditioner; and when that frequency is less than approximately 60 Hertz, the compressor is operated at high speed (two pole). As engine speed increases and CA output frequency consequently increases beyond 60 Hertz, the compressor motor is switched to low speed (four pole) to prevent over-speed damage to the unit.

Two-speed operation of the compressor provides minimum air conditioning capacity of 22,000 Btu/hr and maximum capacity of 27,000 Btu/hr. These capacities have proven to be entirely adequate in field tests, and compare very favorably to the 25,000-to-30,000 Btu/hr capacities of under-floor and running board products that are currently applied to much larger "Wide Body" cabs. It is believed that a product with this level of performance, conservatively designed and requiring no locomotive modification, represents an impressive complement to the cost effective choices that are available to those who air condition existing locomotives.

#### Introduction

The rooftop air conditioner (A/C) is well known in the railroad

industry, and is most often used for cooling the cabs of older, heater-only locomotives. Indeed, thousands of these products are in use at the Class I railroads today, and the need for railroads to air condition virtually every locomotive in the fleet creates the need for thousands more. It is important to recognize, however, that today's rooftop air conditioners have some shortcomings in cost and performance that deserve attention. Specifically, as shown in Figure 1, the products that have been widely used for many years seem to be divided into two categories: low cost, low performance and high cost, high performance products.

Clearly there is a need for a product that achieves improved performance in both cooling behavior and maintenance at low cost – a new product that belongs in the lower righthand quadrant of Figure 1. Dayton-Phoenix Group recently introduced a product of this type to the aftermarket. Providing two levels of air conditioning output and two levels of vent-only operation for optimum crew comfort, the product is referred to as the High Performance Companion Alternator Rooftop Air Conditioner, or simply the High Performance CA Rooftop. The purpose of this paper is to describe this new market entry, and show how it fills the value and performance gap that exists now, among various alternative rooftop products. A review of today's most popular rooftop A/C offerings provides a useful back-

ground to understand the new product and assess its place in locomotive air conditioning.

### **Today's rooftop air conditioners - low cost**

The oldest and most widely used rooftop air conditioner is the type powered from both the companion alternator and 74 volt DC auxiliary electrical system of the locomotive, sometimes referred to as an "AC/DC air conditioner". The refrigeration circuit of these low cost products typically utilizes an inexpensive, automotive-type compressor. Generally a single-speed, integral horsepower, three phase AC motor powered by the CA directly operates this open-drive (shaft-driven, non-hermetic) compressor, at a speed that is directly proportional to locomotive engine speed. Use of this existing power supply for the compressor saves money, but the capacity of the air conditioner changes directly with engine speed, and almost no cooling is provided at idle and the lower throttle notches. Locomotives are typically operated in throttle Notch 3 or higher, simply to get sufficient cooling to satisfy the crew. Therefore, fuel, is wasted, locomotive maintenance is increased, and more emission products and noise are generated when this product is used.

It should be noted that to avoid these limitations, some rooftop A/C products have used a large, 74 volt DC motor (perhaps rated at five horsepower) to drive the compressor. However high motor cost,

brush maintenance expenses and auxiliary generator capacity concerns have kept these products from wide acceptance.

The condenser fan and evaporator blower in these products are usually operated from the 74-volt supply of the locomotive by brush-type DC machines of the type found in the transportation industry. Machines of this type, while relatively inexpensive, are short in hours of life and the air conditioner must be removed from the locomotive for brush maintenance. Similarly, an inexpensive automotive compressor is designed for only a few thousand hours of life and it too may need frequent replacement. Thus it is clear: The "price" of the "low-initial-cost" air conditioner is low cooling performance, extra operating costs and high maintenance. Simply stated, this seemingly low-cost product comes at the expense of higher life-cycle cost.

### **Today's rooftop air conditioners - high performance**

The ultimate in locomotive air conditioning performance is provided by all-AC hermetic air conditioners. This product, introduced in the early nineties, uses an inverter to convert 74 volts DC to the appropriate voltage and frequency for each of three AC motors: the hermetic compressor motor, evaporator blower and condenser fan motor. While this product is usually not serviceable on the locomotive, maintenance requirements are minimal, and it is not uncom-

mon for a rooftop product of this type to remain in service for several years before routine maintenance - usually just simple cleaning of the condenser and evaporator coils. Cooling performance is independent of engine speed, and the hermetic compressor can operate for a decade without service. Thus, the major limitations of the low cost air conditioner are addressed with the hermetic product: cooling performance is good under all conditions, and life-cycle cost is low.

The initial cost of this product is its only drawback. Products of this type may sell for more than twice the price of the CA powered air conditioner. Indeed, should the 74 volt electrical system need to be upgraded to provide about six kilowatts of power to handle its load, the installed-cost on the locomotive could increase dramatically and, perhaps, prohibitively. Thus the "price" of a high-performance air conditioner is simply its high initial cost.

### **New product - low cost, high performance rooftop air conditioner**

Realizing the strengths and weaknesses of today's rooftop air conditioners, a new product was proposed to be a "gap filler", to combine the strong points of low cost designs with affordable features found in high performance products. Certainly, any new product intended to maximize performance while keeping initial purchase costs and maintenance costs

low, must be the result of reasoned compromise and trade-off studies, considering every component and subsystem of the air conditioner. The following summarizes a set of trade studies that were made, from which design direction emerged for an air conditioner intended to satisfy the following goals:

- **Adequate cooling at all throttle notches including engine idle (i.e. no notch 3 or other requirement to obtain acceptable cooling),**
- **No removal from the locomotive for routine service in less than two years,**
- **Maximum interchangeability with existing rooftop air conditioners, and a**
- **Selling price at least 40% below the price of today's high performance hermetic rooftop A/C product.**

### **Compressor Technology**

Without doubt, the single, most fundamental decision in developing a concept for the new product was selection of the refrigerant compressor. While there are any number of different compressors from which to choose, the salient issue quickly emerges: Is the compressor a hermetic type or an open-drive (shaft-driven) type? A hermetic compressor is clearly desirable in many air conditioning systems because of its reliability and low maintenance requirements. A compressor of this type, however, requires very nearly constant voltage and frequency to provide constant-speed operation of

its three-phase hermetic motor. For freight locomotives, unless retrofitted with an auxiliary power unit (APU), no such power supply is available. The only constant voltage available is from the 74 volt DC auxiliary electrical system. An inverter is required, therefore, to produce AC voltage at the required frequency from this power supply.

Michael E. Drylie, P.E., of CSX Transportation, noted in his 2001 LMOA paper entitled "Locomotive Alternative Air Conditioners", that 27,000 Btu/hr would acceptably cool a typical cab by 20-25 degrees Fahrenheit. Under extreme operating conditions, the hermetic motor alone could require in excess of seven horsepower to meet such a cooling requirement. A several-thousand-dollar inverter operating from 74 VDC is implied for just this task and, as Mr. Drylie noted, costs could skyrocket if the locomotive's auxiliary generator should need an upgrade to provide the power.

After a thorough review of both hermetic and open-drive compressor options, for the reasons of inverter cost, hermetic compressor cost and minimum auxiliary generator loading, two key decisions were made for the direction of this product:

- **The compressor would be an open drive (shaft driven) type, and its separately coupled AC motor would be powered from the companion alternator.**

The engineering challenge was simply stated: Find a viable open-drive compressor and a way to operate it such that the well-known capacity and durability limitations of CA powered air conditioners could be overcome.

### Compressor Selection

A compressor manufactured by SELTEC was selected, and is shown in Figure 2. This piston compressor (Model 15HD) is similar in appearance to low-cost automotive compressors, but it is important to recognize that it has been upgraded in critical areas for severe duty applications that demand many hours of service. Specifically, molybdenum disulfide (MoS<sub>2</sub>) lubricant is applied to a steel swash plate that replaces the aluminum swash plate found in automotive compressors. Teflon-coated pistons replace piston rings, thereby providing compliance and preventing seizure should an unusual situation result in rapid and non-uniform expansion of pistons and cylinder walls. Additionally the shaft seal is upgraded to a lip seal design for reliable operation at the high pressures presented by extreme cooling conditions. It is believed that this low-cost compressor, properly applied, meets the reliability and maintenance goals for the product.

The capacity of the compressor, however, changes directly with its shaft speed, just like the low performance products on the market today. Therefore, to achieve the goal of having good cab cooling at

engine Idle RPM, an appropriate drive technique would be needed to provide sufficient compressor speed at idle, and not exceed the compressor's 6000 RPM maximum limit at notch 8.

### Compressor Drive

Locomotives such as the SD-40, GP-38 and others operate over an engine speed ratio of approximately 3.6 to 1. Engine speeds from 250 RPM at idle to 900 RPM at notch 8 produce CA output frequencies from 33.3 Hz to 120 Hz, respectively. An AC motor operates at a synchronous speed (approximately the same as operating speed) defined by:

$$N_s = 120 * F / P$$

where  $N_s$  is synchronous speed-RPM

$F$  is applied frequency - Hz

$P$  is the number of motor poles - 2,4,6

From this equation it is clear that at Idle a two-pole motor is desired to obtain the maximum motor RPM; the motor would operate around 2000 RPM. Indeed, the SELTEC 15HD compressor satisfies capacity requirements at this speed. However, when the two-pole motor is operated at notch 8, the motor speed of 7200 RPM far exceeds the 6000-RPM limit for the compressor.

The equation shows that selection of a four-pole motor reduces the compressor speed in throttle notch 8 to 3600 RPM, an accept-

able value, but at idle its speed becomes only 1000 RPM, and cooling capacity suffers. It is for this reason that many CA powered rooftop air conditioners, built with four-pole compressor motors, are operated in throttle notch 3 (at approximately 1800 RPM) instead of idle to get good cooling. The four-pole motor, however, does avoid the notch 8 overspeed situation for the compressor.

From this simple analysis, it is clear that the ideal drive for the SELTEC compressor is a dual speed motor - a motor that can be operated in either two-pole or four pole mode. With these two operating modes, compressor speed can be kept high at low throttle notches in two-pole mode for good cab cooling, and high throttle notches will not overspeed the compressor in four-pole mode.

Fortunately, motors of this type and their electromechanical control hardware are well known in the railroad industry, finding application on radiator cooling fans, motor driven air compressors and other equipment. The specific motor designed for this product is a three phase, two pole/four pole, single winding, six lead, consequent pole, constant torque, induction machine rated at nine horsepower. Figure 3 shows three, three-pole contactors that are used to connect the six motor wires to produce two pole or four pole motor operation. As shown, the two outside contactors are energized to select two-pole (high speed) operation in a parallel-wye

winding configuration. When these two contactors are opened and the center contactor is closed, a series-delta connection of the winding provides four-pole (low speed) operation.

For optimum reliability in the presence of diesel exhaust, dirt and many other contaminants, the motor is a totally enclosed, non-ventilated design that uses a cast iron NEMA 215 frame and shielded ball bearings. The NEMA C-flange on this motor provides the mount for an adapter that locates the SELTEC compressor for coupling to the motor shaft, as shown in Figure 4. This mounting technique eliminates manual shimming for proper alignment of the motor and compressor. An opportunity for human error is removed, and it is, therefore, virtually impossible to misalign the compressor and motor, and cause an early failure.

### Fan Motors

For reasons of low cost, low maintenance and very high reliability, it was determined that these two motors should be three-phase, AC induction machines with ball bearings, as opposed to any brush-type DC or permanent magnet brushless DC machines. The evaporator blower and condenser fan motors are designed accordingly in totally enclosed, non-ventilated frames to ensure best immunity to the environment. Each motor shaft is directly coupled to the fan it drives, thereby eliminating couplings, belts and other hardware in order to ensure reliability to keep costs

low. Each motor is a three-phase, 0.75 horsepower, four-pole design in a NEMA 56 frame.

For air conditioner performance and crew comfort reasons, these motors cannot be allowed to change speed as the engine changes speed. Even two-speed motors were deemed unacceptable for these reasons. Clearly, therefore, the CA cannot be used to power these fans and provide constant airflow to the cab. An inverter is necessary for this purpose.

### **Inverter and Controls**

A small inverter is required to convert 74 volts DC to adjustable frequency AC to operate the two fan motors at appropriate constant speeds. To keep costs low, these two motors are operated in electrical parallel from a single, 1.5 horsepower inverter. Therefore, even in VENT mode, the condenser fan operates. Also, for inverter cost and motor insulation durability reasons, the motors are designed to operate not at the usual 230 or 460 volt excitation, but instead at 55 volts - the three phase AC voltage that is obtained when 74 volts DC is inverted. For optimum reliability, cool air from the evaporator fan blows directly on the heatsink of the inverter to keep semiconductor junction temperatures low.

The inverter shares a printed circuit board with the control circuitry that determines the operating mode of the compressor motor - two pole or four pole. This circuit simply monitors the frequency of

one phase of the Companion Alternator to determine which mode is appropriate. If the CA output indicates the throttle is in Notch 2 or lower, two-pole operation is selected; for Notch 3 and above, four-pole operation results. Hysteresis about the switching frequency prevents incessant and destructive contactor switching between modes. Selection of Notches 2 and 3 for mode switching causes the compressor to operate from 2000 to 3600 RPM in two-pole mode and from 1800 to 3600 RPM in four-pole mode, speeds that provide good AC capacity and are well below the maximum-RPM limit.

This controller also makes possible a useful system control feature, for almost no extra cost. Since rooftop A/C units have no heating function and, therefore, are generally independent of cab heater operation, it is desirable to "lock out" air conditioning whenever cab heaters are energized. Many of today's rooftop products use a shunt-trip circuit breaker to power the A/C normally, and accomplish this purpose. In that case, whenever heaters are operating, "heater on" power activates the shunt trip of the breaker to remove CA power from the air conditioner. In the new rooftop product, a feed of 74 volts from the "heater on" circuit to the interlock "I" terminal of the air conditioner causes its solid-state control circuit to inhibit cooling whenever the heater operates. Thus, no circuit breaker needs to be reset, and

equivalent system functionality is accomplished for a fraction of the cost of a shunt-trip circuit breaker. The circuit board containing the inverter, frequency detection circuitry and heater interlock function is shown in Figure 5.

### Condenser Coils

Condenser coils on rooftop air conditioners operate on top of the locomotive in perhaps the worst environment that any heat exchanger experiences; they are constantly being bombarded by locomotive exhaust, diesel fuel spray, dirt and other contaminants. It was decided accordingly that this product should absolutely maximize condenser coil area, minimize fin density and allow contaminants to "blow through", and use no filters because of maintenance and service personnel safety reasons. While it is recognized that any rooftop air conditioner will eventually have to be removed from the locomotive to clean the condenser coil, a goal of this design was to achieve at least two years of operation before such service would be required. The condenser was designed, therefore, in a "U shape" with fins on three sides of the unit, providing an unusually large surface area for the condenser.

### Refrigeration Circuit

The complete refrigeration circuit is shown in Figure 6. An environmentally friendly refrigerant, R-134a, was selected because there are no U.S. government

restrictions on its use, and there are many cost effective refrigeration-circuit components available for use in a new rooftop product. The key to reliable operation of any compressor in refrigeration service is simply stated:

- **Always ensure that the compressor pumps refrigerant gas and never pumps refrigerant liquid.**

For this reason, the refrigeration circuit was provided with a suction accumulator to collect any liquid refrigerant immediately before the intake (suction) port of the compressor. Through consultation with the manufacturer of the compressor, it was decided that for reliability reasons this accumulator should be complemented with an outside air temperature (OAT) sensor such that the air conditioner could never be operated at temperatures where potentially catastrophic "liquid slugging" of the compressor could occur. Other devices such as a crank case heater, liquid line solenoid for a pump-down cycle, and a high-pressure relief valve were considered, but were deemed to be unnecessary additional cost items.

The remaining components, including the evaporator coil, thermal expansion valve (TXV), head pressure relief solenoid, pressure switches, sight glasses and other refrigeration circuit hardware were chosen based upon experience and proven durability in similar locomotive applications.

### Interchangeability

All of the electrical, electronic and refrigeration circuitry is packaged in a cabinet that is mechanically interchangeable with almost any rooftop air conditioner currently in service; i.e. the product preserves the standard bolt pattern of early rooftop air conditioners. Rooftop products from other manufacturers over the years have, however, had three different styles of electrical hookup, and two different provisions for the condensate drain. To realize the goal of maximum interchangeability with existing products, all three electrical hookup and both drain provisions are incorporated in this product.

Because of these electrical and plumbing provisions, installing the high performance rooftop A/C on a locomotive for the first time, or replacing another rooftop product already in service, is no different from installing or replacing any other "AC/DC" or CA-powered product. Since the new air conditioner does provide more cooling, however, a 65-ampere circuit breaker is supplied with each unit to replace the physically identical 30-amp A/C breaker found on most of the older locomotives.

### System Performance

Figure 7 shows the capacity of the High Performance CA Rooftop Air Conditioner as a function of engine speed at its rated condition: 95 degree outdoor temperature, 80 degree dry bulb and 67 degree wet bulb cab conditions. The

capacity varies from 22,000 Btu/hr to 27,000 Btu/hr depending upon the specific engine operating speed. Various tests across the southern United States have shown 22,000 Btu/hr to be entirely adequate for cooling in idle. This capacity for the smaller cabs found in older locomotives compares favorably to the 27,000 to 30,000 Btu/hr systems used in much larger "wide body" cabs. Test in outdoor temperature conditions in excess of 115 degrees have indeed produced very favorable results and positive crew responses.

Since the product is located in the ceiling of the cab and is very close to the crew, low noise performance and good control of air distribution are important characteristics. Careful attention to balance specifications for the compressor motor and its coupling to the compressor results in very acceptable cab noise figures that change little between HIGH VENT and HIGH COOL operation at the various throttle notches. The use of eight automotive-style adjustable air diffusers ensures that each crewmember can adjust the air delivery for optimum comfort.

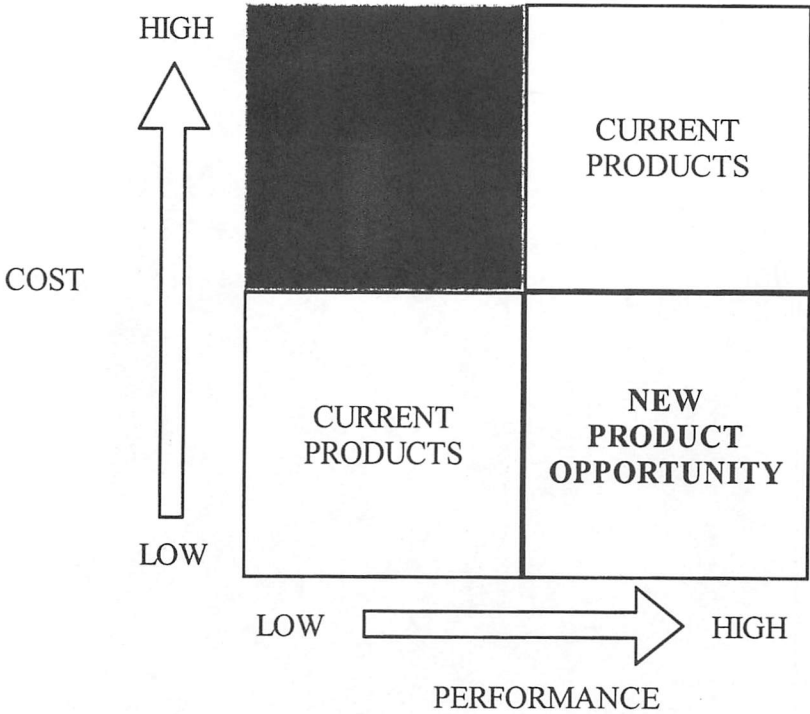
### Conclusion

The CA rooftop air conditioner described in this paper does indeed offer high performance at relatively low cost, as compared to the competing alternatives. However, does this new product make obsolete, now and for evermore, all of those products? The

answer to this rhetorical question is "Probably not."

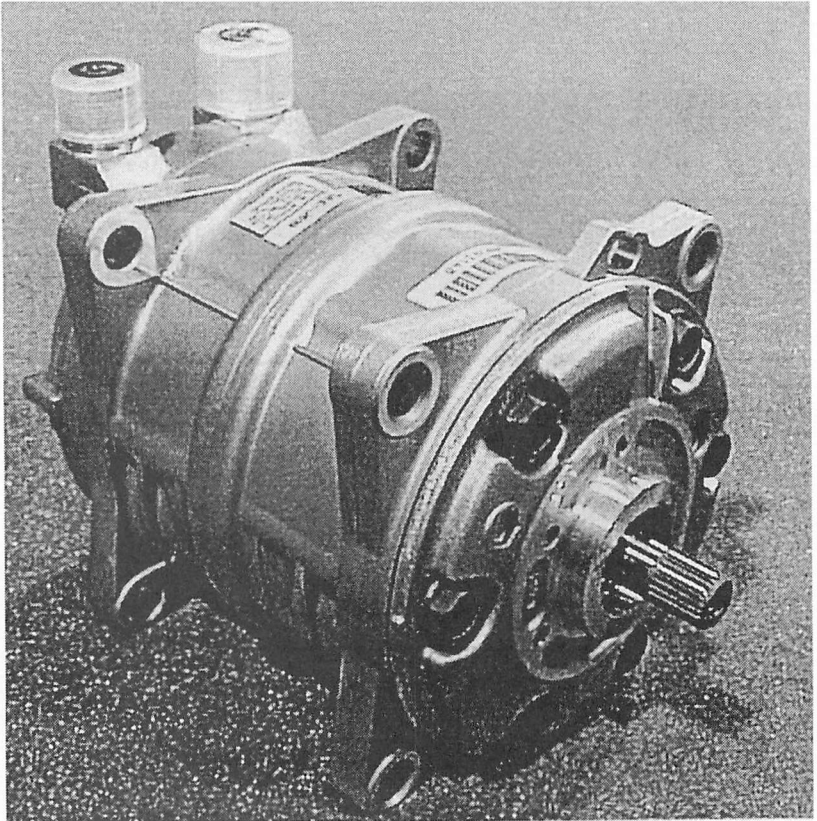
For those who need the pinnacle of performance, or those who are budget conscious and need low purchase price above all other considerations, this product has no place - it does not compete. Where, however, the need is for very good performance at reasonable cost, this new product finds its place. The high performance C/A rooftop air conditioner, therefore, does not make obsolete all other rooftop air conditioners. Instead it offers an impressive complement to the broad spectrum of alternatives available to those who must air condition today's locomotives.

AIR CONDITIONER COST - PERFORMANCE COMPARISON

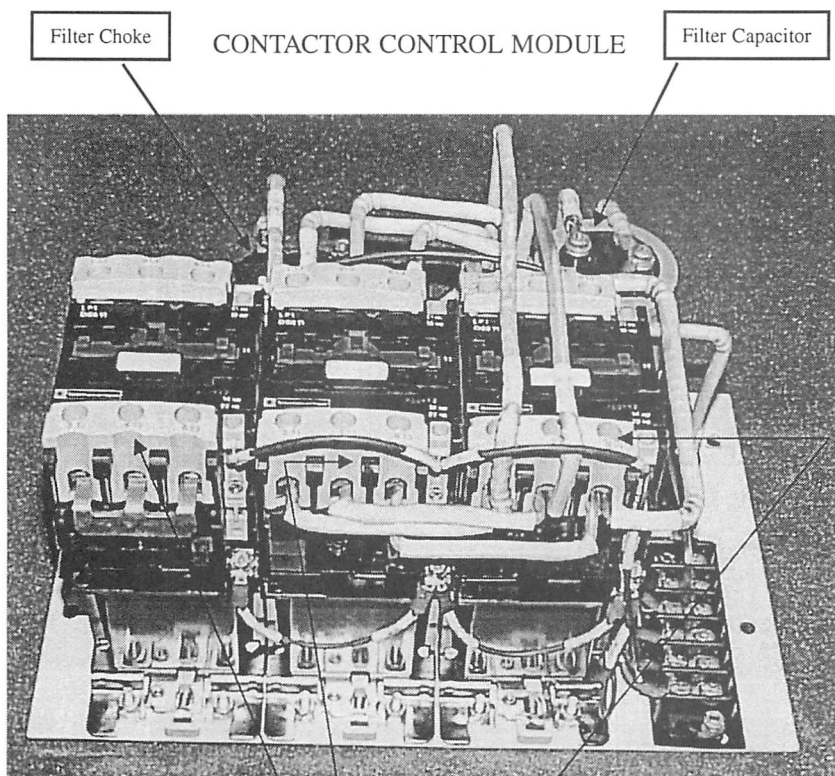


(Figure 1)

## SELTEC 15 HD COMPRESSOR



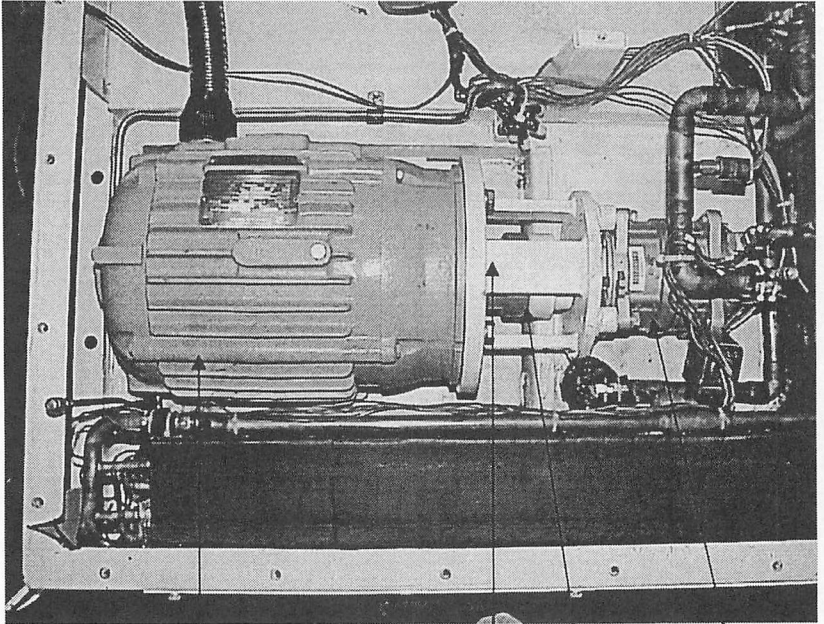
(Figure 2)



(Figure 3)

Contactors

### COMPRESSOR and MOTOR MOUNT



(Figure 4)

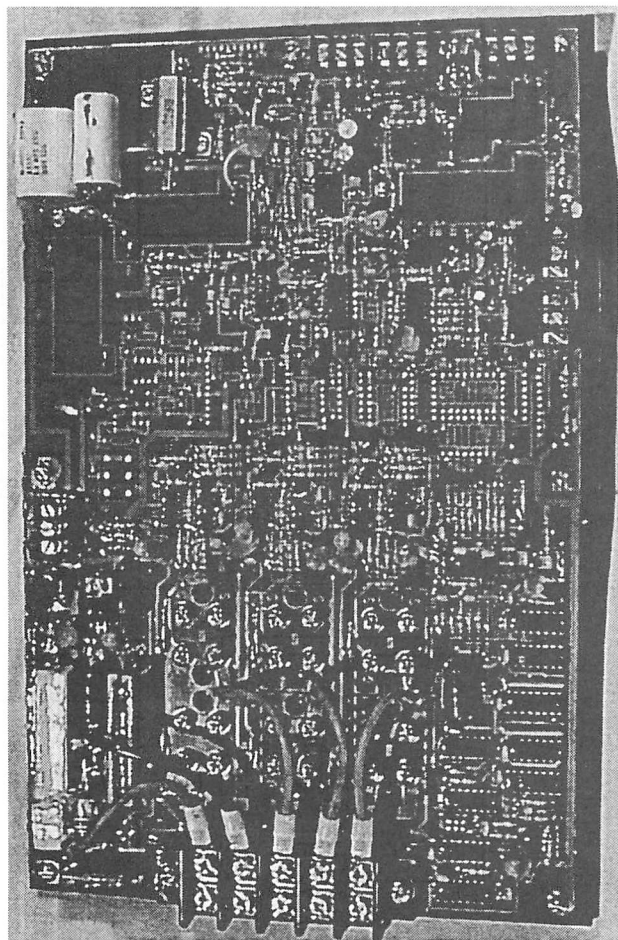
2 Speed Motor

Adapter

Coupling

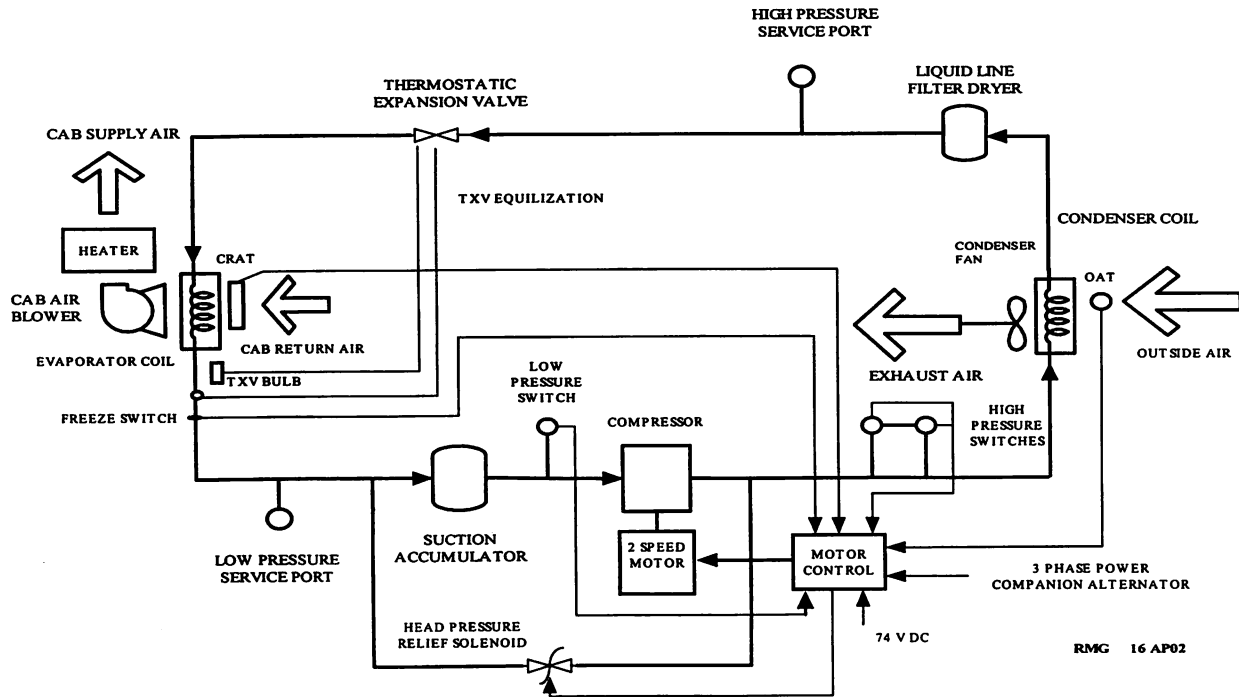
Compressor

**INVERTER and CA FREQUENCY DETECTION CIRCUIT**



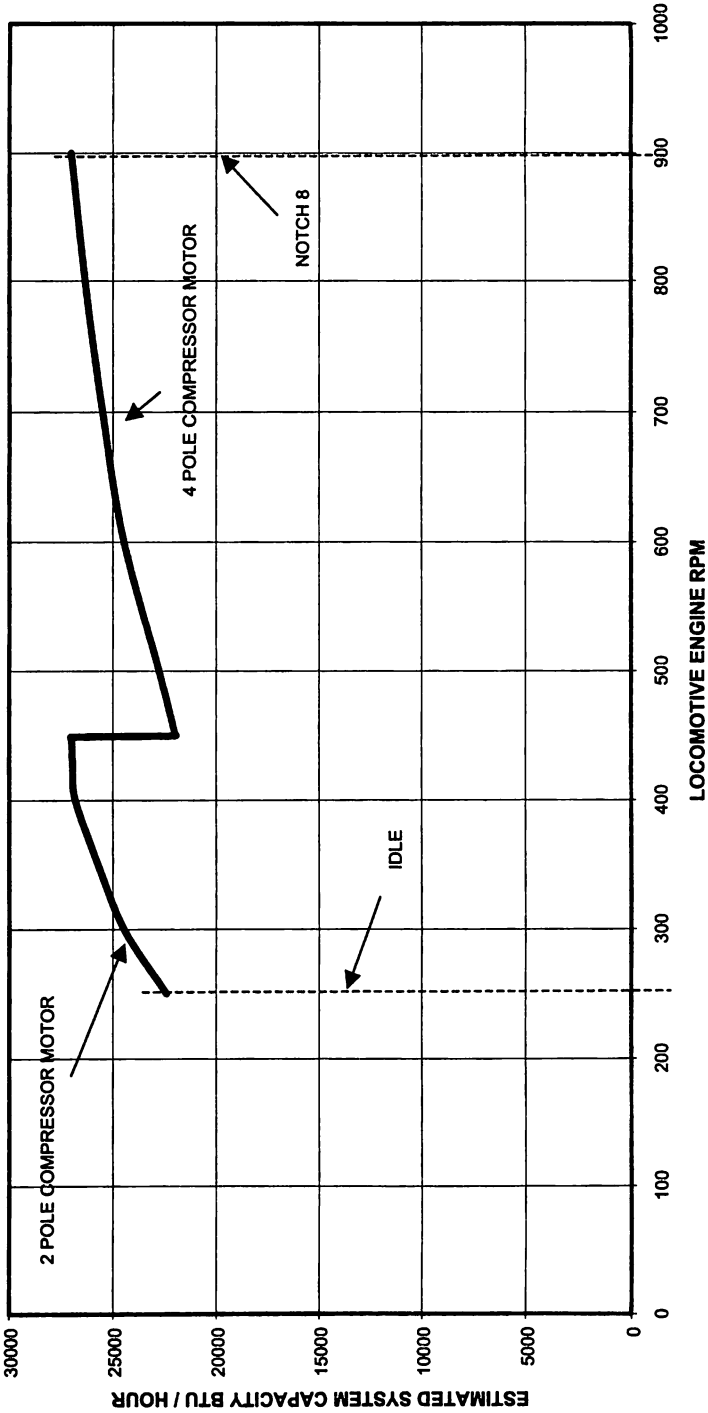
(Figure 5)

# REFRIGERATION CIRCUIT SCHEMATIC



(Figure 6)

**ESTIMATED A / C CAPACITY vs. LOCOMOTIVE ENGINE RPM**



(Figure 7)

## 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 contract for his or her services with appropriate compensation.

**Section 5** - Advisory Board - There shall be an Advisory Board composed of at least nine members, who are Senior Mechanical Officers, Assistant Vice Presidents or Vice Presidents. They will be invited by the Board of Directors and serve as ex-officio members of the General Executive Committee without vote.

#### **Article V - Officer, Nomination and Election of**

**Section 1** - Elective officers shall be chosen from the active membership. The nominating committee, composed of the Board of Directors, shall submit the slate of candidates for each elective office at the annual convention.

**Section 2** - Election of officers shall be determined by a voice vote, or if challenged, it shall require show of hands.

**Section 3** - Vacant offices. Vacancies in any elective office may be filled by presidential appointment, subject to approval of the Board of Directors.

#### **Article VI - Officers - Duties of**

**Section 1** - The President shall exercise general direction and

approve expenditures of all affairs of the Association.

**Section 2** - The First Vice President, shall in the absence of the President, assume the duties of the President, he shall countersign all expenditures of the Association and be responsible for preparing and submitting the program for the Annual Meeting.

The Second Vice President shall be responsible for selecting advertising. He will coordinate with the Secretary-Treasurer and contact advertisers required to underwrite the cost of the **Annual Proceedings**.

The Third Vice President will be responsible for maintaining a strong membership in the Association. He will ensure that membership applications are properly prepared and distributed, monitoring membership levels and reporting same at appropriate time to the General Executive Committee.

**Section 3** - The Secretary-Treasurer shall:

A. Keep all the records of the Association.

B. Be responsible for the finances and accounting thereof under the direction of the Board of Directors.

C. Perform the duties of the Secretary of the Board of Directors, Nominating Committee, and General Executive Committee, without vote.

D. Furnish surety bond in amount of \$5000 on behalf of his/her assistants directly handling

Association funds. Association will bear the expense of such bond.

**Section 4** - The Board of Directors shall be responsible for the following duties:

A. Assist and advise the President in long-range Association planning.

B. Contract for the services and compensation of a Secretary-Treasurer.

C. Serve as the Nominating Committee.

D. Serve as the Auditing and Finance Committee.

E. Determine the number and name of the Technical Committees.

F. Exercise general supervision over all Association activities.

G. Handle all matters of Association business not specifically herein assigned.

H. The Vice President shall perform such other duties as are assigned them by the President.

I. Those present at any meeting called on not less than thirty days advance written notice, shall constitute a quorum.

**Section 5** - There will be one Regional Executive officer assigned to each technical committee. Their duties will consist of:

A. Participate in the General Executive Committee meetings.

B. Monitor material to be presented by the technical committees to ensure reports are accurate and pertinent to the goals of the Association.

C. Represent LMOA in their respective regions.

D. Promote Association activ-

ities, 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  
TWENTY ONE YEAR INDEX**

**2001**

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

**2000**

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

**1999**

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

**1998**

1. LMOA Best Practices Series: GM Engine Crankcase Pressure Troubleshooting
2. Union Pacific's New EMD Diesel Engine Rebuild Line At

Downing B. Jenks Locomotive Facility-No. Little Rock, Arkansas

3. GE Turbo Rebuild Procedures
4. Mechanical Impact of Locomotive Emissions Regulations
5. Locomotive Engine Bearing Developments

**1997**

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

**1996**

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

**1995**

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

**1994**

1. Electronic Fuel Injection.
2. ICAV - The Physical Affects on Instantaneous Crank Shaft Angular Velocity Technology.
3. Maintenance Practices Comparison Between Regionals and Class I Railroads.
4. Amtrak Document Management.

**1993**

1. EMD's Three-Axle Radial Steering Truck
2. The Natural Gas Locomotive at BN RR

3. Locomotive Waste Oil Retention
4. Fragmented Maintenance

**1992**

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

**1991**

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

**1990**

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

**1989**

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

**1988**

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

**1987**

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

**1986**

1. Rebuild of Valve Bridge Assemblies.
2. Update of New Locomotive Service Problems, EMD and GE Effecting Quality Performance.
3. Chromium Plating and Its Uses.
4. Development of a New Diesel Engine for Heavy-Duty Locomotive Service.

**1985**

1. Procedures for Storing Serviceable Locomotives for Quality Performance.
2. New Locomotive Service Problems, EMD and GE.
3. 92 Day Service Requirements: EMD, GE and Bombardier.

**1984**

1. Mechanical Aspects of New Locomotive Designs.
2. Maintenance of Locomotive Components.

**1983**

1. Leaks: Cooling Water, Lube Oil, Fuel Oil and Air.
2. Torquing Recommendations.
3. Update on Fuel Efficient Locomotives.
4. Radiator Screens
5. Alternate Starter Systems

**1982**

1. Fuel Conservation - Effects on Maintenance.
2. Fuel Conservation - What It Costs.
3. Diesel Fuel Receipt and Disbursement.
4. Turbochargers.

**1981**

1. Running Gear.
2. Filtration.
3. FRA Rules.
4. Follow-up on Previous Topics.

## DIESEL MATERIAL CONTROL COMMITTEE TWENTY ONE YEAR INDEX

### 2001

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

### 2000

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

### 1999

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

### 1998

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

### 1997

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

### 1996

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

### 1995

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

### 1994

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

### 1993

1. Technology Transfer
2. Electronic Cataloging from a  
Material Perspective
3. Computerized Reordering from

the Mechanical Employee's  
Point of View

4. Electronic Catalogues: OEM  
/Supplier Point of View

### 1992

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

### 1991

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

### 1990

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

### 1989

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

### 1988

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

**1987**

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

**1986**

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

**1983**

1. Improved Locomotive 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 AND PROCESSES COMMITTEE TWENTY ONE YEAR INDEX

### 2001

1. Standing in Railroad Industries - Part II - How to Specify Reliable and Safe Sanding Systems

### 2000

1. The Tandem Wheel Truing Machine at Amtrak's Ivy Shop
2. Shop Talk 2000: Fall Protection Technology
3. Sanding in the Railroad Industry

### 1999

1. Increasing Diesel Shop Capacity
2. Conrail-Cold Asphalt Processing of Environmental Waste Sand and Sludge.
3. Dry Ice Cleaning of GE Intake Ports
4. AAR-LFIS No Spill Fueling System

### 1998

1. Smoke Opacity Testing-Emission Detection Equipment and its Use
2. Hydraulic Tensioning Tools and its Use
3. High Speed Portable Align Boring Series
4. Locomotive Mobile Servicing

### 1997

1. Wheel Truing as Preventive Maintenance
2. Conrail-Selkirk Diesel Terminal Wastewater Treatment Facility Recent Environmental Improvements

### 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 Pre-paration with Sodium Bicarbonate Based Abrasive Blasting
5. Trainline Continuity Tester
6. BN - Railroad Power Assembly Shop of the 1990's.

### 1991

1. Economic Separation of Emulsified Oil from Waste Water Using Ultra Filtration Membranes.
2. EMD Cylinder Head Valve Seat Machining.
3. Automated Barring Over Machine for EMD Diesel Engines.
4. New Equipment for Testing EMD Engine Protectors.
5. Compressed Air for Railroad Facilities Issues and Solutions to Achieve Clean, Dry, Oil Free Air.

### 1990

1. EMD Valve Bridge Machine
2. GE Traction Motor Roller Suspension Bearing Replacement Equipment and Procedure.

3. Locomotive Component Replacement Forklift Attachment.
4. Locomotive Sanding, Fueling and Drop Tables.
5. Hazardous Waste Disposal.

**1989**

1. Automated Locomotive Wheel Shop.
2. Laser Guided Material Handling Vehicles.
3. Bulk Rail Lubrication Storage & Fill System.
4. Pilot Plate Straightening Equipment.

**1988**

1. Fuel Management Control Systems.
2. Locomotive Mounted Rail Lubrication Fill Systems.
3. Comparison of Shop Air Compressors.
4. Locomotive Toilet Servicing Equipment.
5. Innovations in Blue Flag and Derail Protection.

**1987**

1. Modern Servicing Facility for Improved Reliability and Availability.
2. New Developments in GE Tools.
3. Implementation of a Quality Process.
4. A Quality Traction Motor Shop.
5. Wheel Truing Machine Technology.

**1986**

1. Robotics Update 1986 - Now What?
2. CNC Machine Tools.
3. A New GE Power Assembly Area.
4. Locomotive Wash System - 1986.

**1985**

1. Computer-Assisted Preventative Maintenance.
2. New Tools for Material Handling and Overview of Balancing Technology.

3. Effect of Governmental Regulations on Locomotive Finishing.

**1984**

1. Shop Tools.
  - A. New Tools.
  - B. Shop-Made Tools.
2. Traction Motor Shop Equipment Up-Date.
3. Hazardous Waste Handling and Disposal.

**1983**

1. Locomotive Maintenance Using a Production Line Process.
2. Shop Tools to Increase Productivity and Improve Quality.
3. Dynamic On-Line Performance of Locomotives Without On-Board Tele-Metering.
4. Management in Action.
5. New GE Training Center.
6. Welding Qualifications.

**1982**

1. Tools.
2. Rebuild line for EMD turbochargers.
3. Air brake equipment line.
4. Industrial robots.
5. Automated machines.
6. Safety related items and equipment.

**1981**

1. Training Aids.
2. Testing Devices Inspired by New FRA Laws.
3. Tools and Training for Productivity.
4. Changes to Shop Facilities Required by Newly Adopted EPA & OSHA Regulations.
5. Tour Through Conrail Altoona Shop.
6. Supply/Service Facilities.
7. GE Assembly Shop

**DIESEL ELECTRICAL MAINTENANCE COMMITTEE****TWENTY ONE YEAR INDEX****2001**

1. Diagnostic and Predictive Maintenance
2. Locomotive Replacement Control System
3. Automatic Shutdown Startup Controls - Fuel Savings through Technology
4. Locomotive Alternative Air Conditioners

**2000**

1. Custom Electronics and their Applications
2. Locomotive Wire Update
3. Integrated Air Brake & Distributed Power Under EMD Fire System
4. Carbon Brushes - A Fresh Look
5. RM&D - What It Is, What It Does
6. An Alternate Adhesion System

**1999**

1. Transition Panels for Older Locomotives
2. R.S. A.C. Crash Worthy Event Recorder Update
3. Traction Motor Suspension Bearing Temperature Monitoring System
4. EMD SD90MAC 6000 HP Locomotive-An Update
5. IGBT-What's New for GE AC6000 Locomotives

**1998**

1. Locomotive Troubleshooting Assistant
2. Locomotive Electronic Brake Maintenance
3. SD70MAC Capacitor Discharge Procedure
4. Power Savings for Electrical Locomotives
5. Auto Stop/Start and Layover Systems

**1997**

1. Review of Battery Maintenance and Available Options
2. Battery Charger/Booster
3. Locomotive System Integration

**4. Electronic Governors****1996**

1. EMD SD80MAC High Voltage Safety
2. GE AC Locomotive Electrical Safety Features
3. Electromagnetic Interference (EMI on AC Locomotives)
4. QTRAC 1000 Adhesion Control System
5. Locomotive Health Monitoring-The Key to Improved Maintenance

**1995**

1. Canadian National Battery Water Usage
2. Remote Diagnostics-Radio Download
3. Programmed Preventive Maintenance
4. Commutation Monitoring in Locomotive DC Traction Motors
5. The EMD Diesel Engine Control (EMDEC) System

**1994**

1. Safety First - Video on Electrical Safety.
2. Locomotive Health Monitoring Systems.
3. Event Recorder Update.
4. SD60 Dynamic Brake Improvements

**1993**

1. Automatic Engine Shutdown and Restart System
2. Layover Systems/Standby Power Systems
3. CN North America - Electronic Temperature Control
4. Speed Sensing Devices
5. Adhesion Alternative
6. Modern Tooling Update

**1992**

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

**1991**

1. Locomotive Rebuilding - Something Old - Something New. Standardization of Electrical Equipment.
2. Locomotive Batteries
  - a. Storage Handling Procedures.
  - b. Recommended Maintenance Procedures.
  - c. Recommended Repair Procedures.
3. Amtrak's AC Traction Locomotives.
4. Modern Tooling for Electricians Recorders.
3. Why Can't We Have One Central Computer?
4. EPA and Regulation Driven Cleaning.

**1990**

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

**1989**

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

**1988**

1. Utilizing Magnetic Tape Event Recorders for Locomotive Maintenance.
2. Solid State Locomotive Data Recorder.
3. Improved Utilization of GE DASH 8 Data Recording Systems.
4. Locomotive Health Data and Its

Uses To The Railroad.

5. Improved Data Acquisition From EMD's 60 Series Display Computer.

**1987**

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

**1986**

1. Cleaning, Handling & Storage of Electrical Equipment
  - A. Solid State Components.
  - B. Rotating Equipment
2. Qualification of Locomotive Power plants through self load.

**1985**

1. Locomotive Microprocessor Technology in Retrospect.
2. Dynamic Brake Protective devices and Troubleshooting EMD-2 and GE-7 Locomotives.
3. Indicators and Recorders for Locomotive Retrofit Application - Fuel, Speed, Power and Selected Events.

**1984**

1. On-Board Diagnostics.
2. GE's **CATS** (Computer Aided Troubleshooting System).
3. Fuel Conservation Through
4. Electrical Modifications.
5. Performance of Locomotives After Storage.

**1983**

1. Ground Relay Trouble Shooting.
2. Specification for 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.

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**NEW TECHNOLOGIES COMMITTEE  
NINETEEN YEAR INDEX**
**2001**

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

**2000**

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

**1999**

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

**1998**

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

**1997**

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

**1996**

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

**1995**

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

**1994**

1. Electronic Fuel Injection 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 Caterpillar 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.
4. 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****TWENTY ONE YEAR INDEX****2001**

1. On-Board Oil Management System
2. Evaluation of Locomotive Engine Oil Analytical Laboratories
3. Fuel Additives - Friend or Foe

**2000**

1. Biodegradability and its Relevance to Railroad Lubricants and Fluids
2. Engine Lubricating Oil Evaluation Field Test Procedure
3. Detecting Abnormal Wear of AC Traction Motor, Pinion End, Armature Bearings Through Lubricant Wear Debris Analysis
4. Further Development in Top-of-Rail Lubrication Testing

**1999**

1. Lube Oil Analysis-Achieving Quality Results
2. Effects of Engine Lubricants on Oil Filtration
3. Recycling and Re-refining of Used Lubricated Oils

**1998**

1. Safety and Chemical Cleaners
2. Development of a Low Emissions, Dual Fuel Locomotive
3. Fuel Oil Stability Update
4. Ten Questions on EPA's Locomotive Exhaust & Emission Regulations

**1997**

1. Ferrography-Used Oil Analysis Program
2. 2000 - A New Millennium for Locomotive Maintenance: EPA Exhaust Emissions Regulatory Impacts
3. Standardized Test Procedures - Current Developments
4. Industry Updates and New Developments

**1996**

1. Standardized Test Procedures-The Annual Subcommittee Update
2. Diesel Fuel Standards and their

Applications to Railroad Fuel Quality Issues

3. A Look at Generation 5 Oil Performance and Future Oil Needs
4. LNG as a Railroad Fuel

**1995**

1. MSDS'S - What do they tell us?
2. Applying Satellite Communications Technology to On-Line Oil Analysis of Crankcase Diesel Engine Lubricants
3. Standardized Test Procedures - Past, Present & Future Developments
4. Locomotive Exhaust Emissions Regulations

**1994**

1. TBN-A Review of Currently Accepted Methods.
2. GE Multigrade Lubricating Oil Testing and Specification.
3. The Economic Impact of Low-Sulfur Diesel Requirements.

**1993**

1. Used Oil Analysis of Multigrade Oils and Condemning Limits.
2. Insoluble Determination with the Advent of Multigrade Diesel Engine Oils
3. Bioremediation.

**1992**

1. Environmental Issues Relating to Multigrade Railway Issues.
2. Readily Biodegradable and Low Toxicity Railroad Track Lubricants
3. Support Bearing Oils.
4. Recycling and Re-refining Locomotive Oils.

**1991**

1. Infrared Spectroscopy as an Analytical Tool.
2. Diesel Exhaust: Health Effects Research and Regulations.
3. Traction Motor Gear Case Seals and Lube Containment (Oil Lubricant)
4. Partnership in Development.

**1990**

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

**1989**

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

**1988**

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

**1987**

1. Common Fuel Additives and their Effectiveness.
2. History of LMOA Lubricating Oil Classification System.
3. Performance Requirements Needed by the Railroads for a New Generation Lube Oil.
4. How do we Provide the

Performance Needed for a New Generation Oil.

**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 Multigrade 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**

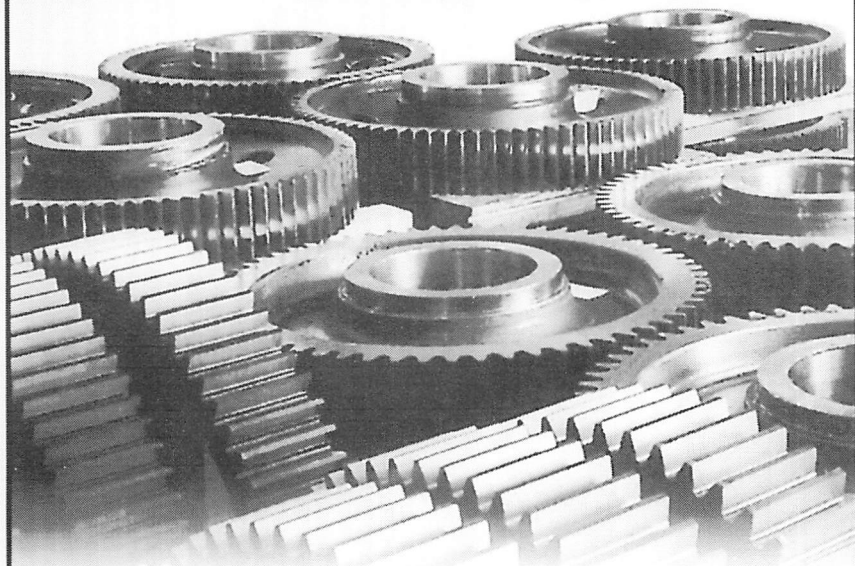
1. Effects of Using Alternate Fuels on Existing Diesel Engines.
2. Update on Cold Weather Procedures for Fuels.
3. New Techniques in Lube Oil Analysis.
4. Traction Motor Gear Lubrication.
5. Multi-Viscosity Oils as an Energy Conservation Technique.

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