LMOA

Locomotive Maintenance Officers Association

Proceedings of the 62nd Annual Meeting

September 18-20, 2000

Chicago Hilton & Towers

720 S. Michigan Ave.

Chicago, Illinois

2000 ADVERTISERS INDEX

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INDEX

1999 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 1999.

Name	Company	Committee
Rejean Parent	CN/IC RR	New Technologies
Bob Reynolds	CP Rail	Diesel Electrical
Rick Gates	BNSF Rwy.	Diesel Mechanical
Kevin Coté	Exxon	Fuel, Lube & Environ.
Jim Hartwell	Progress Rail	Diesel Material Control

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

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., 1061 Nelson Ave., Jacksonville, FL 32205
1956 -	T. T. BLICKLE (Deceased) General Manager - Mechanical, A .T. & S. F. Ry.
1957 -	J. T. DAILEY (Deceased) Asst. to Pres.-Mech., Alton & Southern R.R.
1958 -	F. E. MOLLOR (Deceased) Supt. Motive Power, Southern Pacific Co.
1958 -	F. R. Denny (Deceased) Mechanical Supt., New Orleans Union Passenger Terminal
1959 -	E. V. MYERS (Deceased) Supt. Mechanical Dept., St. Louis-Southwestern Ry.
1960 -	W. E. LEHR (Deceased) Chief Mechanical Officer, Pennsylvania R.R.
1961 -	O. L. HOPE, (Deceased) Asst. Chief Mechanical Officer, Missouri Pacific R.R.,
1962 -	R. E. HARRISON (Deceased) Manager-Maintenance Planning & Control, Southern Pacific Co.
1963 -	C. A. LOVE, Retired Chief Mechancial Officer, Louisville & Nashville R.R.
1964 -	H. N. CHASTAIN, (Deceased) Gen. Manager-Mechanical, A. T. & S. F. Ry.
1965-	J. J. EKIN, JR. (Deceased) Supt. Marine & Pier Maintenance, B. & O. R.R.
1966 -	F. A. UPTON II (Deceased) Asst. Vice-President-Mechanical, C. M. St. P. & P. R.R.
1967 -	G. M. BEISCHER, Retired Chief Mechancial Officer, National Railroad Passenger Corp. Washington, D.C. 20024
1968 -	G. F. BACHMAN, Retired Chief Mechanical Officer, Elgin Joilet & Eastern Ry. Rt. 1 Box 28010, Albia, IA 52531
1968 -	T. W. BELLHOUSE (Deceased) Supt. Mechanical Dept., S. P. Co., - St. L. S.W. Ry.
1970 -	G. R. WEAVER (Deceased) Director Equipment Engineering, Penn Central Co.,
1971 -	G. W. NEIMEYER (Deceased) Mechanical Superintendent, Texas & Pacific Railway
1972 -	K. Y. PRUCHNICKI (Deceased) General Supervisor Locomotive Maintenance, Southern Pacific Transportation Company
1973 -	W. F. DADD, (Deceased) Chief Mechanical Officer, Chessie System
1974 -	C. P. STENDAHL, Retired General manager M.P.-Electrical, Burlington Northern Railroad, 1052 W. California Ave., St. Paul, MN 55117
1975 -	L. H. BOOTH, Retired Assistant C.M.O.-Locomotive, Chessie System, 906-13th Ave., Huntington, W.V. 25701
1976 -	J. D. SCHROEDER, Retired Assistant C.M.O.-Locomotive Burlington Northern Railroad, 244 Carrie Drive, Grass Valley, CA 95942
1977 -	T. A. TENNYSON (Deceased) Asst. Manager Engineering-Technical, Southern Pacific Transportation Co.
1978 -	E. E. DENT, (Deceased) Superintendent Motive Power, Missouri Pacific Railroad,
1979 -	E. T. HARLEY, Retired Senior Vice President Equipment, Trailer Train Company, 289 Belmont Road, King of Prussia, PA 19406

1980 - J. H. LONG, Retired Manager Locomotive Dept., Chessie System
5454 Cleander Drive, Cincinnati, OH 45238

1981 - R. G. CLEVENGER, Retired General Electrical Foreman, Atichison, Topeka & Sante Fe Rwy.

1982 - N.A. BUSKEY (Deceased) Asst. General Manager-Locomotive, Chessie System

1983 - F. D. BRUNER (Deceased) Asst. Chief Mechanical Officer-R. & D. Union Pacific Railroad

1984 - R. R. HOLMES, Retired Director Chemical Labs and Environment, Union Pacific

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

1986 - D. H. PROPP, 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, Mgr. Regional Process & Quality
Union Pacific RR, 6400 Martin Ave.-Bldg. B, Kansas City, MO 64120

1994 - M.A. COLES, Senior Mgr.-Loco. Engineering & Quality, Union Pacific R.R.
1416 Dodge St., Omaha, NE 68179

1995 - C.A.MILLER, 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, Ellcon National, 1016 Williamsburg Lane,
Keller, TX 76248

1999- JAKE VASQUEZ, Consultant, JSV RR Co.
98 McKinney, Dayton, TX 77535

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

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

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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

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

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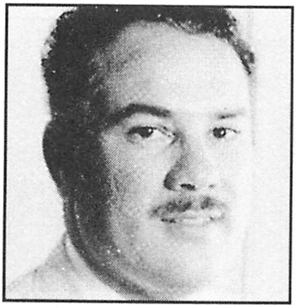

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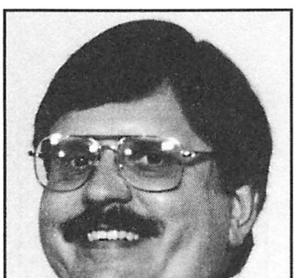
Consultant
JSV RR Company
Dayton, TX 77535



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Supt. - Locomotives
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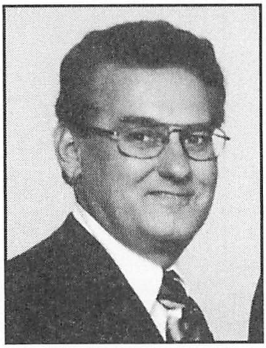

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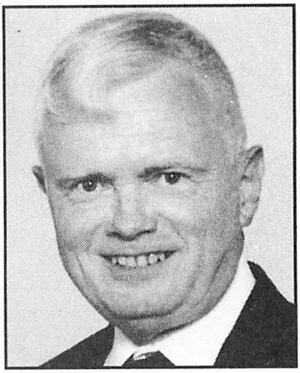

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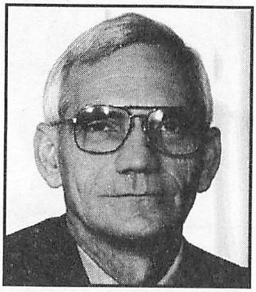

3rd Vice President
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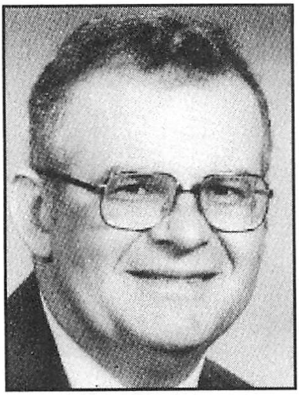
Supt. - Locos.
Florida East Coast Rwy.,
New Smyrna Beach, FL 32170

OUR PAST PRESIDENTS



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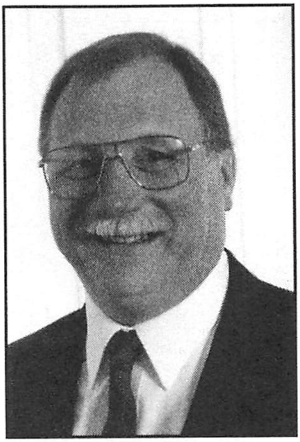
Cleona, PA 17042

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

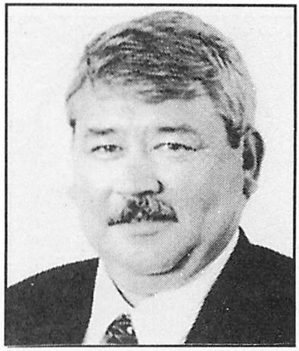
MR. DARRELL M. WALKER
Asst. Shop Mgr.
Norfolk Southern Corp.
Atlanta, GA 30315



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

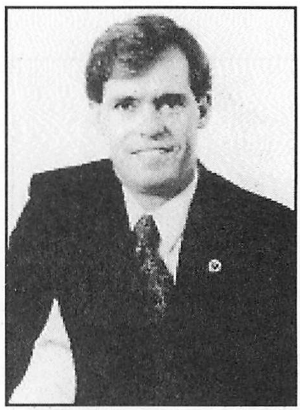
OUR PAST PRESIDENTS

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



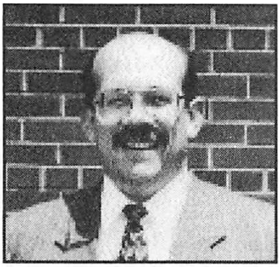
MR. GIL BRUNO
Assistant. Gen. Mgr.
Terminal Services
Amtrak
Seattle, WA 98134

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



MR. WEYLIN R. DOYLE
Manager Regional Process &
Quality
Union Pacific Railroad
Kansas City, MO 64120

OUR REGIONAL EXECUTIVES



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EJ & E
Gary, IN 46402

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General Foreman Air Brake Shop and Material Mgmt.
Norfolk Southern
Altoona, PA 16603

MR. TAD H. VOLKMANN
Manager - Loco. Facility - Engine Components
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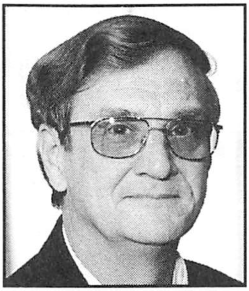
North Little Rock, AR 72114



LES WHITE
Senior Reliability Specalist - Electrical
CN/IC RR
Montreal, PQ
Canada

NOT PICTURED

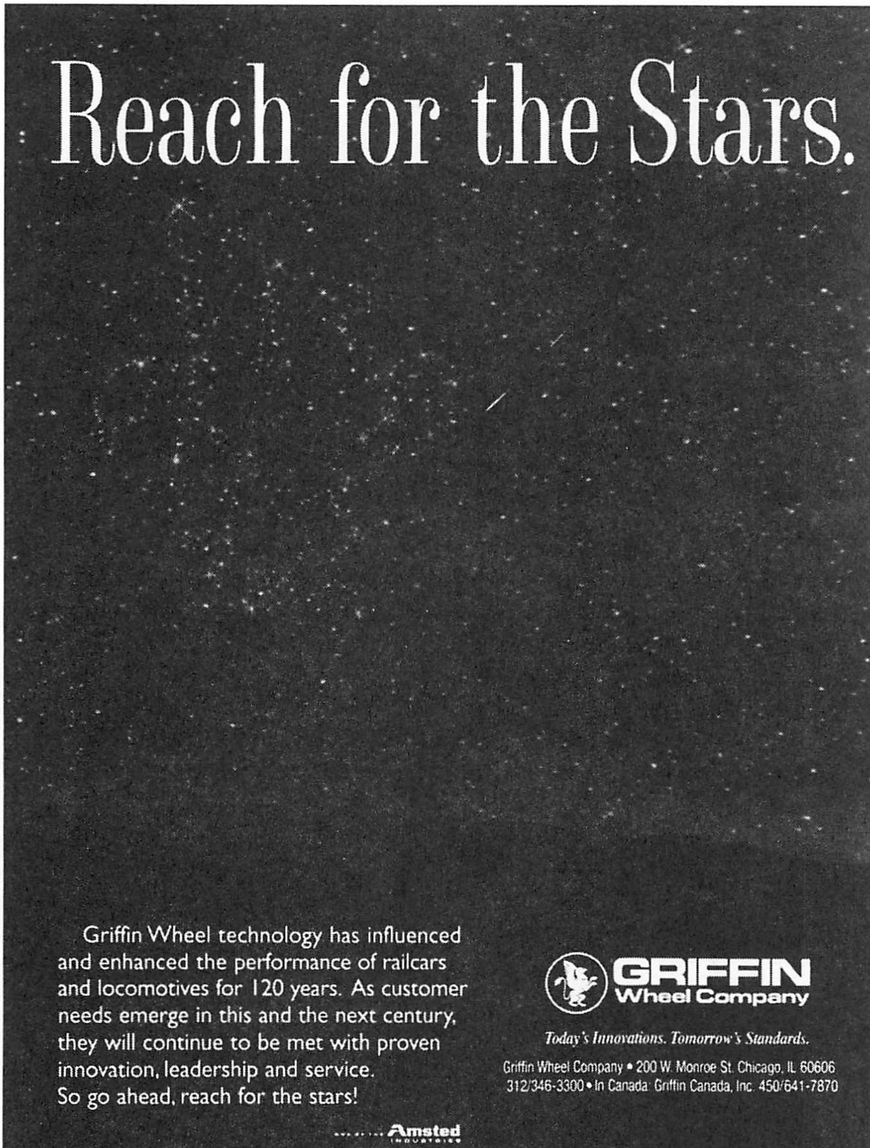
MR. CHUCK KUNKEL
Sr. Mgr. Research & Dev.
Union Pacific
Omaha, NE 68179

NOT PICTURED

MR. MIKE SCARINGE
Asst. Gen. Mgr. - Backshops
Amtrak
Beech Grove, IN 46107

Outgoing President Jake Vasquez, places LMOA blazer on newly elected 3rd VP, Brian Hathaway, Florida East Coast Rwy., in the presence of newly elected President Ron Lodowski

Outgoing President Jake Vasquez, hands over the gavel to newly elected President Ron Lodowski. Past President Dave Wetmore, former Amtrak now NJT was present for the ceremony.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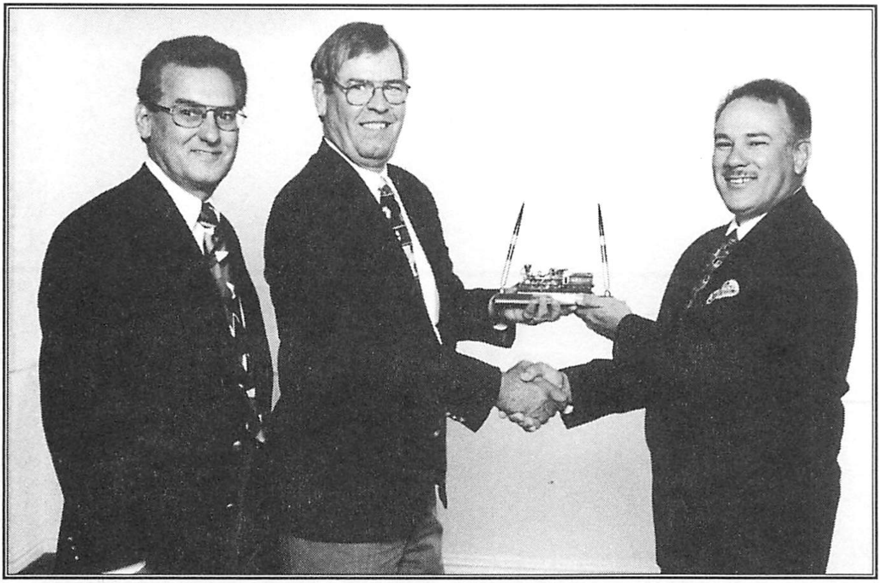
Outgoing President Jake Vasquez, former CMC Railroad now JSV Rail Company, places LMOA blazer on newly elected 1st VP, Lou Cala, former Norfolk Southern now LJC Rail Consultant, which was witnessed by newly elected President Ron Lodowski, CSX Transportation.

Outgoing President Jake Vasquez, places LMOA blazer on newly elected 2nd VP, Bob Runyon, retired Norfolk Southern Corp. now Engineering Consultant, as newly elected President Ron Lodowski looks on.



Chairman of the Board Mike Pennell, Ellcon National, presents the General Desk set to outgoing President Jake Vasquez which was witnessed by newly elected 1st VP Lou Cala.

Past President Bill Brown, BP Associates, presents Past President's Pin to outgoing President Jake Vasquez. Past President Dale Propp, New York Air Brake Company, attended the ceremony.

LMOA Executive Committee Members: (seated, left to right)
Past President Bill Brown, Past President Dale Propp, Outgoing President Jake Vasquez, Chairman of the Board Mike Pennell, and Past President Dave Wetmore.
(standing, left to right)
Tom Shedd, newly elected 1st Vice President Lou Cala, newly elected President Ron Lodowski, newly elected 2nd Vice President Bob Runyon, newly elected 3rd Vice President Brian Hathaway, and Secretary Treasurer Ron Pondel.

State of the Union Address by President Jake Vasquez, Vice President Operations CMC Railroad, Inc. Dayton, Texas September 20,1999

The first and most important part of my state of the union address is to have Ron Pondel come to the front. As he comes to the front we at the LMOA would like to recognize Ron's dedicated, unending service to our organization. He has handled our need, for over 13 years through lean times, difficult times and good times. His leadership, dedication and behind-the-scenes work does not and will not go unnoticed by all members and officers of this association and the four coordinated mechanical committees.

As you may not know, Ron and his wife Alicia lost their son from complications from leukemia at the age of sixteen. In an effort to keep Joel's memory alive, the board of directors and officers passed a motion at our meeting in April to set up an annual $1,000.00 LMOA scholarship in Joel's memory at Joel's school, St. Rita High School. The school will administer the scholarship with approval from the Pondel family. Ron, we hope this scholarship will ease some of your family's pain and indicate to you and your family our association's appreciation for all the hard work and sacrifices you have made for this organization.

We would next like to thank all the suppliers and sponsors who continue to support our association so that we can continue to keep our members and member railroads informed of best practices, innovations and leadership skills through technical committee reports.

We would especially like to thank the Motive Power Family Companies for sponsoring our coordinated group meeting in Las Vegas in April. Also, Bob Singleton for handling the meeting arrangements and Pete Urban for representing the Motive Power companies during the meeting and Jim May of the Durox Company for their sponsorship and participation. We would also like to thank the Southern Southwestern Railway Association for sponsoring the Electrical committee pre-convention presentations during their July meeting in Florida.

We would like to thank Engine Systems, a Motive Power Company, for sponsoring the Mechanical committee's pre-convention presentation, and Simmons Machine and Amtrak for opening their facilities for tours during the Mechanical committee meetings in Albany, NY in May.

As I am the last president in this century and with Ron Lodowski taking us into the new millennium with strong support from our members and suppliers with innovations, new technologies and leadership, we will continue to grow as an organization. With Dave Wetmore's annunciating the process, Ron has spearheaded our association into a new era of computerization by setting up a full-blown LMOA web site.

We were strong in the Shortline & Regional Association this past year and hope to continue along that line because I believe our major growth will come from this part of the railroad industry. On a personal note, the records indicate I am the first shortline-regional member to be the president of this great LMOA organization.

Again this year I would like for you to write these six items down and put them to memory for the next time someone asks you when you get back from a committee meeting, a presentation or convention, what can be gained from being on a LMOA committee? You can use these items to make them aware of the real benefits of our LMOA organization.

- Teamwork - the ability to work with others for a common goal.

- Your company will benefit from the education and experience gained from member participation.

- Gained public speaking experience.

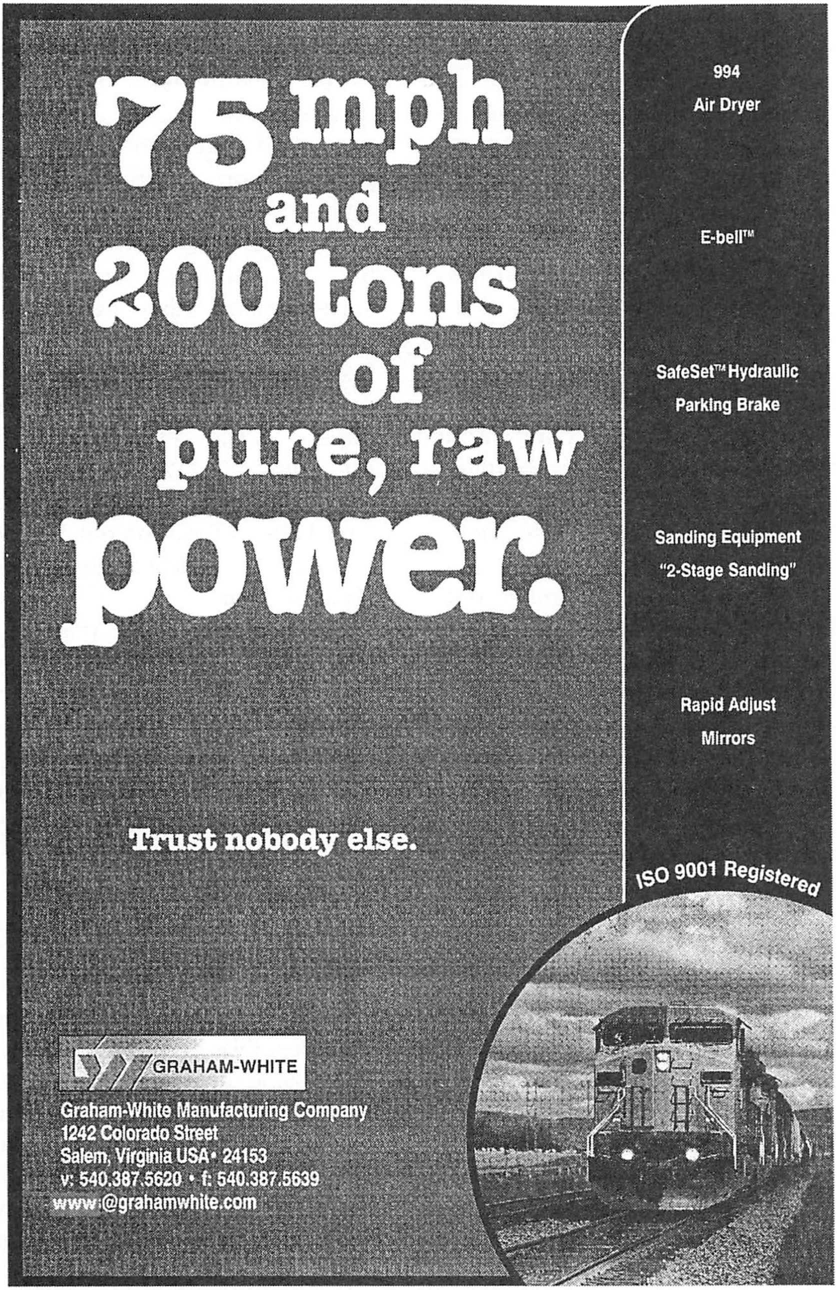
- Increased technical knowledge and time scheduling ability.

- Expanded people skills

- Social aspect - making business relationships and friends with suppliers and fellow railroaders.

As we all know, but hesitate to say, no one can get through life without the help of friends, associates and family. In that perspective I would like to thank the members, my officers, vice presidents and board members for all their support. Also, I would be remiss if I did not recognize my number one fan, supporter, the one who stands beside me through the good and bad, my best friend and lover, Shirley.

I would like to say in closing that this has been a great year for me and I am very proud to have served as your President.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Acceptance Speech by President Jake Vasquez, CMC Railroad, Inc. September 23,1998

Thank you Mike and welcome to the morning session of the LMOA presentations. It is with great pleasure and honor that I accept the presidency for 1998-1999 which will be the last one in this millennium. We as an organization have forged into many areas with many changes during the downsizing of our major class 1 railroads and dramatic increase in the shortline and regional railroads. It is our intention to meet these new challenges with solid full committee support to meet not only our major railroads' needs but also to use our best practice presentations to demonstrate to all railroad officials that there are many outstanding and subtle rewards to be gained by all who listen to our presentations and personal growth for those who take the challenge to be on the committees that make the presentations.

The topics the committees have chosen over the years have saved our companies large amounts of money by using our coordinated support of committee members to give our industry real solutions to actual railroad problems or an outlook into innovations brought on by technology.

It was refreshing as we read over the papers given this year to note how well the committees connected with each other. For example, the locomotive trouble shooting assistant from Electrical was tied closely to the paper on expert systems by New Developments paper. Excerpts from hydraulic tensioning tool paper (Shop Equipment) were referenced and mentioned in both the GE and EMD articles on 6000 hp locomotives from New Development. Also the Material committee did a paper on new fastener technology which was mentioned in the Shop Equipment paper. The effects on the upcoming EPA emissions regulations were discussed in the Fuel Lube & Environmental paper and the Mechanical paper you are about to hear.

Being president of this great organization is the reward and honor for the many hours spent by people who participate in committee presentation, work on and present papers not only to this convention but also at one of the pre-convention meetings held throughout the United States so that we can expose the benefits of our papers to people who could not come to this convention.

From the committees our members take on more challenges by moving up the ranks to vice chairman, to chairman, to regional executive and through the three vice presidents to president. As members of the LMOA we understand the rewards of our labor. However, I feel we as an organization need to keep our bosses and the companies we work for more attuned to the benefits committee participation has on our companies' bottom lines. These benefits are not only monetary. They also come from the social and individual growth and self-satisfaction that comes from giving presentations, team work, scheduling, completing tasks and helping with a paper that someone else will get the recognition for.

In closing I would like for you to write these (6) items down or put them to memory for the next time someone asks you when you get back from a committee meeting, a presentation or this convention, "Well how was the party?" Make them aware of the real benefits of our LMOA organization.

1. Teamwork - the ability to work with others for a common goal.

2. The company will benefit from the education and experience gained from member participation.

3. Gained public speaking experience.

4. Increased technical knowledge and time scheduling ability.

5. Expanded people skills.

6. And yes, the social aspects were beneficial and enjoyable.

I would like to thank all the committee members and officers for their continued support.

Thank you for your attention.

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

MONDAY, SEPTEMBER 18, 2000 10:15 A.M.

Pre-Convention Presentation: Hosted by: Griffin Canada, Inc. Western Reman and Canadian National (CNIC)	**Jay Holley, Chairman** Director Mechanical Operations CSX Transportation Vice Chairman **Dennis L. Nott** VP Sales O & M Boise Locomotive	May 2000 Winnipeg, MB (Canada)

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PERSONAL HISTORY

Jay J. Holley

Jay J. Holley, Chairman of the LMOA Committee on Diesel Mechanical Maintenance, was born August 4, 1944 in Huntington, W. Va.

Jay began his career with the former Chesapeake and Ohio Railway as a machinist apprentice in October, 1963. In 1973 the Chesapeake and Ohio Railway became part of the Chessie System. Jay transferred to Russell, Ky. in 1975 and was promoted to a contract foreman in 1983. He transferred to the Cumberland locomotive shop Cumberland, MD in 1984 where he worked the position of planner and assistant superintendent of production.

In 1986 Chessie System became part of CSX Transportation and Jay was promoted to assistant department foreman and transferred to the Corbin locomotive shop Corbin, Ky. in 1987. In 1988 he became manager quality assurance with responsibility for Corbin, Cincinnati, Louisville and Evansville.

Jay was promoted to Manager of Operations at the Kenneth C. Dufford Operation Center in Jacksonville, Fl. in 1991, with the responsibility for managing the locomotives on the line of road and the scheduling of maintenance locomotives.

Jay has been most recently appointed director mechanical operations. He is responsible for managing the locomotive and car fleet to ensure maximum availability and reliability and a minimum of shop detention time. He is accountable for the improvement of locomotive performance. He is responsible for ensuring proper locomotive flow for scheduled maintenance, program repair and failed locomotives to the maintenance shop in an expeditious manner. He also has the responsibility for all cars set out on the line of road to ensure repairs are made and the cars are returned to service.

Jay and his wife Candy have been married for 36 years and reside in Jacksonville. They have 2 children, Jeff and Amy.

THE LMOA DIESEL MECHANICAL

MAINTENANCE COMMITTEE,

Wishes to express their sincere gratitude

to

Griffin Canada Inc,

Western Reman Inc,

and

Canadian National

for hosting their preconvention

presentation at

Winnipeg Manitoba in May 2000.

I. 2000 EMISSIONS REVIEW, PARTS 1 AND 2

Prepared by:
Richard A. Marchese
Electro Motive Divn. - GMC and Locomotive Leasing Partners, LLC

Introduction

The information presented in this paper will be in three parts. Part 1 is a brief overview, that is "generic" in nature, of the regulations applying to Tier "0" emissions compliance. Part 2 is specific to locomotives engines manufactured by the Electro-Motive Division of General Motors Corporation. Part 3 is specific to locomotives and locomotive engines manufactured by General Electric Transportation Systems, and is presented as a separate paper.

Part 1 - 2000 Emissions Review-Federal Regulations

40 CFR Parts 85, 89 & 92 was published on April 16, 1998 and titled "Emissions Standards for Locomotives and Locomotive Engines; Final Rule". This Federal regulation covers emissions of oxides of nitrogen (NOx), hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM).

Definitions of Some of The Terminology Used in This Paper:

Remanufacture - The final rule regulation defines remanufacture as the act of replacing, or the inspection and qualification of all power assemblies of a locomotive engine at one time, or within a period of 5 years based on Class I railroad practices.

Tier 0 Switching Locomotives - are defined as locomotives dedicated to switching operation and rated at or under 2300 HP.

Emission standards are applicable throughout the "useful life" of the locomotive as spelled out in the regulations. The useful life is 7.5 times the traction horsepower in megawatt-hours (MWH) or 10 years whichever comes first. On older Tier 0 locomotives that are not equipped with a MWH meter the life is 750,000 miles or 10 years, whichever comes first. States are pre-empted from regulating emissions for the period of 133% of the useful life.

Three "tiers" of regulation were mandated.

Tier "0" applies to locomotives originally manufactured before 1/1/2002 and on or after 1/1/1973 and is the focus of this presentation. Tier 0 allows for selection of an "Interim Provision Option" to be selected by the manufacturer which determines the effective date for freight and switch locomotives. Passenger locomotives have a delayed effective date. Passenger locomotives originally manufactured on or after 1/1/1973 and before 1/1/2002 are not required to comply until remanufactured on or after 1/1/2007. Pre 1973 manufactured locomotives may, at the owner's option, be included.

Tier "1" applies to locomotives

manufactured during the period 1/1/2002 to 12/31/2004 inclusive.

Tier "2" applies to locomotives manufactured 1/1/2005 or later.

Each tier contains increasingly restrictive emissions standards.

The "Interim Provision Options" for Tier 0 allow the certificate holders to select the best scenario for their circumstances and it determines the effective date of compliance phase in:

Option 1 requires that beginning 1/1/2001 all freshly manufactured locomotives and all remanufactured locomotives originally delivered 1/1/1994 or later comply with Tier 0 standards. The Tier 0 standards apply to all other locomotives manufactured 1/1/1973 through 12/31/2001 when remanufactured on or after 1/1/2002.

Option 2 requires that beginning 1/1/2000 a remanufacture kit will be available to meet Tier 0 standards for the "primary engine family" delivered 1994-1997 (when remanufactured) and that all locomotives freshly manufactured after 1/1/2000 be compliant with Tier 0 standards. Adherence to this option allows locomotives first delivered 1/1/98 through 12/31/2001 to be phased into compliance when remanufactured on 1/1/2002 or later.

Option 3 requires that for any combination of locomotive models manufactured or remanufactured after 1/1/2000 emissions reductions must be achieved that are greater than those achievable through Option 2.

Locomotives manufactured prior to 1/1/1973 may be brought into compliance with Tier 0 at the owner's option by upgrading them into a certified configuration. Such locomotives would then be subject to these regulations for the remainder of their service lives.

The specific emissions standards for Tier "0" are as follows:

Constituent	Freight	Switch
NO_x	9.5	14
PM	0,6	0.72
HC	1	2.1
CO	5	8

These emissions are measured in grams per brake horsepower hour (g/bhph) based on the EPA duty cycle noted.

The standards for opacity of exhaust (visible smoke) are as follows:

Steady-state	30-sec. peak	3-sec. peak
30	40	50

The standards are in percent opacity normalized to a one-meter path length.

Exemptions and exclusions are specified in the regulations. "Small railroads", as defined in the regulations, are exempted. Locomotives powered solely by an external source of electricity are excluded. Historic steam locomotives are excluded. Some smaller diesel engines (high-speed diesels) as defined in the regulations are excluded. Subparts I & J of 40 CFR Part 92 provide for some other exemptions.

Certificates of Conformity issued by the EPA cover families of engines. A family is a group of similar engines expected to have similar emissions characteristics. Characteristics such as combustion cycle, type of air inlet cooling, bore and stroke, timing characteristics, turbocharged or Roots blown, electronic or mechanical injection determine family members.

It is the responsibility of the locomotive owner/operator to apply a certified emissions kit at overhaul. Records of emissions related maintenance must be retained for eight years from maintenance date. The manufacturers' required maintenance for emissions compliance as approved by the EPA must be followed or an equivalent alternative in terms of maintaining emissions performance. Some "in use" testing to insure compliance is required by the EPA; some to be performed by owner/operators, some by the manufacturers. The exact requirements are spelled out in the regulation.

Additional information, including copies of the regulations themselves are available electronically at the web page of the US EPA at: http://www.epa.gov/oms/locomotv.htm. Information may be obtained in writing from: US Environmental Protection Agency, Office of Mobile Sources (6403J), 401 M. Street S.W., Washington, DC 20460.

Part 2 - 2000 Emissions Review-EMD Locomotives and Locomotive Engines for Tier "0" Compliance

The Tier 0 compliance timeline for EMD engines reflects the second interim provision option offered by the EPA.

A remanufacture kit is currently available for all of the primary engine families delivered between 1994 and 1997. Therefore Tier 0 compliance for these units is effective when they are remanufactured on 1/1/2000 or later. All new production delivered on 1/1/2000 or later is also Tier 0 compliant. This allows all other freight and switch locomotives delivered from 1/1/1973 to 1/1/2000 to be phased into compliance when remanufactured after 1/1/2002. Passenger locomotives have a delayed phase in. All passenger locomotives delivered from 1/1/1973 to 1/1/2002 are not subject to compliance until remanufactured after 1/1/2007.

The EMD primary engine families subject to Tier 0 compliance when remanufactured after 1/1/2000 are as follows:

- Electronic unit injected (EUI), separately aftercooled (SLAC), 710 CID series engine.
- Electronic unit injected, jacket water aftercooled (JWAC), 710 CID series engines.
- Mechanical unit injected (MUI), jacket water aftercooled, 710 CID series engines.

Included in the emissions

remanufacture kit box for 710 MUI equipped locomotives are:

- A set of instructions
- 16 emissions compliant Ecotip injectors
- An emissions compliant logic RAM pack (60 series locomotives, only)
- An emissions compliance name plate for the engine with mounting hardware
- An emissions compliance name plate for the locomotive with mounting hardware

The kit for 710 EUI equipped locomotives contains:

- A set of instructions
- An emissions compliance name plate for the engine with mounting hardware
- An emissions compliance name plate for the locomotive with mounting hardware

What items are included with the kit but aren't actually in the box? Maintenance Instruction 1791 details the scheduled maintenance required to ensure emissions compliance. For 70, 80 or 90 series locomotives an EMD field service engineer will assist with EM2000 emissions compliant software for MUI locomotives or EMDEC emissions compliant software for EUI locomotives. The kit is also supported by Electro-Motive test engineers and design engineers, who are monitoring and measuring emissions compliance on a daily basis at our emissions measurement site in LaGrange, Illinois.

Included in the kit instructions are recommended locations and procedures for attaching the emissions compliance nameplates. These locations are not legislated but are suggested for consistency. We recommend locations near the engine serial number plate and locomotive builders plate.

EMD offers emission compliant retrofit kits for the following engine configurations:

- 60 Series MUI JWAC 3800 THP
- 70 Series MUI JWAC 4000 THP
- 70 Series EUI JWAC 4000 THP
- 70 Series EUI JWAC 4300 THP
- 70 Series EUI SLAC 4000 THP
- 80 Series EUI SLAC 5000 THP
- 90 Series EUI SLAC 4300 THP

II. 2000 Emissions Review Part 3 Tier 0 Engine - GE Transportation Systems

By: Darlene Kisko
Co-Author: Adam Oser
GE Transportation Systems

Introduction

Part 1 of this three-part presentation summarizes the EPA regulations for emissions and, as the rule states, there are two options for compliance. Part 3 covers the option selected by GE Transportation, and the process used in developing, designing, testing, validating and implementing an emissions compliant program. Also included are the major parts affected for the GE Tier 0 Engine and a summary of the results of this program.

Option Selected

GE Transportation Systems reviewed the options, and based on our customers' needs and GE's products and service offerings, EPA rule Option 1 was selected. What does this rule require?

- New Locomotives

  Beginning January 1, 2001, and for that year only, the manufacturer and remanufacturers must build new and remanufactured locomotives that meet the Tier 0 emission level. This includes GE's DASH 9™, AC4400™ and AC6000™ locomotives.

- Remanufactured Locomotives

  In 2000 and 2001, during remanufacture, railroads must install emissions kits in locomotives built after 1989 if a reasonably priced kit is available. Kits will be available to comply with this part of the rule effective January 1, 2000 for GE's DASH 9 and AC4400 locomotives.

  Beginning January 1, 2002, railroads must install Tier 0 kits in locomotives as they are remanufactured if they were built after 1972. Kits will be available for all other GE line haul locomotives to comply with this part of the rule.

Choosing and implementing an option was not an easy task. GE used Design For Six Sigma (DFSS) methodology, a systematic process approach to designing and manufacturing that meets both GETS quality standards and customer expectations.

Customer CTQ's

The first step in this approach was to determine the customer critical to quality (CTQ) items. The results were:

- Emission Compliance
- Reliability
- Fuel Consumption
- Maintenance Impact
- Performance
- First Cost

One example of a CTQ

consideration is NOx versus specific fuel consumption (SFC). As Fig. 1 illustrates, the traditional approach of retarding timing results in a decreased NOx return, with an increase in fuel consumption and particulate emissions. GE, by developing and applying technology, has been able to positively shift the curve to meet emissions requirements without penalizing fuel economy.

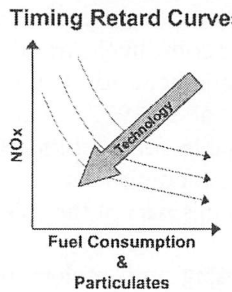


Fig. 1

Emissions Program

The next step was to develop a program for the future emissions requirements as well as GE's and its customers' current testing needs. Rigorous analysis determined the four major elements of GETS' program:

- Facility changes
- Design analyses
- Design validation
- Field testing

Facilities Changes

Grove City test facility (Fig. 2)

At Grove City, Pa., the GE diesel engine manufacturing site, there is one test cell which is a fully certified EPA testing facility. There are also four test cells capable of limited emissions testing.

Erie facilities

The Engine Development Lab at Erie has one design test cell for a complete engine (Fig. 3) with the following capabilities:

We can simulantaneously measure:

- 16 channels of:
  Cylinder pressure,
  Injection pressure,
  Needle lift;
- 450 data input channels including:
  Horsepower,
  Fuel consumption,
  Mass air flow (for turbo development),
  Bearing temperature,
  Individual exhaust temperature,
  5 gases + particulates + smoke;
- And concurrently control intake air, water, fuel, and oil temperature.

There is also a single cylinder test cell (Fig. 4) which is used for combustion development testing at the sub-assembly component level.

Locomotive certification facility (Fig. 5)

This is a $5.5 MM facility with

two high bays to accomodate complete locomotives. It is a dedicated EPA test, audit and certification site with state-of-the-art EPA compliant test equipment and controls. This facility was designed to meet GE's and its customers' current and future needs for required locomotive testing and development. The facility allows for rapid testing and return of locomotives through its automated systems.

Mobile facility (Fig. 6)

GE has a fully equipped test car developed by a co-functional team. It is capable of validating locomotive emissions in various environments. The EPA rule requires compliance @ 7000 feet and 105°F. Raton, New Mexico was chosen as the test sight to validate the system at high altitude. Testing was done in May, 1999 and successfully demonstrated the ability to maintain emissions compliance at high altitude. The impact of high altitude on emissions performance was then used to develop a model to predict the effects on the engine of future designs and improvements.

Design Analyses

Extensive design analyses were done in the areas of:

- Performance (specific fuel consumption and environmentally inducted horsepower deration),
- Systems level (cooling, control, locomotive),
- Finite element analysis (FEA),
- Emissions sensitivity,
- Torsional analyses,
- Bolted joint (i.e., piston to skirt, power assembly to frame, pump to power assembly, cam sections),
- Thermal stress
- Hertzian stress

All of these analyses have provided a high confidence in GE's emissions compliant designs.

Design Validation

To validate the design, GE sucessfully completed rigorous validation testing in Erie, Grove City, and at various customer locations. This testing included:

- Tunnel operation,
- Thermal overload (pistons, exhaust valves, cylinder heads, and injector tips),
- Piston cracker test (validate cylinder pressure and new crowns),
- Extended performance deterioration factor (DF),
- Lube oil soot loading,
- Fuel consumption,
- Thermal cycling,
- Altitude testing.

Field Testing

This validation testing was followed by an extensive field test of 70 new and unit echange locomotives.

The 70 unit field test consists of the following:

♦ BNSF - 10 new DASH 9 and 15 unit exchange DASH 9

- CSX - 10 new AC4400
- NS - 10 new DASH 9
- UP - 10 new AC4400 and 15 unit exchange DASH 9

Based on the in-house testing and field testing to date, design and durablilty goals are being achieved or exceeded.

We would like to acknowledge and thank our railroad partners for assisting GE with this testing and validation program!

Fleet Test Results Support the Following Parameters:

- Baseline testing of all locomotives,
- Periodic unit inspection,
- Continuing deterioration factor testing,
- High reliability of emissions parts,
- No emissions related component failures at time of publication,
- The locomotives on test have accumulated more than 50 years of service at time of publication.

Major Components Affected (Fig. 7)

The engine components affected for Tier 0 compliance are:

- Turbocharger
  Pressure ratio
  efficiency;
- Power assembly
  Compression ratio,
  Port flow,
  New piston.
- Elecronic fuel injection
  Flexible injection timing,
  Provides diagnostics.
- Optimized cam profiles
  Injection rate,
  Optimized duration.

These design changes meet or exceed the CTQ's identified earlier in this presentation and collectively comprise a proven emissions recipe for performance, reliability, and fuel consumption.

Key Points

The following maintenance practices help to ensure Tier 0 compliance:

- The engine components identified above are emissions critical and CANNOT be interchanged with current production parts. Damage and federal fines can occur if parts are misapplied.

- When servicing a Tier 0 engine ALWAYS refer to the current service manual for that specific locomotive road number. Parts manuals (Fig. 8) and maintenance instructions are available electronically, and should be referenced for the CURRENT applicable part or procedure.

- The maintainer is responsible for proper maintenance in accordance with the OEM submitted EPA procedures.

- Proper documentation is required.

Emmisions Compliance Engine Labeling

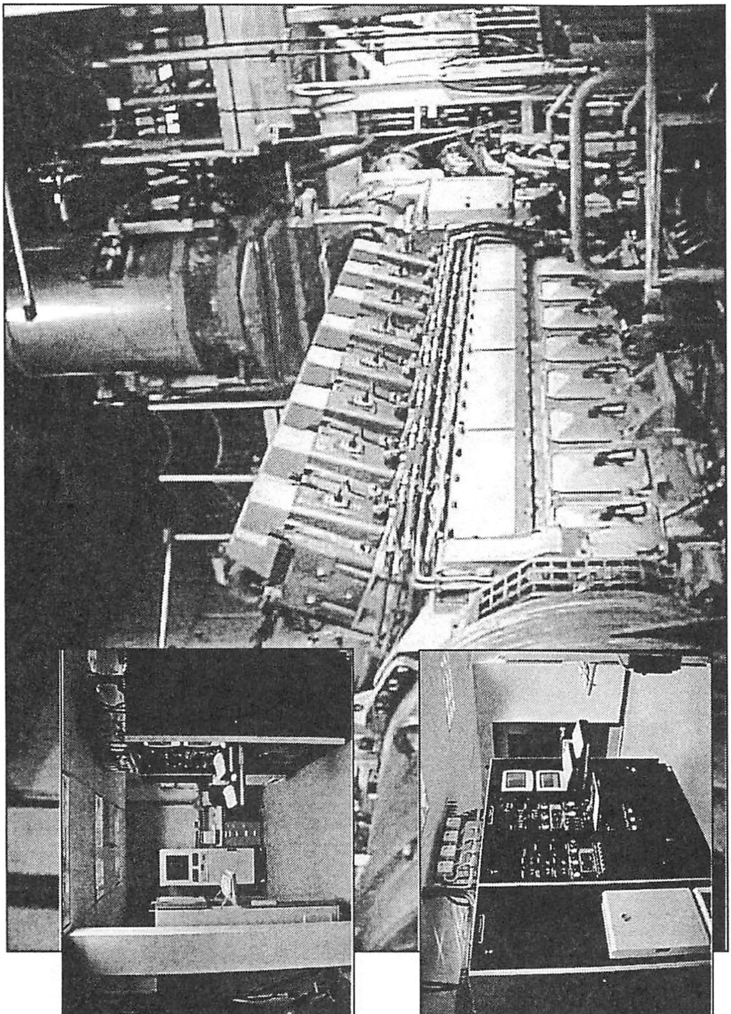
Engines with the Tier 0 emissions compliant package have been defined with a large "E" on each power assembly (Fig. 9) and turbo. There are also large labels (Fig. 10) applied to the locomotives at key locations including the operator's cab, auxiliary cab, and engine access doors (carbody).

Summary

With customer CTQ's emissions compliance, reliability, fuel consumption, maintenance impact, performance and first cost, driving the design for six sigma (DFSS) quality process GE is meeting EPA regulations for Tier 0 emissions, while providing increased value to customers.

Acknowledgements

The authors gratefully appreciate the contributions of time and expertise of the following individuals: Ted Stewart, CSXT; Tom Gerbracht, Donna Perino, and Nels Sandberg, GE Transportation Systems.



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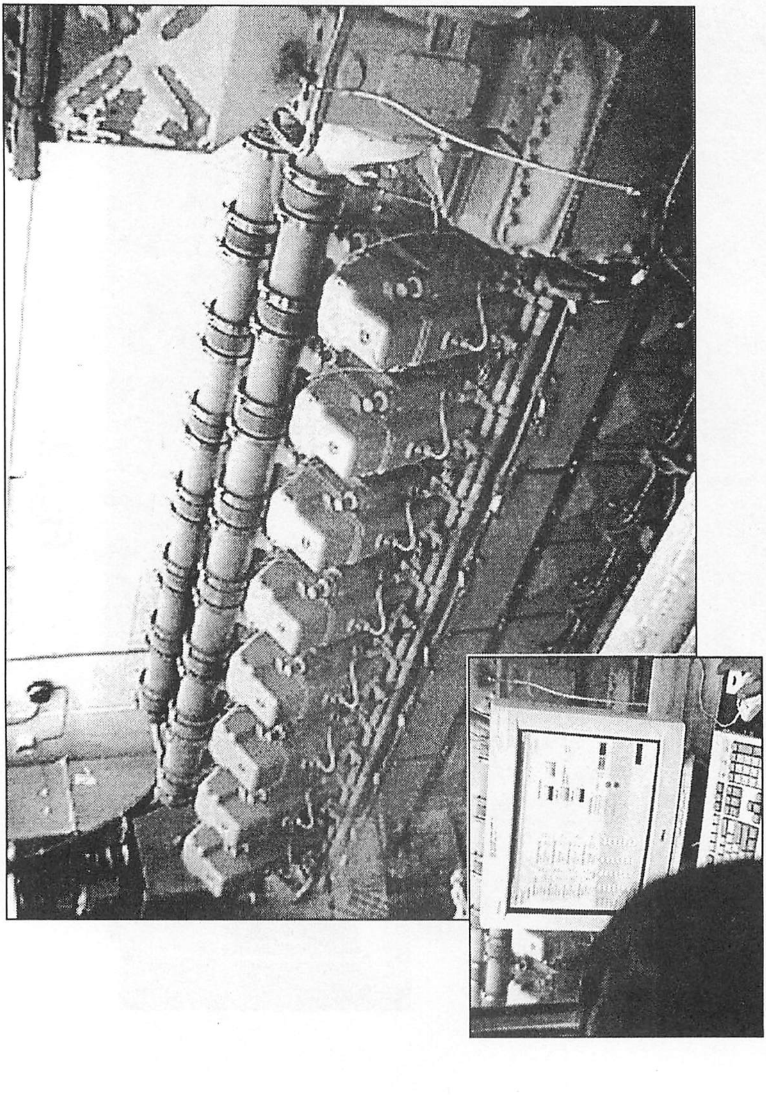

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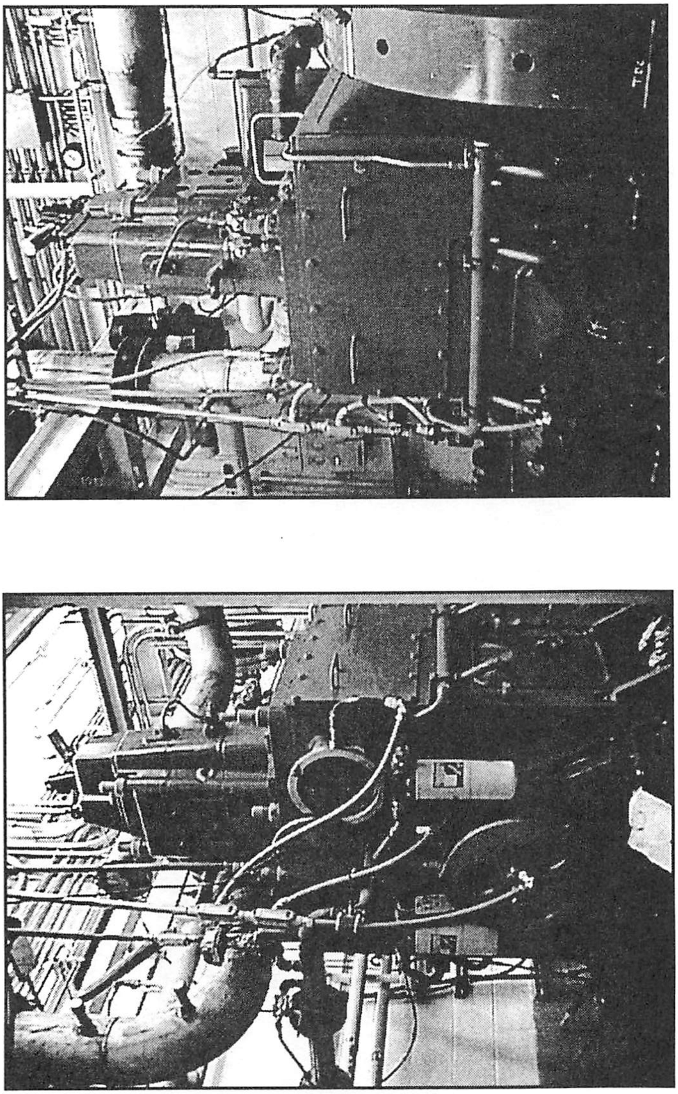

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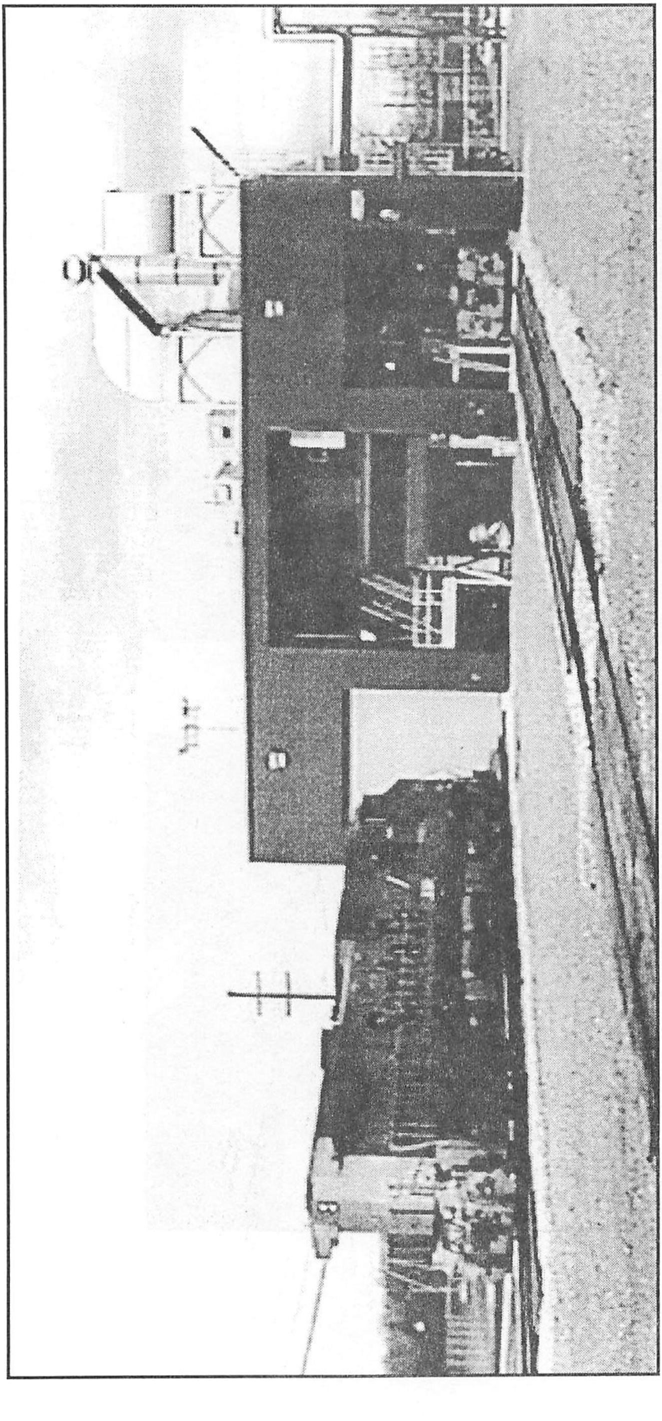

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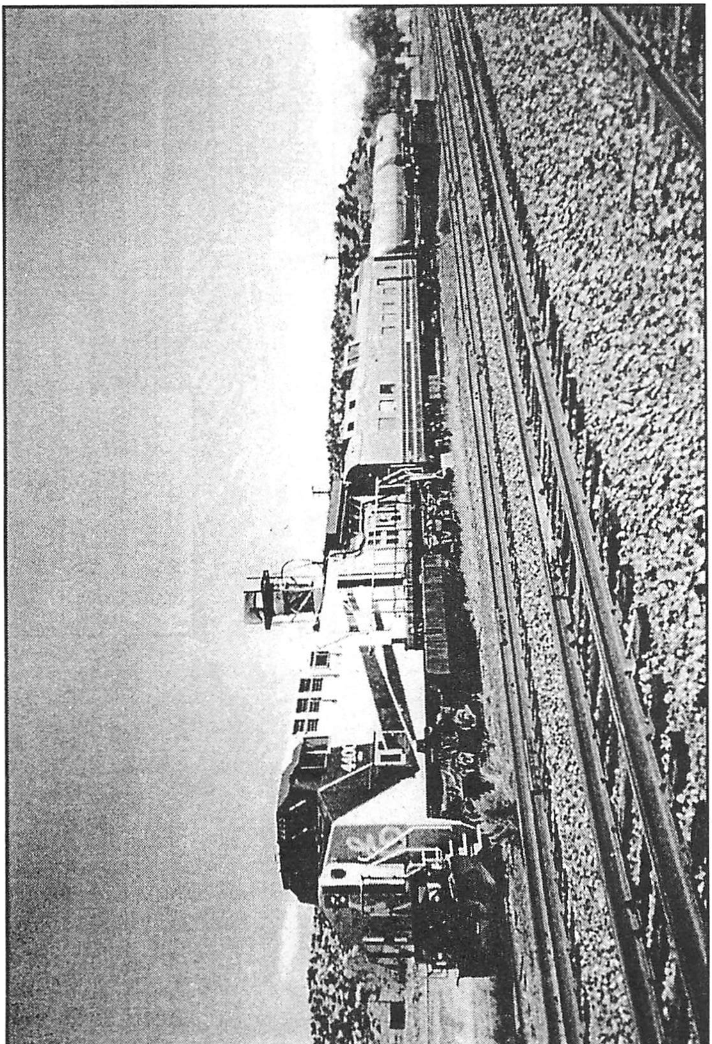

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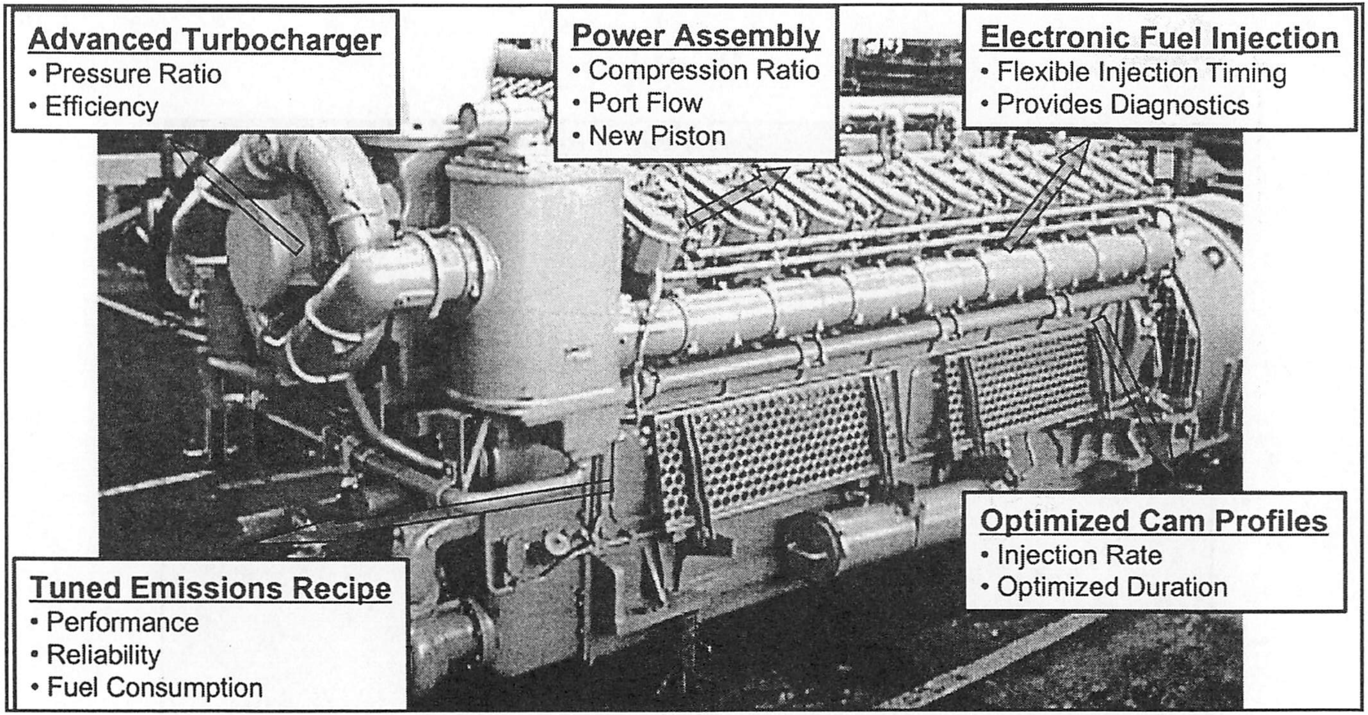
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• Efficiency
Power Assembly
• Compression Ratio
• Port Flow
• New Piston
Electronic Fuel Injection
• Flexible Injection Timing
• Provides Diagnostics
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• Injection Rate
• Optimized Duration
Tuned Emissions Recipe
• Performance
• Reliability
• Fuel Consumption

Fig. 7

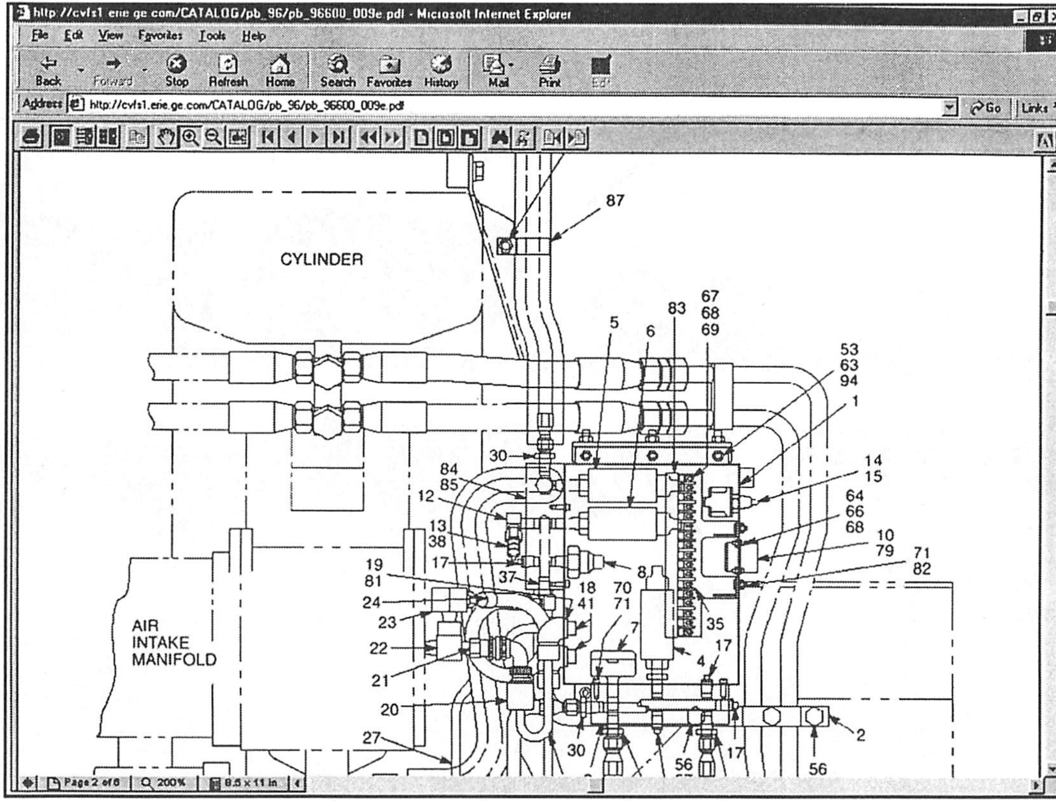
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Fig. 8

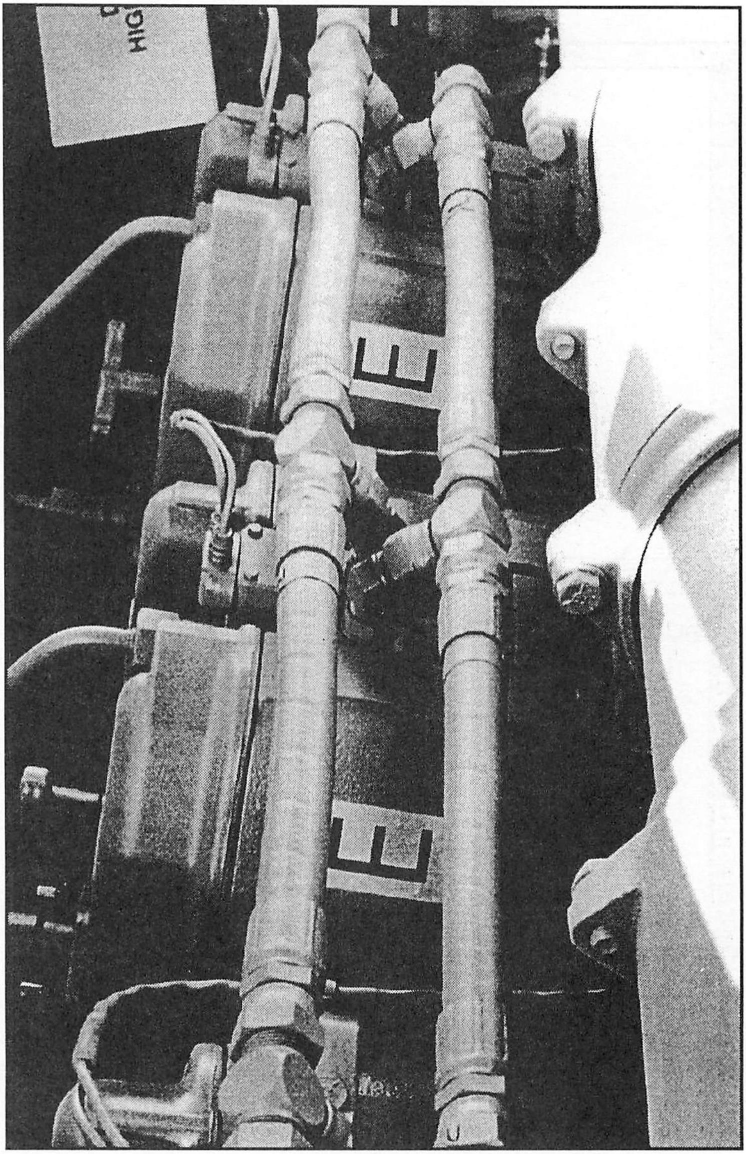


Fig. 9

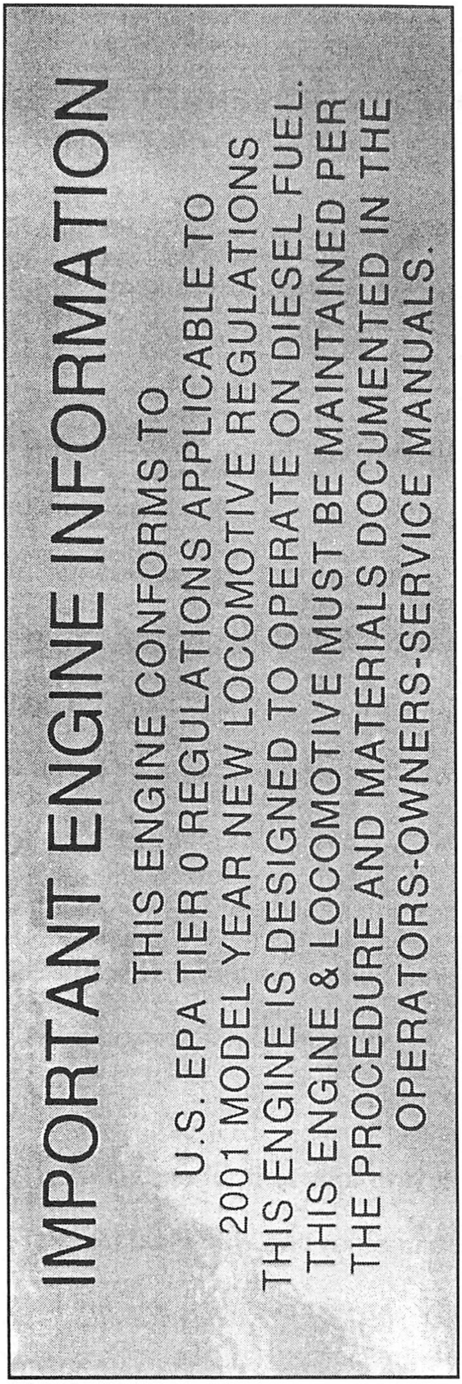

IMPORTANT ENGINE INFORMATION
THIS ENGINE CONFORMS TO
U.S. EPA TIER 0 REGULATIONS APPLICABLE TO
2001 MODEL YEAR NEW LOCOMOTIVE REGULATIONS
THIS ENGINE IS DESIGNED TO OPERATE ON DIESEL FUEL.
THIS ENGINE & LOCOMOTIVE MUST BE MAINTAINED PER
THE PROCEDURE AND MATERIALS DOCUMENTED IN THE
OPERATORS-OWNERS-SERVICE MANUALS.

Fig. 10

III. EMD DIESEL ENGINES CRANKSHAFT MAIN BEARINGS EDGE-LOADING CONDITION (DESCRIPTION, DETECTION AND RESOLUTION)

Prepared by:
Klaus Stadlymayr, Applications Engineer, MIBA Gleitlager AG and Ted Stewart, Mechanical Systems Engineer, CSX Transportation

1. Service and Maintenance of EMD Engines

Most locomotive and engine service and maintenance practices are focused to support and satisfy railroad operating department requirements for high reliability and availability and low costs. These practices may differ for various railroad companies due to the maintenance policies to which they subscribe. Past presentations of the LMOA Mechanical Committee have dealt with such maintenance concepts. Most maintenance practices fall between the following two policies: a) operate to failure, or b) reliability based maintenance. In the second process, the parts are changed just before failure based on an accurate monitoring system that was developed with past failure experiences and maintenance histories. This predictable and reliable failure detection system is continuously monitored and studied to further define trends and clues that will help achieve the goal of preventing, and therefore reducing, costly catastrophic failures. This policy can work especially well for engine components operating in the lube oil systems such as bearings and bushings, in which a monitoring system based on periodic oil analysis has been developed.

Service and maintenance are a very critical part of the total operating cost, yet it is under constant pressure to be reduced. The main influencing parameter to reduce overall maintenance and prolong the engine overhaul interval is predicting the total service life of the associated parts; then, to develop a comprehensive plan for extending the overall package's life cycle.

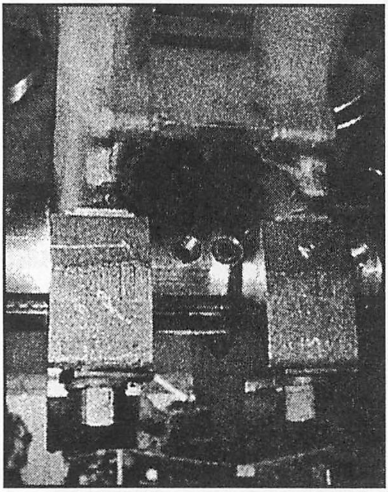
This paper describes a bearing service and maintenance phenomenon found on EMD locomotive engines, how it is being monitored and an alternative bearing design that provides extended service life.

2. EMD Crankshaft Design

Most of the EMD locomotive engines found in the railroad industry today are of the 645-16 cylinder "E" type engine models that range between 2000 and 3000 horsepower. The crankcase of these engines is a fabricated design in which the crankshaft main bearings are an integral part of an "A" frame structurally welded into the crankcase structure. The main bearing caps are assembled to the "A" frames with either two or four stud bolts. The most critical "A" frames are numbers 5 and 6, (in the 16 cylinder engines), because they support the two

piece crankshaft's midsection where two mating surfaces are bolted together. These center "A" frames only have two main bearing stud bolts and their bearings are the most susceptible to edge loadings. The mounting of the crankshaft thrust bearings are also found on these same "A" frames. See Fig. 1.

FIG. 1 ***View at the center "A" frames No. 5&6***

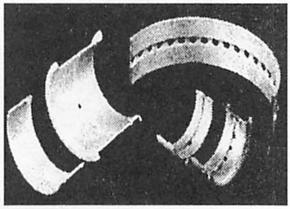


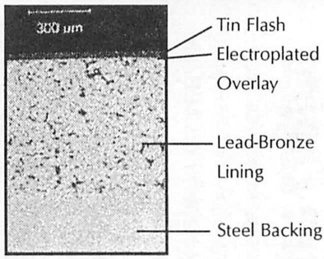
It has been found that after a certain amount of service life, deflection or misalignment of the main bearing caps, or perhaps even the "A" frames, may take place and directly affect the performance of the bearings. This condition can be clearly observed on the bearing running surfaces usually in various degrees of distress, designated as edge loading. This condition is described in detail in the following sections.

3. Main Bearing Description

The standard bearing type in EMD engines is a tin-lead-bronze tri-metal designed bearing. A typical bearing and the corresponding cross-section are shown in Fig. 2.

FIG. 2 Ordinary Trimetal Bearings and Cross Section.

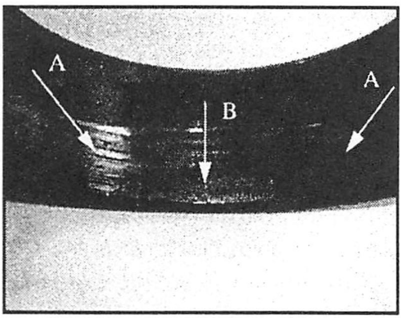




The top layer, (electroplated overlay), is very soft and offers a margin of conformability for running break-in and provides good emergency running protection in case of extraordinary conditions or loads. The main drawback of this bearing type is the delaminating or loosening of the overlay during actual operation. Wear, corrosion/erosion, or geometrical deviations, (i.e. line bore), can cause this condition which sacrifices the required tribological properties needed for satisfactory bearing performance. As more of the bronze lining material is exposed as the new running surface, the probability of failure increases dramatically.

A typical example of a bearing that has reached this stage of extreme distress is provided in Fig. 3. The unavoidable and final failure of such a bearing, if allowed to continue running, is the seizing of the bearing to the crankshaft journal and catastrophic engine failure. Area A is the exposed intermediate bearing lining surface and Area B shows the delamination of the lining surface to expose the steel backing shell.

FIG. 3



The possible causes of edge loading are as follows:

- Mis-alignment of engine crankcase and crankshaft due to long periods of service life without being removed for periodic line bore checks.
- Axial motion of the crankshaft caused by hard couplings, derailments, etc. The center "A" frames that hold the thrust bearings absorb this momentum shift and may become tilted.
- Mis-alignment or micro-motion at the mating faces of the two-piece crankshaft during operation.
- Improper bearing installation or assembly bolt torquing practices, especially conditions of over-torque.
- Incorrect shape or dimensions of the bearing housing or the journal itself.
- Improperly balanced crankshafts that can lead to "tumbling".
- Incorrect crankshaft fillet dimensions.
- Worn serrations/crank deflection/crank bearing position.

4. Edge Loading Description

Main bearing edge loading, (or cap tilt as it may be commonly known), is a condition found on the EMD diesel engine bearings and is mainly a geometrical alignment concern. One of the above mentioned conditions may occur and cause the main bearing cap and bearing assembly to be slightly tilted axially with only one side of the bearing surface supporting the crankshaft. The necessary clearance between the bearing's running surface and the crankshaft journal decreases causing the oil film to become thinner thus creating very high oil film pressures and temperatures. Finally, the increased friction, in combination with the increase in oil temperatures, will cause the crankshaft journal to remove or "relocate" the soft running layer of lead-tin and expose the lead-bronze surface of the support layer. There are several edge-loading stages that can be seen on the bearing face, such as: fine cracks in the overlay, small traces or rivulets (channeling), different surface appearances, (dull vs. shiny) and the area of exposed bronze, can all be seen in Fig. 4. This bearing condition of distress can be readily detected in the oil analysis as a rise in the copper, lead and tin concentrations at a certain rate in a specific amount of time.

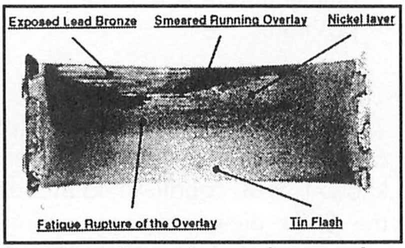


FIG. 4 Overview of an edge-loaded Trimetal Bearing

5. Lube Oil Condition Monitoring

An oil expert system, (OES), was developed as a reliability based maintenance condition-monitoring tool that utilizes data collected from locomotive engine lube oil samples. The OES was designed to provide the schedule for which the oil samples are taken, the evaluation of the sample's oil quality and the consequential resultant action, if any, that is to be taken to protect the engine. Detrimental conditions that directly affect the engine's operating life include all changes in oil quality and contamination. If any abnormal condition is detected, OES issues "lab alerts" to the maintenance shops with a corresponding level of seriousness which can range from "immediate shutdown" to "repair at the next scheduled shopping". These alert levels are based on both tribological rules regarding the degree of bearing distress and business risk policy rules.

The goal of the OES is to predict potential engine damage and take appropriate action to minimize the cost of maintenance, (i.e. catastrophic engine failures). Implementation of an effective oil expert system is critical to support a business decision to move toward a predictive maintenance policy through the use of condition monitoring. Predictive maintenance practices are based on the collection and analysis of accurate input data and action is then taken to effectively and accurately predict if and when the component(s) in question will fail. Because the success of an OES is based on the ability to have these component(s) removed immediately prior to failure, an historic record of past catastrophic engine failures must be developed and investigated as to root cause along with the lube oil analysis history. A trend equation of the relevant wear metals is then developed and used to predict and prevent future occurrences on other locomotive engines.

6. Data Collection

As was stated earlier, an OES system is based on the collection of "good" input. Three areas became the point of focus in order to provide a solid foundation on which to make accurate decisions. First, it was found that the oil sample and resultant lab alert accuracy depended on the correct identification and sampling techniques. Bar coding and scanning instrumentation were implemented for all sample bottles, which helped to significantly improve the OES credibility. Second, every catastrophic engine failure was carefully investigated for clues that would have warned or predicted the failure. And finally, due to the large number of crankshaft bearing related failures, all main bearings were collected whenever and wherever they were changed and then photographed and dated. These photographs of the entire bearing set provided a snapshot of the engine's condition in regard to all past maintenance practices that were applied (or mis-applied). It also provided information in regard to the current crankshaft/bearing geometry, or line bore integrity, past assembly and torquing methods and the correct oil package protection and lubrication qualities. It was during these many bearing inspections that the various stages of bearing edge loading were identified.

There are several other key factors that need to be documented concerning the success of this condition-monitoring tool: 1) a reliable and consistent oil analysis process at a centrally located lab; 2) a predictable time sequence between the time the sample was taken, processed and reported is a requirement for gathering effective data on which to base the lab alerts; and 3) a high level of confidence in the alarms and predictions in the eyes of the shop personnel and the fleet managers. This trust and confidence can only be achieved by demonstrating the system's effectiveness, which was accomplished by reducing catastrophic engine failures by nearly 60% in a two year time period.

To develop the trend equations on which to base the prediction of the main bearing distress condition, fourteen engines' lube oil histories that had been identified with various degrees of edge loading were evaluated and graphed in order to show the relationship of the increase of copper over time, Fig. 5. The lower boundary limit was established and programmed into the OES to provide the first indication that edge loading may exist and issue an alert that the maintenance shops would investigate. From experience it is known that the bearing will not fail immediately when the lead-bronze material is first exposed, but the bearing's functional properties decrease. If any contamination occurs during this time that disturbs the very thin oil film, such as dirt particles, water or diesel fuel, the oil film will be disrupted and the bearing will very likely fail.

7. Improved Bearing Design: The Rillenlager

To establish the functional criteria for the development of a new bearing design, it is necessary to observe the operating behavior after application of the bearing in actual field service as well as the theoretical bearing design. The following criteria were identified as critical to the design development of a "new" bearing:

- Increased wear resistance to extend useful service life and to reduce operational risk.

- Improved performance to cope with sudden high loads and low oil film thickness caused by extraordinary events.

The bearing which has been designed to meet these two improtant criteria, is the Rillenlager, which was previously described in an LMOA Mechanical committee paper presented by Mr. John Sadler. This bearing's running surface contains a high strength lining material, (A1Zn4,5), to a maximum content of 25% in its original condition and an electroplated lead-tin running overlay. The ridges of lining material, as seen in Fig. 6, support the electroplated overlay and are responsible for the significant decrease in wear rate. The bearing's running surface geometry was changed to a somewhat barrel-shape configuration to provide a decreased wall thickness on both bearing sides.

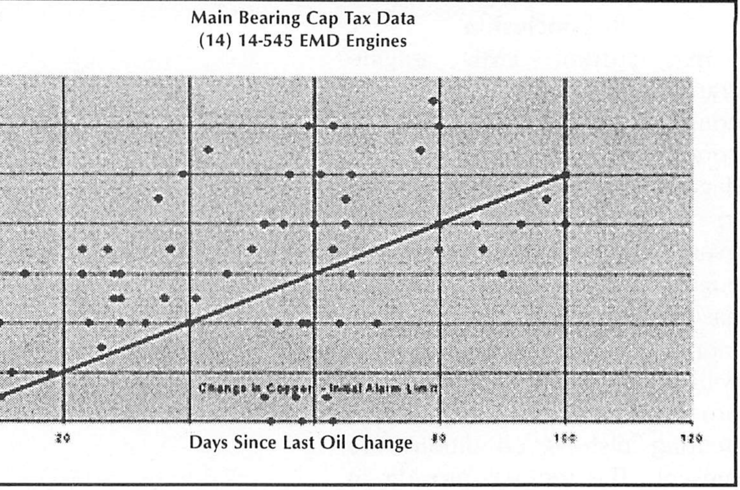
Actual field test results, completed on several SD40-2 16-645E3B engines that had known cap tilt conditions, show that the Rillenlager convex running surface design helps to minimize edge loading and improve the emergency running capability when the bearings are in a condition of distress, as seen in Fig. 7. The Rillenlager surface wear in these test bearings was found to be minor and should provide extended bearing service and life. It should be noted here that the oil analysis over the bearing's service life will now show higher aluminum and lead readings rather than copper and lead.

The Rillenlager bearing is being used in many heavy duty engine applications in the US and around the world, such as heavy-duty trucks, locomotives, ships and stationary equipment. Currently on the CSX railroad, the Rillenlager is in service in GE locomotives for both the FDL and the HDL engines and is undergoing field tests for the EMD crankshaft main bearings.

8. Conclusion

The current EMD engine crankshaft support design and configuration is susceptible to conditions that cause various degrees of bearing distress referred to as edge loading, that can eventually lead to catastrophic engine failures if left unresolved. It has been proven that condition-monitoring of the engine lube oil with an oil expert system can be programmed to issue alarms when bearing distress conditions are present. This tool will provide an extremely cost effective early warning system that is a useful and vital fleet management system. Advanced bearing designs, such as the Rillenlager for railroad applications, are available to help promote longer engine overhaul periods, extend the useful service life and offer additional protection for the major components of the engine.

FIG. 5



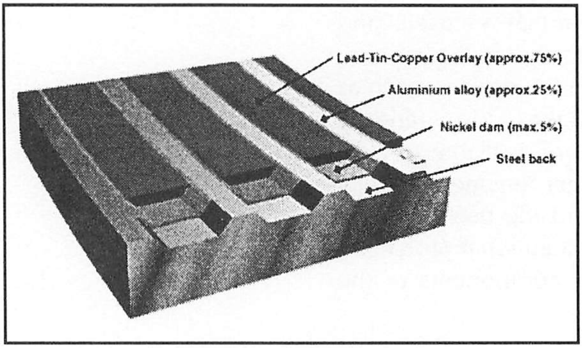


FIG. 6 (left) Rillenlager design features

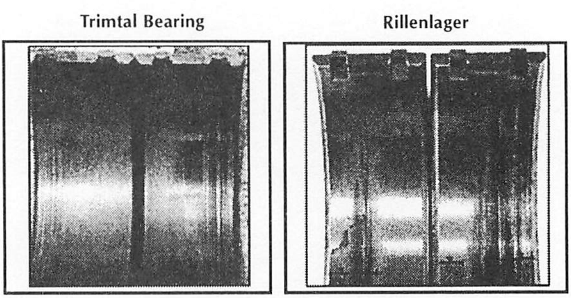


FIG. 7 (right) Test in extreme misaligned bearing housings 5&6: Wear comparison of Rillenlager and ordinary Trimetal Bearing in the same engine after three months in service.

IV. LMOA 2000 BEST PRACTICE SERIES: LOCOMOTIVE TRUCK OVERHAUL PROCEDURES

By Jack Kuhns,
Hadady Corporation

Introduction

There are many different models of locomotive trucks and for each model there are as many different perspectives on the rebuild procedures as there are people who rebuild them. Rather than defining the proper rebuild procedures from yet another position, the goal is to point our what the "Best Practices" are for some of the key areas. These Best Practices are those that have been observed to have the best return on the investment, in both price and longevity. The type of service the locomotive is utilized in dramatically affects the service life of the trucks, and therefore the maintenance decisions should reflect this. Traditional overhaul cycles should be updated, balanced and integrated whenever possible. Locomotive downtime and utilization are prime targets for improvement.

The general size and shape of locomotive trucks dictates the need for a large work area and large support systems such as overhead cranes and elevators. This keeps most truck overhaul work done only in backshops. While truck rebuilding is not a highly technical process, proper procedures must be followed. Multi-department coordination is also necessary to make truck overhauls fit in with the locomotive overhaul process. An industry wide challenge seems to be the coordination between the traction motor overhaul shop, the wheel shop, and the truck shop. In addition, adding to the difficulty of scheduling in advance is the large number of different truck types. An efficient truck shop is an essential department for large fleet maintenance.

Actual overhaul procedures industry-wide are similar as would be expected, although there are enough differences to note what appear to be the "Best Practices." All Class I railroads as well as most regionals have the shop facilities to rebuild their own trucks in-house and currently have rebuild programs active. The reported times necessary for truck overhaul range from 65 to 85 man-hours per truck for the North American Class I railroads and several rebuilders polled.

Disassembly and Cleaning:

Complete truck disassembly is of course necessary. Some shops prefer to disassemble after cleaning, some before. Regardless, complete disassembly is necessary to enable complete access for inspection and repair. This allows all sub-assemblies to be reduced to the component stage for complete rework, as well as to enable a thorough inspection of the frame for cracks or other signs of fatigue. The cleaning systems currently in use range from agitated chemical cleaning vats/tanks to high-pressure automatic washing machines designed specifically for truck cleaning, to hand scraping and hand pressure washing.

Normally a thorough cleaning is thought to be necessary to reveal all possible cracks or defects. Considering this comes at a stiff price, as large capital investments in equipment for cleaning and handling must be made and then continuously maintained. In addition, if a frame has a crack, it is generally caused by a derailment or accident and dirt does not hide it. Depending on the experience level with a particular truck style's aging characteristics, the most cost effective system would be hand scraping followed by hand pressure washing. The goal is to produce, as cost effectively as possible, a truck that will last from 10 to 15 years in service. Does maintaining staffing and repairing all that expensive wash system equipment really contribute to the product you are trying to produce? Considering that with the declining use of hi-tack gear lube, lubricated journal boxes, lubricated suspension bearings and the increase in use of more tightly sealed gear cases, less dirt is attracted to the frame.

The "Best Practice" recommendation would be to reduce emphasis on cleaning.

Truck Frame Handling:

A common goal among the most efficient shops is to minimize overhead movement; this from the safety standpoint as well as from eliminating work disruption. Many methods have been utilized over the years to turn and position trucks. The tried and true method still seems to be the large overhead crane. Truck rotators or positioners seem to take too much time to set up. In concept, they would eliminate several overhead crane moves, but the time required for setup has never been effectively reduced.

The "Best Practice" recommendation would be to minimize frame movement by adjusting workflow.

Qualification of the Truck Frame:

The qualification of the frame and its many wear points should always include tramming. The proper procedure is explained in excellent detail in the respective OEM shop repair manuals. Long term negative side effects that can contribute to poor wheel wear characteristics can only be identified and addressed at this time.

The "Best Practice" recommendation is to follow the tramming procedure thoroughly without exception.

Pedestal Jaw Repair:

This introduces the topic of pedestal jaw repair. This area of the overhaul is arguably one of the more sensitive areas, or should be. This statement is made because journal box to pedestal liner clearance has a pronounced effect on ride quality and wheel wear and must be addressed with this understanding. This should first be based on the intended use of the locomotive. A technical paper was written on this topic co-authored by Mehi Ahmadian, associate professor, and director of advanced vehicle dynamics laboratory of the Mechanical Engineering department of Virginia Tech and Robert Cantwell, chief executive officer of the Hadady Corporation. To summarize from this paper; in its simplest form, for high-speed service tighter journal box to pedestal liner spacing is desired. This to help control truck hunting and axle wandering. For low speed and drag service, wider clearances are preferred to assist in curve negotiation and high adhesion conditions. Wheel wear and ride quality are dramatically affected by this and overall fleet maintenance decisions should take this into account.

The manner in which journal box repair is addressed around the industry ranges from welding and specialty machine grinding back to new or nearly new dimensions of all truck frames pedestal jaws at each overhaul, to a quick inspection for a max width dimension or excessive wear step followed by spot welding and hand grinding. Our recommendation would rest somewhere in between. There should be an established minimum and maximum dimension as well as a check for vertical parallelism of corresponding jaw to one another. The type of pedestal liner that was previously used as well as that style intended for use may influence these procedures. This is mentioned because with the advent of newer style soft-back versions the industry has seen substantially less jaw surface wear after an equivalent time in service compared to the hardback style. Therefore, by installing this type there is a significant reduction in labor necessary to rework the jaws at the next overhaul. Utilizing this style also reduces the need for a "perfect" surface for the jaw/pedestal liner interface. The soft strips can absorb surface irregularity.

The "Best Practice" recommendation is to establish minimum and maximum jaw width opening dimensions based on service requirements and repair by welding and hand grinding using the softback style pedestal liner.

Component Reclamation:

At this point in a rebuild the various sub-components have either been rebuilt in-house or sent out for overhaul. The cost effectiveness of in-house rebuilding of all the sub-components such as the brake rigging and crossover levers, the air ducts, the nose packs, the brake cylinders and the bolsters of the truck should be evaluated very closely. Cost effective usage of railroad labor warrants looking closely at all in-house practices and procedures. Often times, delegating certain responsibilities to vendors can have very positive effects on shop detention time and quality. Vendors often meet much higher quality standards than those imposed on in-house services and the competition between vendors drives price as well as quality. This coupled with just-in-time delivery can help reduce railroad's inventory.

The "Best Practice" recommendation is then to use as many external vendors as necessary if high production and low detention times are the goals. If detention time is not the governing factor and the lowest direct cost is, then rework all components in-house.

Shock Absorbers and Dampers:

Shock absorbers and dampers were left out of the above grouping for the simple reason that shock absorbers and their important contributions to truck performance seem to have become, in the eyes of the industry, worth renewing completely at overhaul. Those on the journals can be easily inspected for visual signs of failure. Testing of shocks can be accomplished with the appropriate equipment and the savings against replacing all with new at overhaul may justify the acquisition costs of that equipment. Those on the bolsters or those in opposing service should always be replaced in pairs.

The "Best Practice" recommendation for shocks would be to qualify, and replace in sets for those in opposing applications.

Bolsters, Center Plates:

The bolster would present the largest challenge for outsourcing due to its size and weight. It is possibly the most labor-intensive component to rebuild alongside the hangers and levers due to all the welding and possible machine work on the center bowl. Generally it has been observed that if the unit had been previously equipped with a composite center bowl and lubrication was maintained, then little or no rework is necessary in this area. Composite bolster wear plates also perform well and are easily replaced. Several different configurations of composite center bowls have been utilized in the industry and all seem to have contributed to reduced wear in this area. Bolt-on composite bolster wear pads currently used on EMD HTC style as well as those retrofitted on Flexicoil style trucks work well.

The "Best Practice" recommendation is that composite wear plate usage provides the best service and reduces future labor costs.

Springs, Coil, Rubber and Elliptical

The next area of attention should be the journal box and bolster mount coil spring. The observed industry practices range from complete replacement with new, to a very labor intensive qualification system. The original manufacturer recommendations include all necessary methods for spring qualification including spring rate testing, free height measurements and a given load compressed dimensions are seldom followed.

Unlike coil springs, the rubber bolster springs are generally rejected for visual defects such as cracking of the rubber between the compression plates and plate distortion. They can be tested and sometimes are dimensionally qualified. Due to the small difference between loaded and unloaded height, it is generally observed that all rubber springs are replaced at overhaul. Unlike the practice of combining new and qualified coil springs, it is the recommendation that all rubber springs be replaced in sets at overhaul. The effective service life of rubber springs is much less predictable than with steel coil springs. It is observed that elliptical springs are replaced individually more often than what the qualification guidelines spelled out in most overhaul manuals call for. The reason it seems is that most locomotives equipped with this style of truck could possibly be seeing their last overhaul and are intended to last as long as possible.

Another component should be mentioned here that has proven itself in service is the composite coil spring pad. Pads not only shield two wear surfaces from one another, springs and spring seats, but they also reduce traction motor brush jumping. They also reduce harmonic vibration and shock, thereby extending spring life and reducing breakage.

The "Best Practices" recommendation for springs would be to follow a consistent qualification system. For coil springs, it would include a free height measurement as well as visual inspection looking for damage to the coils outer surfaces. For rubber springs, complete set replacement on those springs that have been in service for more that 6 years. For elliptical springs use free height measurements and visual qualification. Utilize composite pads to extend spring life.

Brake Rigging and Crossover Lever Pins and Bushings:

Now lets look at pin and bushing replacement. The longevity of pins and bushings based solely on the condition of them at truck disassembly might be misleading. Quite often crossover lever bushings are not renewed based on the perception that after 10 to 12 years of service they do not exhibit a lot of wear, hence the decision is made not to replace them. It is important to point out that bushings generally have about .030 to .040 depth of hardness and their associated pins about the same. Crossover lever pins and bushings are possibly the only components that have worn to their original design expectation. They are probably just now wearing through this hardness and

the wear will quickly begin escalating now into the soft-core material. These pins and bushings will then require replacing in the next year or two of service. While replacing these at service tracks and running repair shops is possible, the associated downtime cost to do this far outweighs the minimal cost and time to renew these at overhaul. The correct analysis is that the other pins and bushings such as those for the brake hangers and levers have far exceeded the original design expected service life as evidenced by their general condition. The reality is that pin and bushings wear is the life-limiting factor of trucks. Composite bushings whose wear characteristics far exceed those of steel on steel have not had much success in these areas. This is because the excellent wear properties cannot be utilized by simply duplicating the original steel bushing dimensions. A redesign of the brake rigging geometry is necessary to successfully capitalize on the properties which composites offer. The forces of gravity and vibration contribute to the wear, as does the actual application of braking forces, for the same reasons that freight cars experience 40 to 50% of component wear while running empty. The combined weight of the brake hanger assemblies and slack adjusters is acting on the pivot bushings and hanger pins generating this wear. Some slack adjuster designs might be heavier than others in measurable amounts.

The "Best Practice" recommendation concerning pins and bushings would be to replace all at overhaul.

Break Heads:

A qualification of brake head condition needs to be performed at overhaul as well. Brake heads wear not only in the ferrule/bushing area, but also on the brake shoe face. Very few shops rebuild brake heads at this time although a few will qualify used ones. The option of angled versus straight-faced brake shoes is also present.

The "Best Practice" recommendation would be to qualify or replace all brake heads at overhaul.

The Following are "Best Practice Observations,"

Modified Brake Shoes:

Monitoring braking efficiency, common on freight cars, should be considered for locomotives. The deterioration in the efficiency most definitely increases with bushing and pin wear. The use of different design brake shoes intended to compensate for worn rigging only serves to hide the problem. These modified shoes can also affect the braking geometry originally designed into a particular locomotive's brake system. By either reducing or increasing the surface area of a brake shoe from that originally designed for, the stopping distances can be dramatically affected and unwanted side effects such as higher wheel rim temperatures during heavy braking can result. Be aware of the side effects resulting from using modified brake shoe geometry.

Truck Service Life Expectations:

Most Class I railroads expect a minimum of 10 years of main line service and up to 15 years for switcher service between truck overhauls. Most locomotive engines now demonstrate a minimum of 6 to 8 years service between major overhauls. Consequently, rebuilding a truck at those intervals would be considered wasteful, but expecting the truck to last until the next engine overhaul is unrealistic. A truck used in mainline service that has not been overhauled in 12 years more than likely is due.

This mismatch between overhaul cycles that the truck has experienced over the years has crept steadily wider. Not too many years ago, we overhauled engines at the 3-year mark, roughly the life of the power assemblies and engine bearings at the time. We then overhauled the truck every third engine overhaul. As the prime mover started advancing to 4-5 years between overhauls, we were able to try for every other overhaul. Now at the aforementioned 6-8 year mark we cannot go 12-16 years between overhauls. A bridge is now needed for the obvious gap that exists; this bridge can be in the form of mid-life tune-up to high wear areas such as the hanger pins and bushings. A concurrent goal would be to focus on a study of the redesign of the pivot points and hanger pins in an attempt to balance out the service life equal to that of the crossover levers. The reduction of the weight of the brake systems moving components could possibly reduce the high wear tendency, thereby extending truck service life.

Conclusion

In summary, it can be assumed, if not proven definitively, that as ride quality diminishes, wheel wear goes up, braking efficiency goes down and fuel usage increases. It can be expected that the trucks that are under the locomotives slated for service through the upcoming EPA emissions era will need overhauling at least twice more. Therefore, a service cycle must be implemented that will cost effectively see them through the balance of their expected service careers. To take advantage of the opportunities that are available we should consider overhaul techniques and materials that will quickly and cost effectively add to the bottom line. Using "Best Practice" techniques to reduce maintenance costs and increase operating performance while at the same time increasing the service life would be a good place to start!

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT AND PROCESSES

MONDAY, SEPTEMBER 18, 2000
2:00 P.M.

BILL PETERMAN, Chairman
Consultant
Peterman Railway Technologies
Baie D'Urfe, Quebec

Pre-Convention Presentation: June 26, 2000, Albany, NY
Sponsored by: Engine Systems and Simmons Machine Tool

Vice Chairman
JOHN MORGANO
Mechanical Superintendent
Wisconsin Central Ltd
Fond du Lac, WI

COMMITTEE MEMBERS

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THE SHOP EQUIPMENT AND PROCESSES COMMITTEE

Would like to thank

Simmons Machine Tool

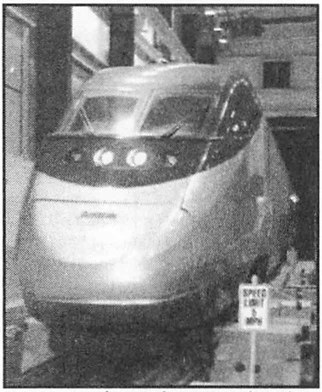
for hosting the committee's

pre-convention presentation

in Albany, NY

in June 2000

I. THE TANDEM WHEEL TRUING MACHINE AT AMTRAK'S IVY CITY SHOP



Written by: Blaine Salvador
Simmons Machine Tool
Presented by:
Pat Gagne
St. Lawrence & Hudson
(CP Railway)

Introduction

In order to meet both the productivity and machining accuracy requirements for the high speed trainset maintenance facility at Ivy City Yard, Washington D.C., Amtrak selected a TANDEM underfloor wheel profiling machine. The TANDEM machine arrangement allows simultaneous machining of two mounted wheelsets with a high degree of accuracy. The tandem machine consists of two single machines integrated into one high capacity wheel profiling machine.

In addition to high productivity and high accuracy the tandem machine incorporated features to simplify machine operation and automatically store necessary data. This paper shows some of the technological advantages with the TANDEM underfloor wheel profiling machine

Advantages of the TANDEM Wheel Truing Machine

The numerically controlled TANDEM underfloor wheelset profiling machine provides the latest technology of simultaneous machining of two powered or non-powered wheelsets in mounted or dismounted conditions. Each single machining unit can take a maximum axle load of 40 metric tons.

With the TANDEM machine arrangement, it is possible to get maximum productivity together with a high degree of machining accuracy. The probing process, conducted both before and after machining with the direct probing system, guarantees high quality results. The full profile contour milling technology allows a high degree of automation, which includes fully automatic positioning, machining and measuring cycles. This technology also improves working and ergonomic conditions for the machine operator by generating only small chips, even at high metal removal rate, which can be safely removed from the machine and fed into a chip bin. The essential advantages of small chips include a high degree of operator safety and no damage to vehicle cables caused by long and sharp chips due to the fact the chip flow and disposal is absolutely controlled. Another advantage of the milling technique is the generation of compressive residual surface stresses resulting in the hardening of the outer material layer.

By using the milling instead of the turning technology, the cost per wheelset is minimized through the following:

a. The machine rail-to-rail time is reduced.

b. Tool cost per wheelset is minimized.

c. Labor cost per wheelset is minimized as only one operator per machine is required.

Operation of the Underfloor Wheel Profiling Machine

The TANDEM wheel profiling machine layout installed at Ivy City is shown in figure 4.

By applying the full profile milling technology and the machine concept, an almost automatic sequence of machining operations is generated. The detailed operator guidance will guide the operator through the entire machining process. The operation of reprofiling a wheelset on the machine consists of positioning the wheelset onto the machine, pre-probing, machining, control probing and releasing the wheelset. These steps of the operating cycle are described below.

3.1. Wheelset Positioning

The vehicle is driven independently on to the machine. The wheelset position is monitored by sensor units and reflector marks which are attached on the rail system. The positions are indicated to the operator by using the operator lights. The wheelset position is completed on both machines. The second machining unit is moveable and can be adjusted to the right axle distance.

The operator then starts the wheelset "take up" process on the machines, the support cylinders move equally upward lifting the wheelset from the rails, then the sliding rails open automatically and the wheelset is lowered

The outboard housing supports are then moved against the axle boxes, the hold down units are mounted onto the adapter plates and the axle is locked in place.

3.2. Measuring of the Wheelset - Pre Probing

The probing system for determining the default data at the profile and for control probing after cutting has been incorporated in the machine. Data acquired during the wheelset probing cycle shall form the basis for future definition of the machining proposal and thus, for the entire cutting process of the wheelset. Probing of wheelset is done in one fully automatic cycle for both wheels on each machining unit. The machine measures the axial run-out at the back face of wheel rim, back-to-back distance [btb], radial run-out in the tape line, wheel circumference in tape line (used for calculation of the diameter), track gauge [ga], flange height [fh], flange thickness [fth], profile wear at the outer tread and front wheel flange (see figure 6). After completion of this cycle, the determined wheel data will be displayed on the main control stations and used for calculation of the optimal programs.

3.3. Wheel Profiling

The wheelset machining is an automatic process which utilizes calculated machining parameters generated by a control system. The process is started after the operator accepts or modifies the machining parameters (diameters). The theoretical profile is incorporated in the cutter. The chip conveyor system is automatically turned on after starting the machining process. The machine can also execute a single cut on a wheelset.

3.4. Measuring of the Wheelset -Control Probing

Further to wheelset machining it is possible to control-probe the wheels for determining the new actual diameter and radial run-outs. After completion of the measuring cycle, all measured data will appear on the main monitor screen.

3.5. Releasing of the Wheelset

To release the wheelset, the hold down system is removed and the outboard housing supports are lowered. The support cylinders then lift the wheelset and the sliding rail can be closed. The support cylinders are moved down and the wheelset placed back on the rail. The cycle is complete and then a new wheelset can be moved into position on the machine.

4. Tandem Feature and Productivity

This is a robust machine, designed for today's heavy operations in a railway environment. In tandem arrangment both machining units function as two individual machines. One machine is fixed mounted to the base and the second machine is moveable. The movement of the second machine along the hardened guideways on the base is realized by the shifting device. By moving the second machine the axle distance between the axles in a truck can be adjusted. The positioning of machine two is possible within ± .004" (0.1mm). Each machine side of machine two has a seperate moving axis, which is monitored by an absolute encoder system. The moving process for both machine sides is synchronized and thus, any tilting and resultant forces are prevented. The traversing rate is approx. 4.921 ft/min (1.5m/min). The shifting axis (V-axis) is configured as NC-axis.

The shifting motion is initiated automatically after identification of vehicle type in the operator guidance. The operator will also

be able to readjust the distance between the machines according to as built axle base tolerances.

The Amtrak Ivy City wheel truing machine specification required reprofiling of a wheelset in 40min. The TANDEM feature on the machine allows to reprofile two wheelsets at the same time. That means the productivity for a single machine is approximately 16 wheelsets per shift. The tandem arrangement of this machine increases the productivity to 32 wheelsets per shift.

The machining time is approximately calculated by (basis is a 3-7.5 mm material removal applicable for customers with high speed applications; time in min):

Positioning of the axles onto the machine 1 **1**

Vehicle data input **1.5**

Shifting of machine 2 to the axle distance **1**

Wheelset take up on both machines **2**

Housing support and hold down mounting **2**

Wheelset pre-probing and calculating of the cutting parameters **3**

Wheelset machining[1] for the following cutting sequence

Diameter 39.37" (1000mm), necessary wheel rotation 1.14

First cut with a_e=.078-.157", v_c=459.312ft/min, v_f =1.968ft/min a_e=2-4mm, v_c=140m/min, v_f =600mm/min **6**

Second cut a_e =.039-.098" v_c =590.544ft/min, v_f = 2.625ft/min a_e =1-2.5mm, v_c = 180m/min, v_f =800mm/min **4**

Finish cut a_e =0-.039", v_c =590.544ft/min, v_f=2.625ft/min a_e =0-1mm, v_c =180m/min, v_f =800mm/min **4.5**

Wheelset take out on both machines **2**

Vehicle moving to the next axle **1**

Proportional tool change time **1**

Total **29**

a_e . . . depth of cut
v_c . . . wheel speed
v_f . . . cutter speed

[1]vehicle type and cutting parameter depending

5. Measuring System

Reprofiling of the high speed trainset requires a high degree of accuracy. In order to meet this requirement, the machine is equipped with a probing system (see figure 5) which can be used for pre-probing and control probing of workpiece positions, axial and radial run-outs, circumference at the tape line and for probing of diferent profile points (see figure 6). The automatic process.

The measuring data from pre-probing cycle are used for future definition of the machining proposal to the operator. The first step during the measuring cycle is the axial run-out probing over a full wheel revolution, simultaneously the workpiece zero point is defined, so that the track gauge complies with the required tolerances. Then the radial run-out and circumference are probed. The circumference of the wheel is measured over two revolutions, the first revolution is used for recording of the radial run-out. Then the wheel diameter can be calculated from the circumference. The last step is the measuring of profile points, such as flange height and thickness or profile wear on the outer tread of the wheel. Those data are used to define the machining data.

After completion of the probing cycle, the wheel data will be displayed on the screen at the main operator panel; the display shows all the different measurement or calculated values (see figure 1).

The probing system is mounted to the cutter spindle housing and can therefore be moved with the slides. The wheelset rotation is monitored by an optical sensor and a reflector mark which is attached to the wheel.

The measuring system is a precise measuring device for measuring the diameter, the axial run-out and the wear on the defined profile points on both sides of a wheelset simultaneously within 0.004" (0.1mm).

All of the data that the CNC received from the measuring device or input by the operator are tested to confirm that the data are within acceptable limits. For instance, a wheel diameter to a particular type of wheel can only be within a certain range. If it is not, the controller sends error messages to the operator and stops the set up process. This feature is provided for all the relevant wheelset data.

Milling Cutters and Tooling Costs

The milling cutter is a full profile milling cutter. The cutter assemblies of the machine consists of two full contour milling heads (left and right hand), consisting of a cutter body, and thirteen cutting blades that contain cylindrical inserts which are arranged with maximum density (see figure 2 for illustration purposes only).

The cutter blades are fixed axially (bearing on cutter flange) to prevent any displacement of the individual cutter blades.

The blades are replaceable and designed so that the cylindrical inserts can be easily indexed and/or replaced.

The round cutter inserts are fastened with Torx screws. The inserts can be used on both sides and can be indexed approx. 8 times per side (total 16 cutting edges).

The inserts are arranged along the blade for maximum density and displaced from blade to blade for optimum surface finish on the wheel. If an insert breaks during the cutting cycle, standard practice allows the operator to continue the cut and complete the entire cutting cycle. The large number of carbide inserts in each cutter provides the benefit of finishing the cutting style without withdrawing from the cut.

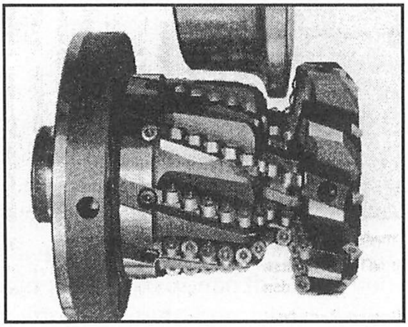


Figure 2: *10 blade cutter with seperate chamfer inserts*

Fifteen to 20 wheelsets can be machined before indexing is required; this depends on the wheel profile wear and metal removal rate.

The 16 cutting positions (8 on each side) on each insert reduces the tool cost per wheel substantially.

Data Management Feature

To effectively manage the high speed train wheelset maintenance, a system was needed to store critical information. The data management system satisfies this requirement.

The operator can transfer important values (such as date, time, machine time, vehicle information, operator, diameter and radial run-out before and after machining, flange height and thickness and axial run-out before machining, gage and back to back distance) to a separate PC for data storage purposes and management reasons. The data management software also provides different features for data comparison and the possibility for print outs on each saved data set.

Figure 3 shows the main screen from the data management system. The template always displays the last received record. The dimensions can be displayed in inch or mm.

In the header lines there are fields for vehicle parameters and truck type, the machine selection, operator's name, date of machining and the actual machining time.

Displayed in the center of the screen are the outlines from two wheels. The measured values are displayed in reference to these contours. In the case where two values are being displayed, one on top of another, the upper value is the initial measurement and the lower is the subsequent measurement.

Explanation of the abbreviations:

fth	flange thickness
fh	flange height
btb	back to back distance
ga	gauge

It is also possible to see the complete database in table form. Displayed in this template are all vehicles which have been machined. The list is sorted according to vehicle number.

For easy handling of the data base is it also possible to transfer datasets or the complete database to a different file format (for example Microsoft Excel format) and use this database then on another PC for data comparison.

Conclusion

The TANDEM underfloor wheel profiling machine incorporates, both a high degree of accuracy, and production capacity necessary to service the high speed trainset at Amtrak's Ivy City Yard.

In addition the wheel profiling machine incorporates features designed for easy operation and increased operator safety.

Key features of the TANDEM wheel profiling machine that meet the requirements for serving the high speed train including the following:

1) Productivity Requirements:
- One wheelset in 29 minutes
- Two wheelsets reprofiled simultaneously, doubling single machine productivity

2) Required Accuracy:
- Profile, tread (chamfer and taper) and flange requirments
- Diameter parity for wheels on the same axle
- Profile form accuracy
- Surface finish

3) Data storage and retrieval
- Vehicle identification information
- Storage of wheelset measurements
- Storage of machining information
- Retrieval of historic data allowing in depth analysis
- Data transfer to different file formats for data comparison reasons

4) Safety consideration:
- Detailed operator step by step guidance
- Milling technologies benefits
- Operator ergonomics

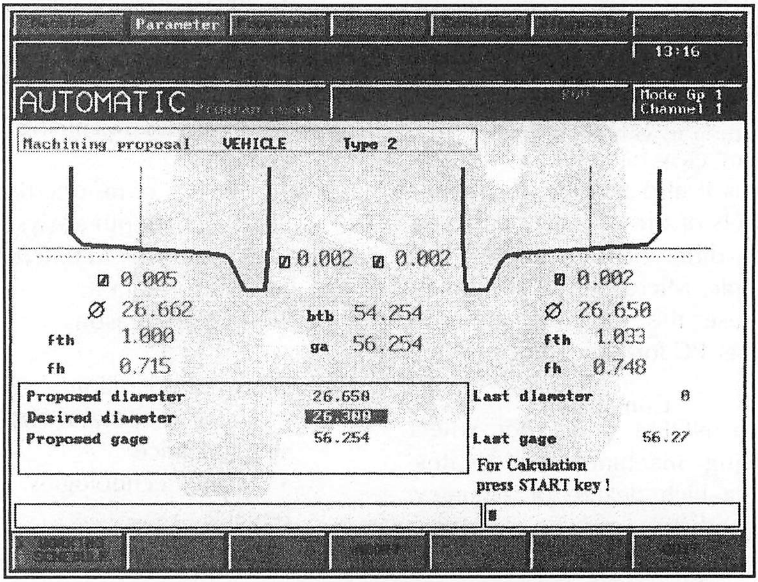


Figure 1:
Machining proposal screen in the automatic operator guidance

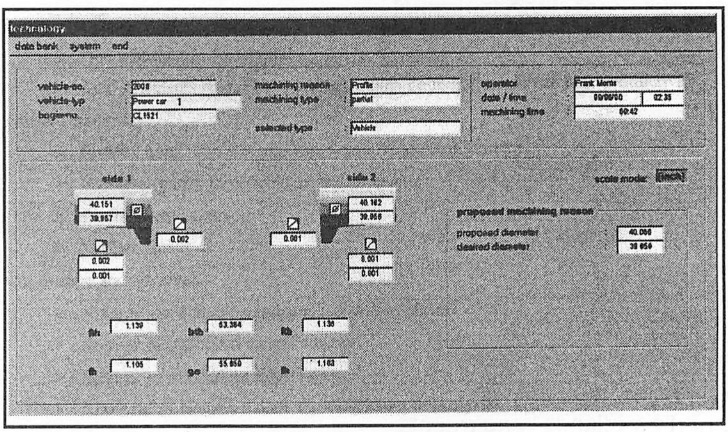


Figure 3:
Technology template from the data managemrnt software

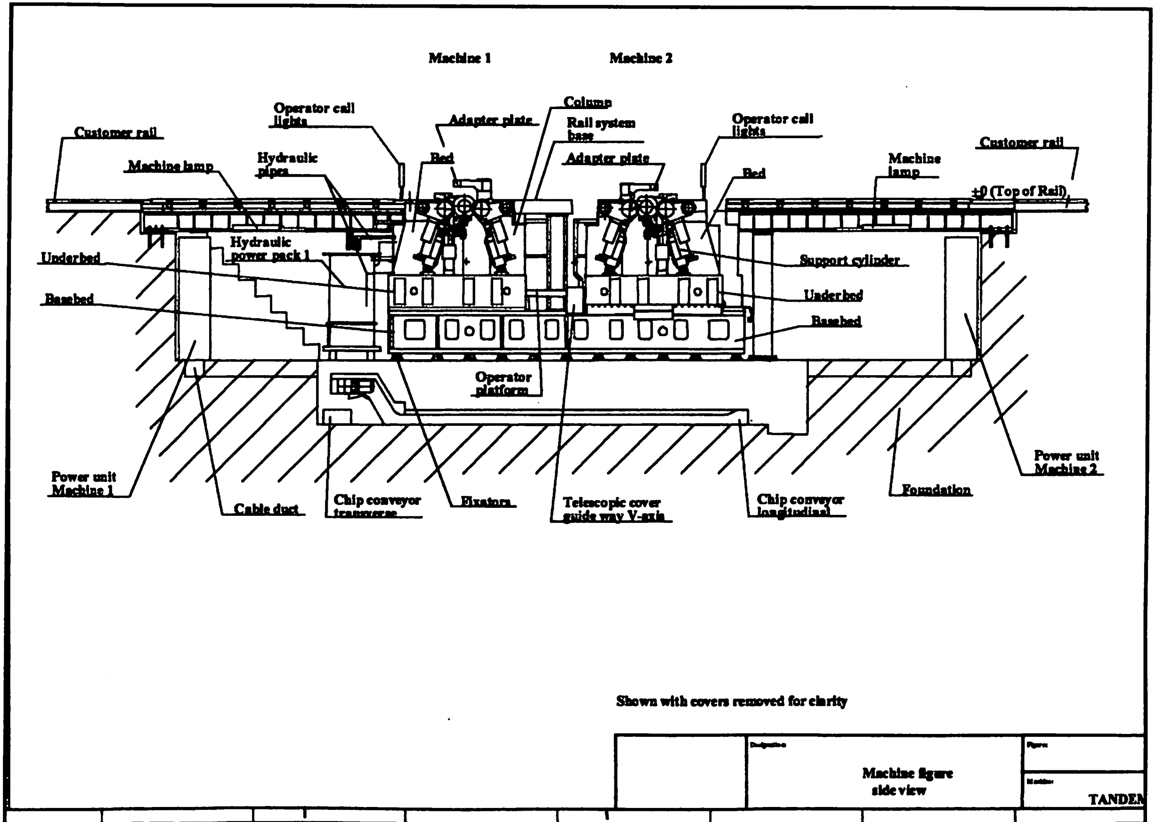


Figure 4 *Machine Side View*

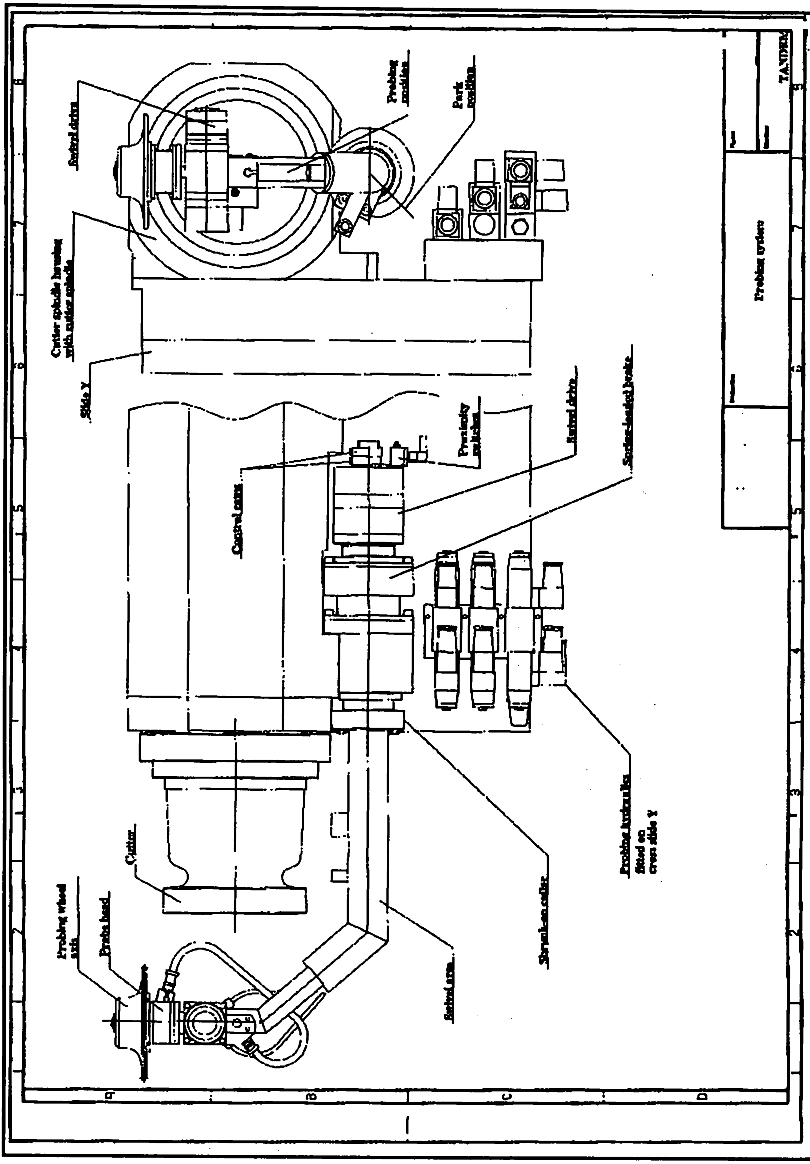


Figure 5 Probing System

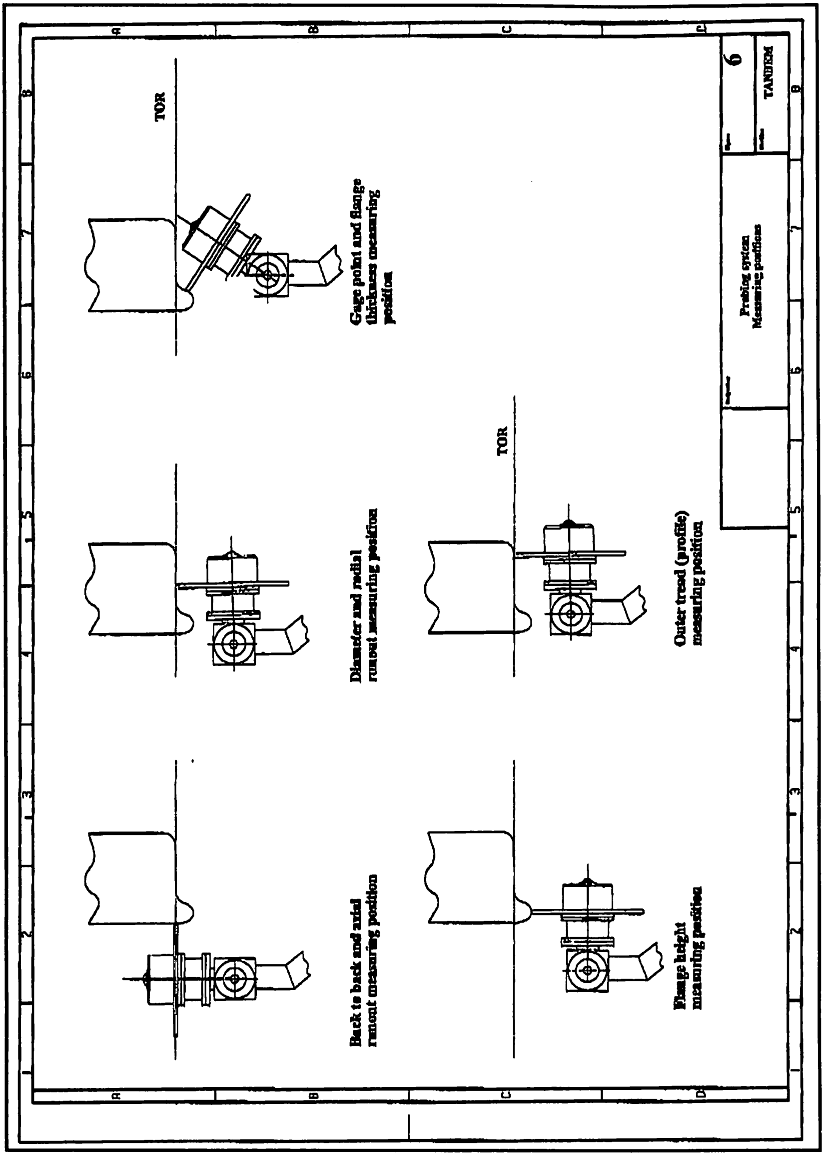


Figure 6 Probing System Measuring Positions

II. SHOP TALK 2000: FALL PROTECTION TECHNOLOGY

Presented by
John Morgano
Wisconsin Central Ltd.

Although personal fall protection is technically only required under a handful of general industry regulations, it is a good idea to set up a "Fall Protection" program and train employees to follow the guidelines. Most of the appropriate guidelines can be found in either CFR 29 Part 1910 or ANSI (American National Standards) A92.2. Rather than getting into the actual regulations and standards, we will discuss several options for providing fall protection.

Falls are dangerous because of three primary elements:

1. The free-fall distance that a worker falls. As a general rule, the free fall distance should be limited to less than four feet, to prevent injuries caused by:

- Collisions with grade level.
- Collisions with obstructions near the work site.
- High arresting forces from fall restraint devices.
- Pendulum like swings that result in a collision with objects.

2. The shock absorption at impact. Shock absorption at impact varies according to the equipment the worker is wearing. For example, falling to the end of a rope lanyard while wearing a body-belt will provide very limited shock absorbing capabilities and often results in serious injuries to the worker. However, the same worker wearing a shock absorbing lanyard and a full body harness, can substantially reduce the probability of injury, because of the increased shock absorption capability of the equipment.

3. The body weight of the worker. Body weight of the worker is the final element that makes falls dangerous. Falls by heavier workers generally result in more serious injuries than falls by smaller/lighter workers. This partially because, like the old saying goes, "The bigger they are, the harder they fall." It is also because heavier workers often have disproportionately larger waists, and fall arrest equipment may not fit them properly.

Personal fall arrest systems are designed to:

1. Prevent a worker from falling more than six feet.
2. Prevent a worker from contacting any lower level during the arrest of a fall.
3. Limit the arresting force on an employees' body to 900 lb. when wearing a body belt.
4. Limit the arresting force on an employee's body to 1800 lb. when wearing a body harness.
5. Bring the worker to a complete stop and limit the deceleration distance to three feet six inches.

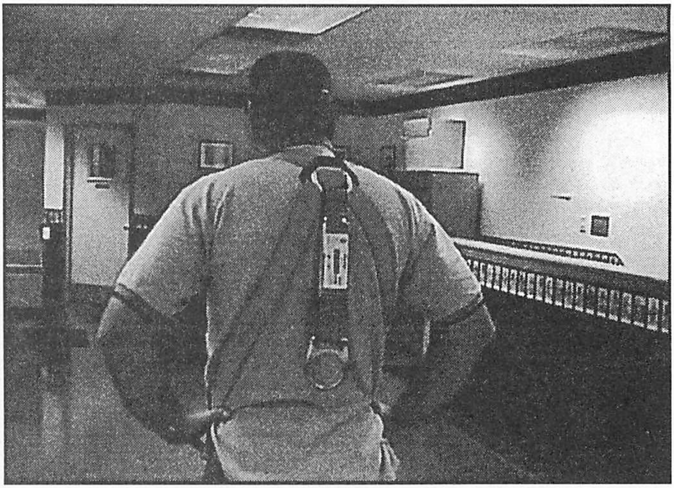


FIG. 1

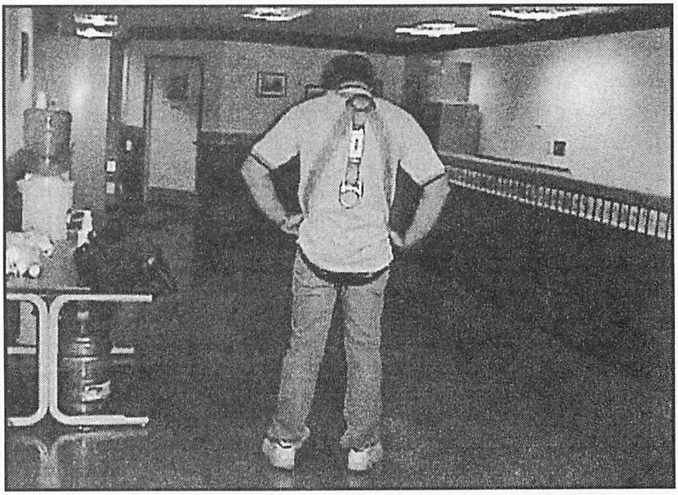


FIG. 2

A body harness with a shock absorbing deceleration device.

Obviously, the best way to eliminate injuries due to falls is to reduce the possibility of falling in the first place. There are several approaches to eliminating falls; we will show several different devices.

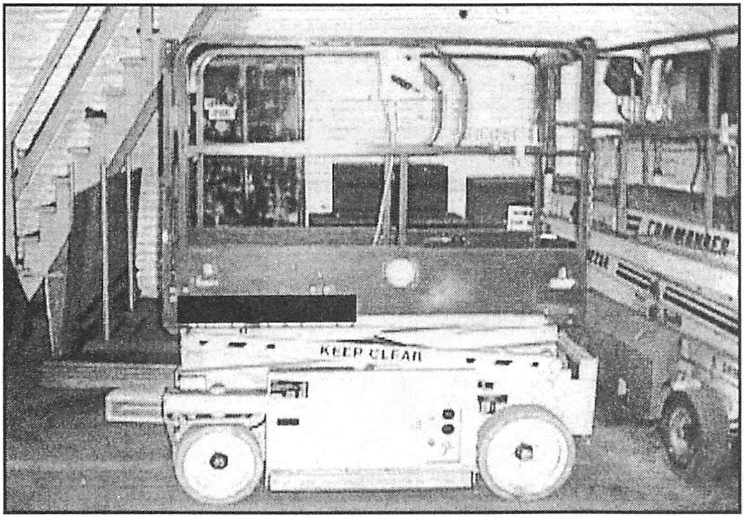


Figure 3: An electric scissors lift.

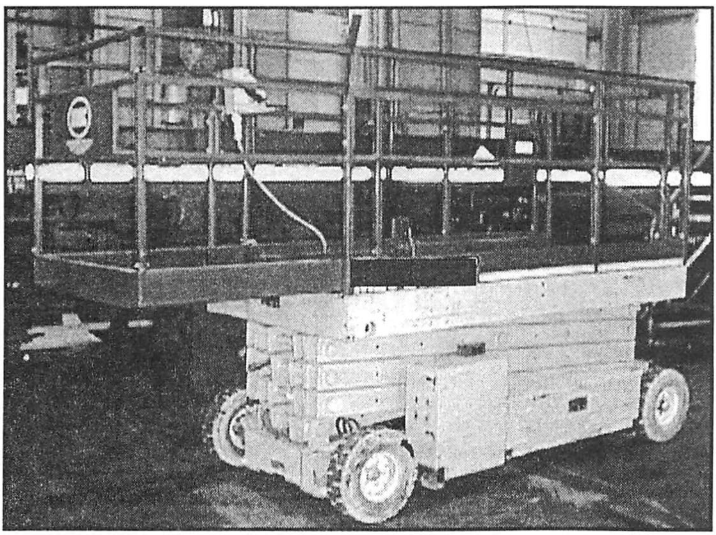


Figure 4: An electric lift with a "gangplank."

One of the most common devices to use is an electric scissors lift. (Fig. 3) These lifts are able to move on hard, level surfaces and provide an elevated work platform. They work very well indoors and can be useful when working on things like overhead cranes, lighting, etc. They provide limited workspace and work best when positioned directly below or next to the piece of equipment you are working on. Some of these devices will have a "gangplank" that can be extended out the front end. This makes them more versatile because they can be extended out over obstructions. A common use for a lift with a "gangplank" would be to position it perpendicular to a locomotive and extend the "gangplank" over the running board. This may be done when working on dynamic brake grids or radiator shutters. These devices require no outriggers and can be re-positioned while raised.

Extensible and articulated boom platforms and buckets are another option. (Fig. 5) These devices are designed for use on hard level indoor surfaces or outdoor surfaces. They may be electrically powered or may have a small engine. They may be mounted on trailers or self-propelled. They are especially good for working on overhead equipment that is obstructed from below. In many cases the worker must extend outriggers to stabilize the device before raising it. This may limit the working range because the device cannot be moved while it is raised. A worker will have to lower the device, raise the outriggers, reposition the lift, lower the outriggers and then raise the lift back up.

These devices work well for working on buildings, overhead electrical lines, and other areas where a scissors lift can't get directly underneath or go high enough.

Another option is a custom built device for a very specific application (Fig. 6). These devices are generally engineered "in-house" for a special need.

The last device we will discuss is a powered lift with a rotating platform on top. These devices are available as platform mounted, trailer mounted, truck mounted, electrically powered or diesel powered. They can be used indoors or outdoors on various types of terrain. Figure 7 shows a truck mounted lift. This is shown with a barrier wall attached. These can be very useful in trainyard applications. This truck mounted device needs no outriggers and can be positioned rapidly. The worker attaches his personal fall arrest device to the wall and performs the required work. We have found this to very useful when doing roof inspections and stack cleaning. Figure 8 shows a self-propelled lift equipped with an expandable cage. After positioning the device where it is needed, the worker expands the cage size to the size he needs.

While inside the cage the worker does not have to attach himself and can move freely about the enclosure. We have found this to be particularly useful in the crane bays, where conventional tether style systems won't work because of the need to keep clear space for the crane to pass through. The enclosure is large enough to permit components like cooling fans and Dynamic Brake fans to pass through, while still providing fall protection for the worker. Figure 9 is a self-propelled unit with a barrier wall attached. When in the collapsed position these units can fit through most doorways and aisles, and can climb most of the grades found in a repair facility. Figure 10 is a stationary lift. A unit like this will typically be positioned near a sand tower and can be used to raise a worker up between locomotives to fill sand boxes. Figure 11 is a trailer mounted lift. Lifts like this are good for working at remote locations.

Prices for the mentioned devices range from a few thousand dollars to upwards of $75,000.

In summary, no matter what the particular circumstances are, there is a fall protection device out there that can address your needs. We can no longer use the excuse "There is no way to provide protection and still be productive." With the devices that are available, we have no excuse for allowing workers to work unprotected. It is up to us to make these devices available to our employees.

Figure 5:
A powered extensible boom lift.

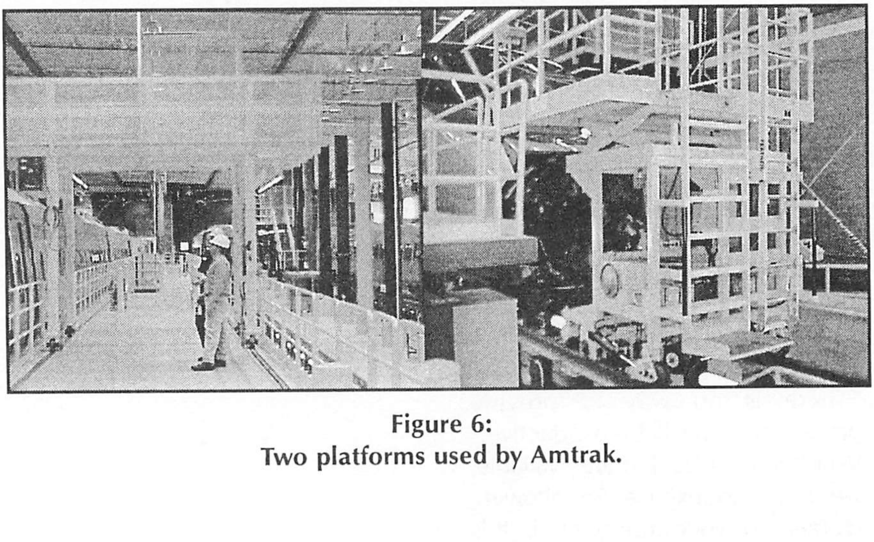


Figure 6:
Two platforms used by Amtrak.

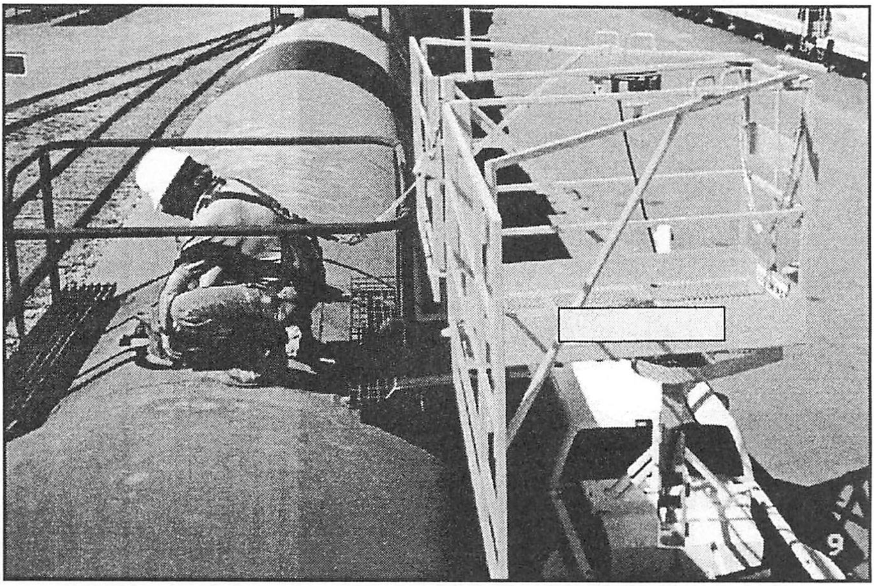


Figure 7:
A truck mounted barrier wall.

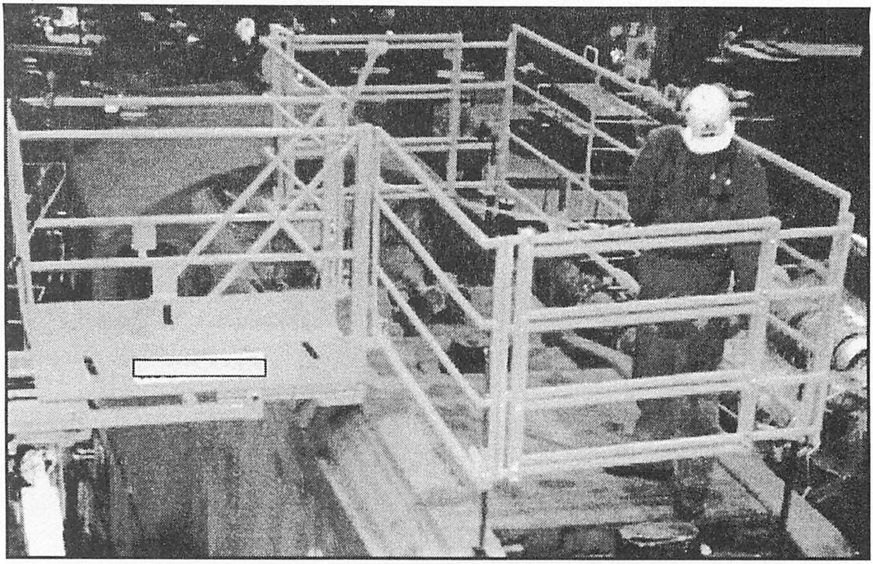


Figure 8:
A self-propelled expandable cage opened.

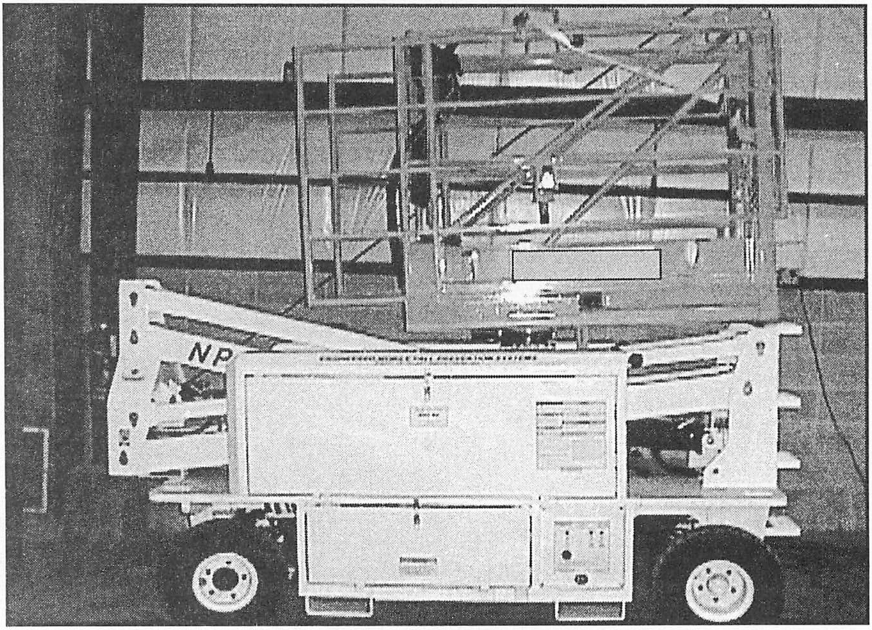


Figure 9:
A self-propelled unit with a barrier wall.

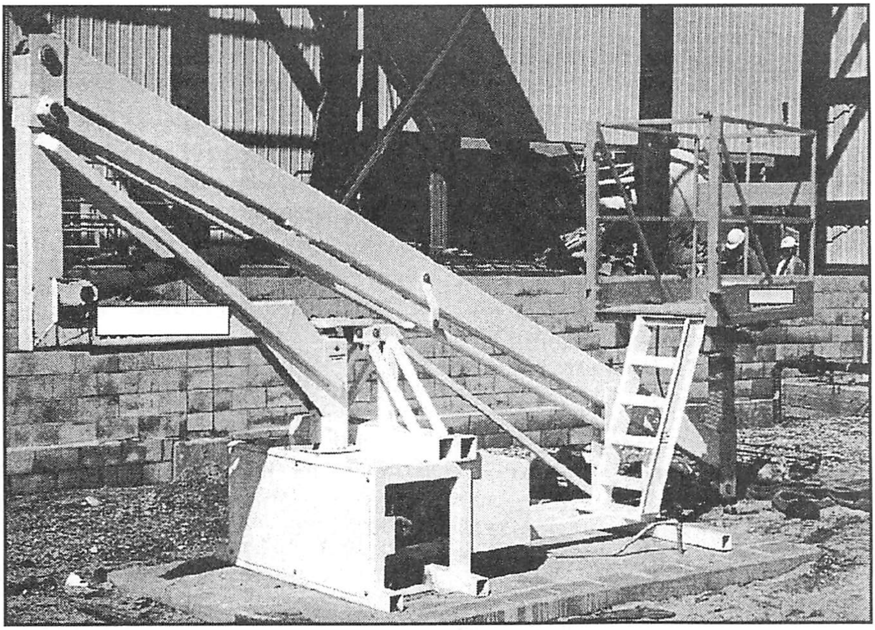


Figure 10:
A platform mounted lift.

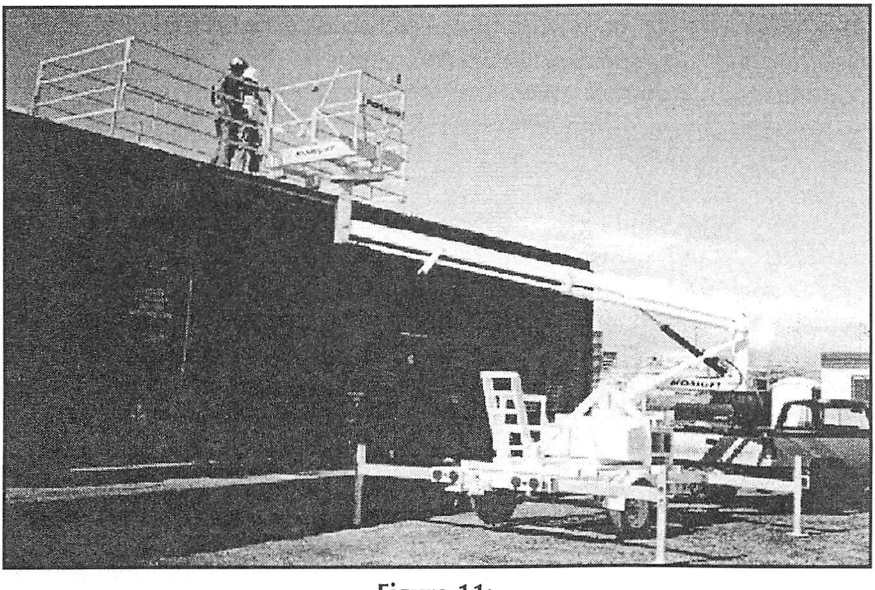


Figure 11:
A trailer mounted lift with cage.

III. SANDING IN THE RAILROAD INDUSTRY

Prepared by
Leonard Buczkowske
Florida East Coast Rwy.
and
Jack Morin, NEU, Inc.

Hundreds of tons of sand are used on a daily basis in the railroad industry. If it were not stored in a compact, dry place with an efficient system to deliver to the locomotive sand boxes, it would not serve its intended purpose.

Uses

On board locomotives, sanding has a very important function. It is used in all types of rail services, from tramway or street cars (in the maintenance and cleaning depots) to passenger cars or Class 1 railroads (in the locomotive maintenance shops during fuel stops or technical checks) to the most modern high speed train operation.

Why Sanding?

First, sanding is a federal regulation and railroads have to comply. More importantly it is a safety issue related to braking and adhesion (wheel to rail).

Four main techniques are used to feed sand to the locomotives.

- Manually (bags)
- Gravity
- Mix: Pressure/Gravity
- Fully automated pneumatic conveying systems.

The systems listed above even include the old fashion way of throwing sand by hand on the rail. This was probably the first way of sanding, classified as manual.

Manual is still used today along with the other three techniques (Figures 1 and 2). This is not a very cost effective method. The price of sand in bags is up to seven times more than the price of sand delivered in bulk. Above all, it does not lend itself to a very safe working condition.

Under the gravity system, the sand is directly delivered from the trucking company to hoppers located above the railroad tracks. The gravity system, if not watched while filling, will cause over-filling and waste (Figures 3 and 4).

Mix Pressure Gravity Systems

Commonly called "the sand tower", this type of system will first move the sand from a main storage silo to hoppers located at a sufficient height in order to gravity feed the locomotive sand boxes (Figures 5, 6 and 7).

Fully Automated Systems

Figures 8, 9 and 10 illustrate what is available on the market today. This process of sanding was developed in order to simplify the sanding operation. You can now sand your locomotive in exactly the same way as you fill your car with gas. This is more or less the sand station concept. The sand is distributed from a main sand storage silo via a distribution tank to several sand pumps located near the locomotive. The operator will simply pick up the sand nozzle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from the pump and the automated system will do the rest. It will start and stop automatically and fill locomotive sand boxes in a dust free environment.

Conclusion

In today's world, it is not acceptable to have labor exposed to unsafe working conditions, using outdated systems when technologies have evolved and will deliver reliable solutions to the railroads. Sanding is no exception and we have seen developments in the last decade that are answers to most of the problems that railroads face when sanding their locomotives.

Railroads need to learn how to specify sanding systems equipment that address the most common drawbacks in this every-day task. Factors to consider are listed below:

- Humidity or moisture
- Abrasion, piping or equipment
- Dust emission
- Sand spillage
- Unfriendly labor interface with the system (heavy bags or nozzle to manipulate).

If a railroad selects the bucket, bag or wheel barrel and shovel method in order to save capital money, it is not doing itself a big favor. On the contrary, it will ultimately spend a great deal of effort, time, unnecessary work and money on this basic but essential aspect of its daily operation.

There are currently available on the market state of the art systems, with sufficient competition between various vendors to keep them affordable. Modern systems, in the long run, will save a lot of aggravation, a great deal of our operating and maintenance costs, and,more importantly will provide a much safer work environment for the labor force.

This presentation was general in nature. The committee expects to go into more detail next year on how to specify a good sanding system, with additional technical research and information.

MANUAL

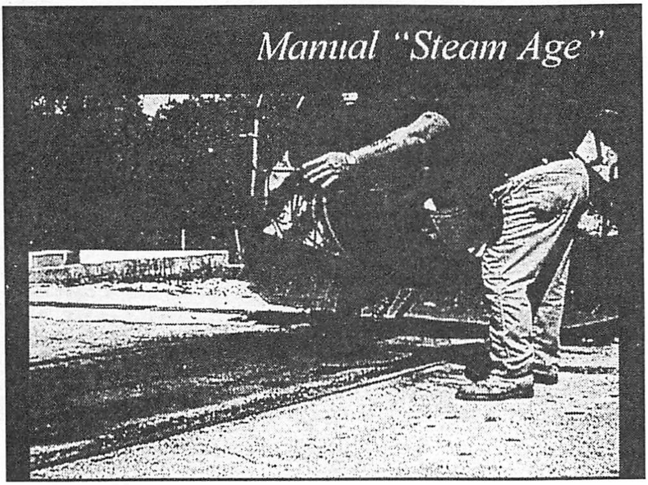

FIG. 1

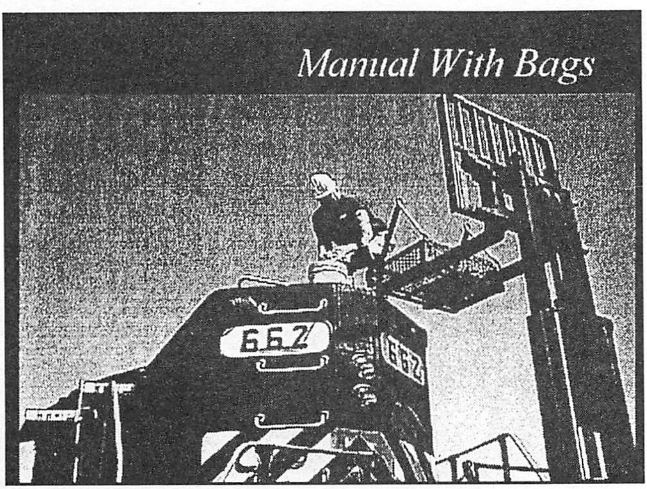

FIG. 2

GRAVITY SYSTEM

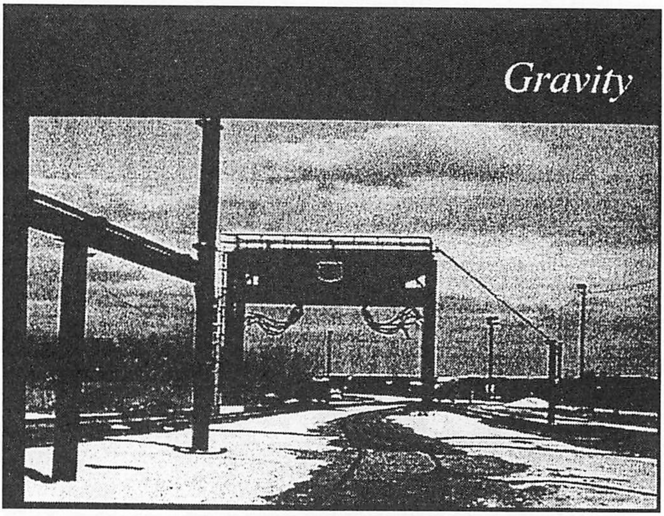

FIG. 3

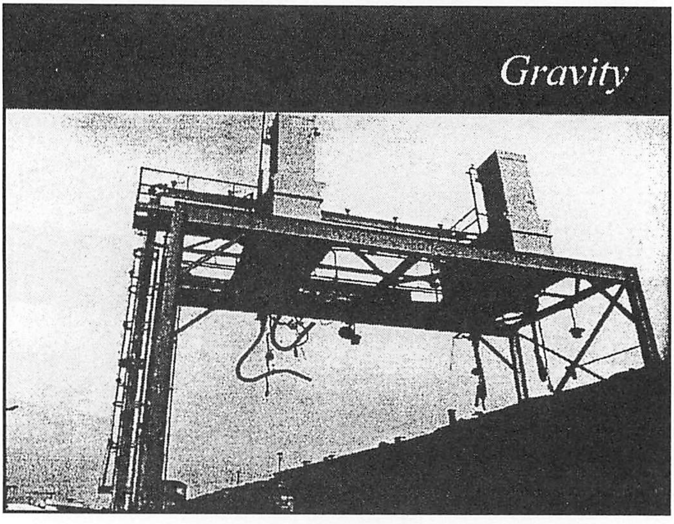

FIG. 4

MIX PRESSURE / GRAVITY SYSTEMS

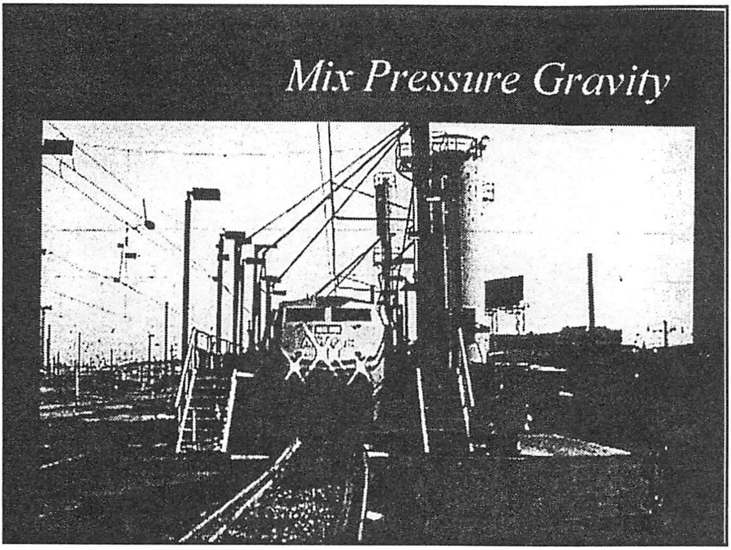

FIG. 5

FIG. 6

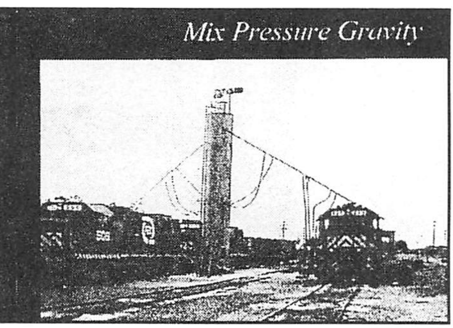

FIG. 7

FULL-AUTOMATED SYSTEM

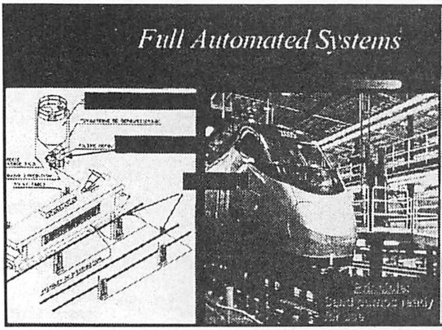

FIG. 8

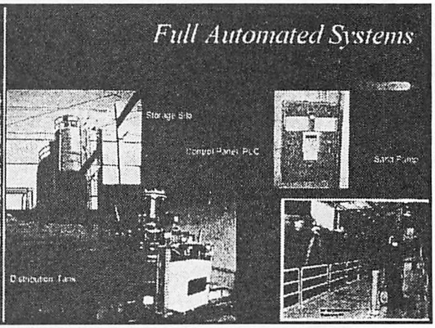

FIG. 9

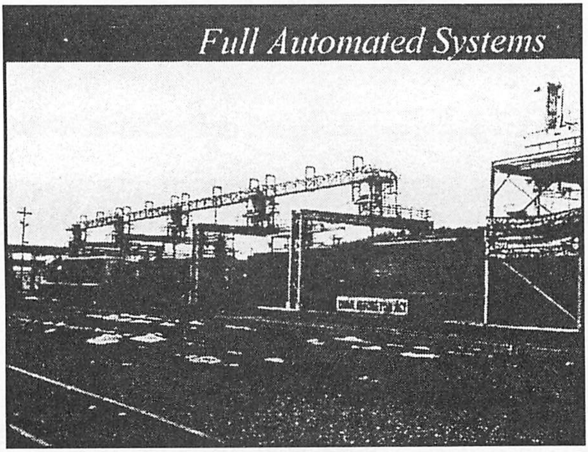

FIG. 10

REPORT OF THE COMMITTEE ON FUEL, LUBE AND ENVIRONMENTAL

MONDAY, SEPTEMBER 18, 2000 3:45 P.M.

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Topeka, KS

Vice Chairman
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K. Wazney	Chemist/Testing Specialist	Canadian Pacific Rwy	Winnepeg, MB
P. Whallon	Manager-Eastern Region	Clark Filter	Lancaster, PA

Note: Guest Speakers: Patrick Kilbane-Predict DLI, Dr. S. Kumar-Tranergy Co. and G. Sedelmeier-Equilon Enterprises

PERSONAL HISTORY

Glenn W. Bowen

Glenn W. Bowen was born in Quincy, Illinois on November 22, 1951. After his high school education he studied at Millikin University in Decatur, Illinois, where he received a Bachelor of Science degree in Chemistry in 1973. This was followed with a Master of Science degree in Organic Chemistry at Xavier University in Cincinnati in 1975.

He began his railroad career as a pipefitter helper/machinist with the Rock Island railroad while attending college. He was hired by Santa Fe railroad as a trackman in September of 1975 and transferred to Topeka as a chemist in the Technical Research & Development department in January of 1976. Glenn has spent his entire career with the Santa Fe (and now, Burlington Northern and Santa Fe) in the Technical Research & Development department in varying positions, including engineer special projects and laboratory manager. His present position is Directory of Laboratory Services where he is in charge of operations of the BNSF chemistry and physical test laboratories.

Glenn's hobbies include boating, fishing and yard work. Glenn and his wife Barb live in Topeka, Ks.

I. BIODEGRADABILITY AND ITS REVELANCE TO RAILROAD LUBRICANTS AND FLUIDS

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and
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The railroad industry uses lubricants and fluids as locomotive engine oils to protect against wear and corrosion, to control sludge and deposits, and as lubricating fluids that reduce friction between surfaces of heavy components. Since these substances are not completely consumed during use and are not completely recycled, there is a concern about their fate in the environment.

In this paper we will be discussing the environmental relevance of biodegradability testing and the different types of biodegradability testing available to evaluate railroad lubricants and fluids. We will also introduce the concept of life cycle assessment as the framework to improve the environmental performance of these substances.

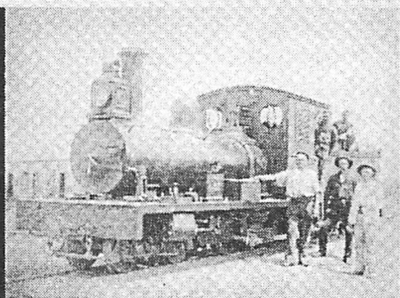
The Natural Removal Processes

Biodegradation *is the process of chemical breakdown of an organic substance by microorganisms.* It is the key environmental fate process for risk assessments and hazard classification of materials because it is one of the primary processes by which these substances are removed from the environment[1]. However, it is not the sole process for determining their environmental fate because non-biological(***abiotic***) degradation processes may also be major routes of removal (see Figure 1). Abiotic degradation can occur in any medium (air, water, or soil) depending on the reactivity of the chemical substance and the presence of factors capable of inducing chemical change and breakdown[1].

Sunlight acts as an inexhaustible source of energy having the power to destroy chemicals so ***photodegradation*** *(degradation of a chemical by ultraviolet light)* must be considered as a substantial route for elimination of railroad lubricants and fluids released into the environment[1]. However, the most important degradation pathways for chemicals released into water and soil environments are ***hydrolysis*** *(the degradation of a chemical by reaction with water)* and biodegradation[2,3]. In these environments even slow hydrolysis or biodegradation is likely to be more important than photo-degradation because of limited exposure to full sunlight.

The Perceived Benefits of Biodegradable Substances

Regulators and the public believe substances that are found to be readily degradable in standard biodegradability tests will also be rapidly degraded in all natural environments[1,2,3]. It is thought these substances will not occur at high enough concentrations in the environment



to cause adverse health effects to human, or toxicity to fish and wildlife. There is also a general belief that biodegradable substances won't be absorbed and ***bioaccumulated*** *(concentrated)* in organisms which could contaminate the food chain to levels that are hazardous to humans[1,2,3].

Resistance to biodegradation has been a major factor in categorizing a broad class of compounds referred to as ***persistent organic pollutants*** or ***POPS***[3,4]. POPS are also called persistent, bioaccumulative and toxic (PBT) chemicals by the United States Environmental Protection Agency (EPA)[3]. POPS are currently receiving considerable attention in a number of international organizations including the Convention on Longrange Trans-boundary Air Pollution and Global Program of Action on Land-based Marine Pollution under the United Nations Environmental Program and the U.S. - Canada International Joint Commission[3,4]. The POPS receiving the most attention are halogenated compounds *(chemicals containing chlorine, bromine, fluorine, or iodine)*[3,4]. These chemicals are considered important due to their low molecular weight, low water solubility and high fat solubility. These characteristics enable them to migrate and accumulate in fatty tissues of animals at the highest level in the food chain and cause human health concerns as shown in Figure 2.

Railroad Lubricants and Fluids Differ from Classic POPS

Railroad lubricants and fluids share some characteristics with POPS like having low water solubility (usually below 1 mg/L) and a potential to be highly soluble in fats. This makes them tend to separate from water and cling to solids where they are not easily accessible to microorganisms. The result is a reduced rate of biodegradation.

But, railroad lubricants and fluids do NOT share the same potential for ecotoxicity, or food chain accumulation, or cause long-term effects to human health. POPS chemicals have characteristics that warrant concern, as shown in Figure 3. POPS generally have smaller molecular size, and are highly mobile and reactive chemicals that easily disperse in the environment and pass through cell membranes into organisms, where they tend to cause toxicity or accumulate in the food chain to levels high enough to cause concern for human health.[1,2,3]

Railroad lubricants and fluids, in contrast, do not have these characteristics. They are relatively stable complex chemical mixtures having high molecular size, high viscosity, and limited mobility if released into the environment[5]. Consequently, they cause little, or no, adverse affects to human health or ecotoxicity due to limited bioavailability to organisms; i.e., they poorly disperse in the environment and are generally not accumulated by organisms[5].

Railroad Lubricant and Fluid Categories and Characteristics

Table 1 lists seven categories of railroad lubricants and fluids with typical component composition. Note that mineral base oil is the major organic component in six of the product categories with levels ranging from 70 to 99% (percent by volume). Consequently, the biodegradability of these fluids is really contingent on the extent of the biodegradability of the mineral base oil.

Coolants are an exception because they contain mostly water and ***inorganic components*** *(chemical salts containing NO carbon)* so they would not be expected to be biodegradable like organic components. However, the borate and nitrate salts in coolants can be highly mobile if they are released into the environment in substantial amounts and could be a cause for concern to drinking water resources and surface water quality.

The Different Types of Biodegradability Tests

Biodegradation is a series of microbial-mediated processes that often involve many kinds of microorganisms acting in concert to degrade both the initial substance and by-products until all of the carbon in the substance is converted into carbon dioxide, or microbial biomass (bug bones). Table 2 provides a simplified diagram of the biodegradation process and shows the common tests used to measure a substance's biodegradability. Note that some tests are more appropriate because they directly measure the process's final output or ***ultimate degradation*** *(carbon dioxide evolution)*[6]. Other tests are less appropriate because they only measure the loss of process inputs such as ***primary biodegradation*** *(the loss of initial chemical substance)* or oxygen consumption[6,7]. ***Ultimate biode-gradation*** is also called ***mineralization*** *(when a substance is completely utilized by microorganisms resulting in the production of carbon dioxide, water, mineral salts and microbial biomass)*[1,6]. Therefore, the ultimate biodegradability test is the preferred method for assessing biodegradability of organic chemicals because it provides conclusive evidence that carbon molecules in the substance are being converted into carbon dioxide.

Several standard test methods exist for measuring the biodegradability of substances, but many of the methods were originally developed for water-soluble materials that are easy to test (like household detergents) rather than poorly water-soluble materials like railroad lubricants and fluids which consist mainly of mineral oil[1,8,9]. Biodegradability of mineral oil is enhanced if it is exposed to a diversified and acclimated microbial population (as measured by higher cell numbers per mL or grams of media) where nutrient (mainly nitrogen and phosphorus) levels and oxygen are adequately maintained at levels high enough to drive the process [8,10]. Yet many of the standard biodegradability tests limit one or more of the requirements that are necessary for carrying out the process. Table 3 lists the test conditions of each standard test method while Table 4 ranks the test methods based on their ability to demonstrate biodegradability of petroleum based oil products like railroad lubricants and fluids under optimal conditions.

It is also important to understand that there are two approaches to conducting biodgradability tests. They differ in the favorability of the test system conditions towards promoting biodegradability. **Ready biodegradability tests** measure the extent of degradation using test conditions that are relatively unfavorable for biodegradation[1,6]:

- low numbers of microorganisms in the test media (10^4 to 10^6 cells/mL),
- a low ratio between micobes and test substance before the test begins,
- NO acclimation of microbes to test substances before test begins,
- sparing addition of nutrients (just sufficient for microbe growth during the test) and
- short test period (21 to 28 days).

The term **"readily degradable"** is applied to substances that are degraded significantly in a ready biodegradability test[1,2,6].

Inherent biodegradability tests measure the extent a substance degrades under favorable test conditions[8,9]:

- the presence of a high biomass (10^6 to 10^8 cells/mL),
- a higher concentration of test substance (20 to 100 mg/L),
- acclimation of the microorganisms to test substance,
- higher nutrient levels and,
- longer test period (> 1 month) to provide a time for microbes to adapt to the substance.

The term ***"inherently degradable"*** is applied to substances that are biodegraded under favorable test conditions[8,9,11]. In these tests substances must be broken down (primary degradation) by over 70 % as measured by loss of test substance, or over 20% as measured by CO2 evolution (ultimate degradation) in 28 days[8,9]. Substances that are degraded less than 20% as measured by primary degradation methods are considered to be ***poorly degradable*** and may be referred to as ***persistent***[8,9].

Biodegradability of Mineral Base Oils

Mineral base oils have demonstrated a potential to degrade in a number of biodegradability tests. In comparative studies between two **ready biodegradability test** methods, the CEC L-33A-93 method (a **primary biodegradability test)** and OECD 301B Modified Sturm test (an **ultimate biodegradability test)**, from 30 to 100% primary degradation and 15 to 30 % ultimate degradation has been reported, respectively[12].

These findings suggest mineral oils may only partially degrade into by-products that resist further degradation. However, in recent ***inherent biodegradability tests*** where microorganisms were allowed to acclimate to mineral oil for 14 days before the test began and the test media was adequately fortified with nutrients, mineral oil achieved an average 50% ultimate biodegradation (+/-12.2%, n=10)[8]. Therefore, the ***inherent biodegradability test*** provides a more accurate prediction of the extent of biodegradability of mineral oils under "real world" conditions although the process is slower than for ***rapidly biodegradable*** substances. It follows that products like railroad fluids that contain 70 to 99 v-% mineral oil would also be ***inherently biodegradable*** to a similar extent. Various physical and chemical properties of oil, such as increased viscosity and increases in average molecular weight and side chain branching of oil hydrocarbons, can reduce the rate at which the oil will biodegrade[3,13].

Currently, EPA does not have any strict criteria for organic chemicals based on biodegradability, but they will most likely consider the European Union' Organization for Economic Co-operation and Development (OECD) criteria compatible with EPA recommended criteria. This is because the United States endorsed the development of a standardized global system (i.e., Global Harmonized System) for classification and labeling of hazardous chemicals at the 1992 United Nations Conference on Environment and Development and OECD. (For more information go to *www.epa.gov/-internet/oppts/*.)

Biodegradability in Relation to Substance Environmental Safety

Some regulatory agencies and consumers have expressed concern that slowly degradable substances may cause long-term harm in the environment because of their ***persistence***. But, a substance's persistence is only one indicator of its fate and does not provide information on its potential to affect human health or the environment. It has yet to be determined if rapidly or slowly degraded substances are really more environmentally desirable. Release of large quantities of rapidly degradable substances may deplete the available dissolved oxygen in waterways in the immediate environment and thereby indirectly affect organisms through suffocation (i.e., fish kills)[14,15]. Or they may be rapidly transformed into substances like the ethoxylate by-products of surfactants that may be considerably more toxic to aquatic organisms than the initial substance released into the environment[16].

There is a clear need for continued efforts to develop more relevant biodegradation tests that assess the biodegradability of lubricants under realistic environmental conditions. There is also a need to develop better techniques for interpreting the data from these tests to provide meaningful assessments of environmental fate and effects of the specific lubricants and fluids that are used in railroad operations. Railroads need to be aware of the available test methods and their applicability to testing railroad fluids, while understanding the test's merits and limitations in assessing overall environmental hazard. These needs will require the continued collaborative efforts by scientists in academia, industry, and the regulatory agencies.

Biodegradability is closely linked to chemical structure just as product performance and economics are highly dependent on the components used. The way to design more biodegradable chemicals is to incorporate molecular features, like ester linkages and hydroxyl groups found in vegetable oils and surfactants, to make the chemicals easily destroyed[3]. But, this may not always be desirable because it also may have an adverse effect on the products' performance or economics. Consequently, the task of producing rapidly biodegradable products can be a very difficult one. It also indicates that chemical design is a multidisciplinary process where product use and ***life cycle assessments*** are the most practical method for decision making.

Using Life Cycle Assessments to Improve Environmental Performance

Life-cycle assessment (LCA) *includes an evaluation of the entire life cycle of a product, process, activity or energy. It includes extracting and processing raw materials; manufacturing, transportation and distribution; use/re-use/maintenance; recycling; and final disposal*[17]. The LCA evaluation scheme is summarized in the diagram in Figure 4[17]. It is often called a "cradle-to-grave" evaluation.

LCA is still a relatively new concept that has been only used in the United States for evaluating consumer products like disposal diapers, Styrofoam containers and plastics[3,4]. EPA has yet to recommend its use in evaluating industrial products like railroad fluids; however, LCA guidelines are currently being developed to evaluate all kinds of products for the European Union. So, just as the U.S. has adopted European Union methods for assessing biodegradability, the EPA could

also adopt European LCA guidelines. If this occurs, LCA may provide a useful tool for assessing net energy and raw material requirements and the environmental benefits of substances like railroad lubricants and fluids, and there may be some surprises.

For example, an LCA of vegetable based oils may show that the consumption of energy, fertilizers, and pesticides needed for cultivation and harvesting plants coupled with the associated production of air, water borne, and solid waste pollution may have a more adverse effect on the environment than a similar LCA for petroleum based oils. Consequently, the perceived benefits of a ***rapidly biodegradable*** vegetable base lubricants, are overcome when compared to a mineral based lubricant that is proven to be ***inherently biodegradable***.

It is easy to see the need to consider biodegradability for high volume consumer products, but it may not be as much an issue for the manufacture and use of many kinds of railroad lubricants and fluids that are not intentionally released into the environment. Assessing the need for a ***rapidly biodegradable*** product is often the balancing process that may demand compromises in function, or efficiency of product use. The desirability of integrating environmental considerations into business decisions and designing products to minimize their environmental impact is nothing new and has been acknowledged in the Chemical Manufacturers Association's Responsible Care program. (For more information go to *www.cmahq.com*)

Most railroad lubricants and fluids can be used without concern for environmental harm because they are used under conditions where they are retained within equipment until they are changed or consumed. If railroads have re-use and re-cycling programs in place there should be little or no environmental effects. Therefore, only under accidental releases should there be a concern for the release of mineral base oil substances into the environment.

Under these circumstances, remediation of soil residues of ***inherently biodegradable*** base oils is possible through processes that enhance biodegradation like soil aeration and addition of nutrients (mainly nitrogen and phosphorus)[10,18]. These activities can be used on an as needed basis to reduce soil hydrocarbon residue to acceptable levels.

Biodegradability appears to be of greatest concern for rail wheel lubes and greases which are intentionally released into the environment. But, if these substances are released at low levels over miles of track the oil residues would not be expected to be found at harmful levels in the railroad right-of-way, nor would they be expected to migrate and be detected in environments adjacent to the railroad right-of-way.

Conclusion

Rapid biodegradation is NOT always synonymous with low environmental hazard. The potential for railroad lubricants and fluids to biodegrade in itself does not always ensure a trend towards a corresponding decrease in environmental hazard. This is because some oil contaminants like sequestered heavy metals accumulated during usage (i.e., used engine crankcase oil), can become more bioavailable and hence show toxicity when released back into the environment. Also, heavier oil residues (i.e., larger molecular weight hydrocarbons C20 and above) are more resistant to biodegradation due to their low bioavailability (i.e., they are too large to pass through an organism's cell membranes)[5]. But, the same low bioavailability also means they will have a low toxicity to organisms.

The combination of chemical's ***persistence*** *(the length of time a chemical can exist in the environment before being destroyed by natural processes)*, bioaccumulation potential, and toxicity along with factors associated with its production, use asd disposal determines the environmental risk associated with that chemical. Therefore, substances like railroad lubricants and fluids can have low environmental risk even if one of the *"**PBT**"* elements *(persistence, bioaccumulation, toxicity)* are high; i.e., high persistence paired with low toxicity. Also, the railroad lubricant and fluid production, use, and disposal practices may be such that releases to the environment are minimal. Hence, there could be low environmental risk in using these substances.

In closing, we believe the following questions should be carefully considered regarding the use of product life-cycle analysis for railroad lubricants and fluids:

1. Is there a responsible care program in place for the safe handling and proper disposal (recycling if possible) of lubricants and fluids?

2. Has raw material usage been reduced by using products with greater in-use longevity?

3. Is product biogradability a major issue relative to the use of a specific substance?

4. What are the net environmental benefits to the railroad for using rapidly versus inherently biodegradable lubricants and fluids?

Acknowledgements

Gary Rausina, the principal author of this paper, unexpectedly passed away in April of this year prior to the the paper's publication and presentation. It was Gary's dedicated effort and desire to make this complex topic understandable that made our paper possible. Thank you Gary.

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Figure 1: Natural Environmental Removal Processes for Substances

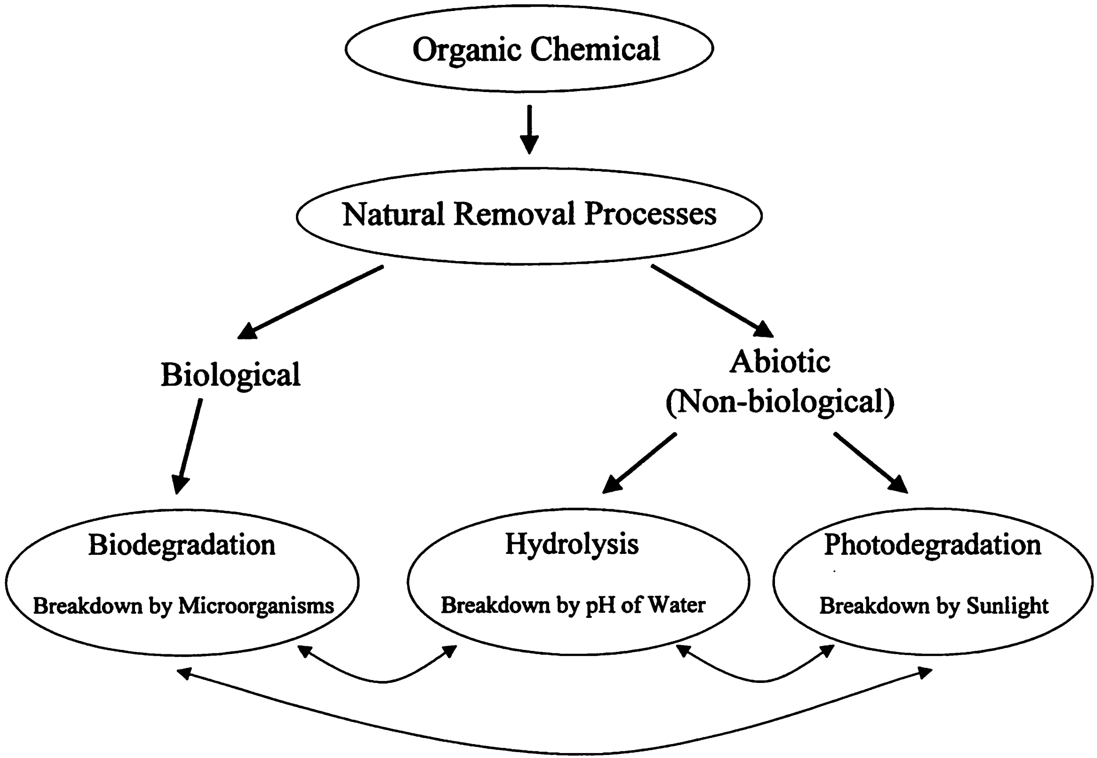


Figure 2: Railroad Lubricants and Fluids Differ from Classic POPS

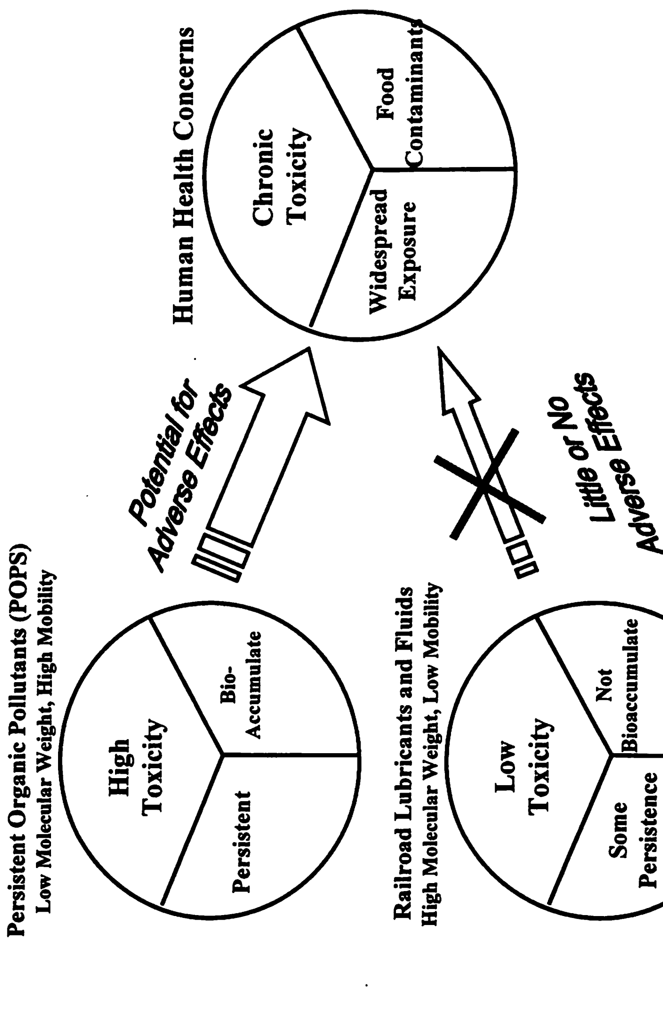


Figure 3: Environmental Impact Data for RR Lubricants and Fluids Relative to Classic Persistent Organic Pollutants

POPS (also called PBT chemicals) Are:

- Highly Toxic; Wildlife LD_{50} < 50 mg/kg, Aquatic Life LC_{50} < 1.0 mg/L
- Highly Bioaccumulative; BCF > 1000
- Highly Persistent; ½ Life > 1 Year

Mineral Oil based RR Lubricants and Fluids:

- Have Low toxicity; Wildlife LD_{50} > 5000 mg/kg, Aquatic Life LC50 > 1000 mg/L
- Do Not Bioaccumulate; BCF < 10
- Have Some Persistence; ½ Life < 2-3 Months

Notes:

LC_{50}/LD_{50} – The concentration of chemical diluted in water (LC_{50}) or per animal body weight (LD_{50}) that would be lethal to 50% of the test organisms exposed to it. The greater the LC_{50}/LD_{50} the lower the toxicity.

BCF – Bioconcentration factor; a value that describes the degree to which a chemical can be concentrated in the tissues of an organism when it takes it up from water directly or through food.

1/2 Life – The time required to reduce by one-half the concentration of a substance in a medium (soil or water).

Table 1: Major Lubricants and Fluids Used by Railroads

Lubricant/Fluid	Annual USA Usage[1] (Lbs.)	Typical Composition: Base Fluid	Typical Composition: Additives
Engine Oil	243,000,000	Mineral Oil ~80%	Additive Package: ~15%: Ca/Mg phenates, Ca Sulfonates Phenolic Anti-oxidants Ashless Anti-wear Inhibitors Succinimide dispersants VI Improver in Multi-grades: ~5%: Ethylene/Propylene copolymer
Air Compressor Oil	900,000	Mineral Oil ~99%	Additives ~1.0%: Hindered Phenolic Anti-oxidant ~0.1 - 0.2% Diphenyl amine Antioxidant ~ 0.1 - 0.2% Ashless Anti-oxidant/Wear inhibitor ~ 0.1 - 0.2% Acidic Rust Inhibitor ~ 0.1%
Rail & Wheel Lubes: Wheel Flange Grease Rail Wayside Grease Rail Curve Grease	2,575,000	Mineral Oil ~70 - 85%	Additives ~15 - 30%: Thickener ~10% Misc. additives ~5 – 20%
Engine Governor Oil	1,200	Similar to Compressor Oil	Similar to Compressor Oil
Traction Motor Gearcase Oil	936,000	Mineral Oil ~95 - 99%	Additives ~1 to 5%: Anti-wear/anti-oxidants Rust inhibitors
Traction Motor Gearcase Grease	418,000	Similar to Rail Grease	Similar to Rail Grease
Coolant	420,000	Water	Borates[2] and Nitrates

1 = Estimated annual usage by USA railroads.
2 = Boron residues are a concern in areas like Florida, USA.

Table 2: Test Methods for Measuring Biodegradation

PROCESS INPUTS | PROCESS OUTPUTS

C_xH_y + Microorganisms + O_2 => CO_2 + Water + Biomass

Measures of *Primary Biodegradation* | Indirect Measures of *Ultimate Biodegradation* | Direct Measure of *Ultimate Biodegradation*

OECD Screening Test	CEC Test L-33-A-93	MITI Test	Closed Bottle Test	Sturm Test & ASTM D-5864	ISO Headspace CO_2 Test	Biomass Measurements
Measures: Decrease of DOC (dissolved organic carbon)	Decrease of oil content (extraction + IR spectroscopy)	Biological O_2 demand plus Chemical analysis of oil and major degradation products (CO_2 can also be measured)	Biological O_2 demand (BOD/COD or ThOD)	Quantitative determination of CO_2 formation	Quantitative determination of CO_2 formation	Only roughly quantitative (chemical analysis of proteins, ATP, etc.). Academic applications.

Table 3: Test Conditions

Bold lettering under each category designates the most ideal conditions for demonstrating a test substance biodegradable.

Test	OECD Screening Test/ DOC Die-A-Way/ CEC	MITI / Manometric Respirometry	Closed Bottle	Sturm Test	ASTM D-5864	ISO Headspace
Test Substance Concentration:						
TS - mg/L		**100**	2 – 10		10 – **20**	**20**
DOC - mg/L	10 – 40			10 – 20		
ThOD – mg/L		50 –100	5 – 10			
Concentration of Inoculum:						
SS – mg/L	≤30	30				
Effluent – mL/L	<100					
Approx. cells/mL	$10^5 – 10^7$	**10^7 - 10^8**	10^4-10^5	10^5 - 10^7	**10^6 – 10^7**	**10^6 – 10^8**
Acclimated to TS	No	No	No	No	**Yes**	**Yes**
Concentration of Nutrients (elements) in Mineral Media (in mg/L):						
P	**116**	29	11.6	**116**	**22.5**	**110**
N	1.3	1.3	0.13	1.3	**12**	**16**
Na	**86**	17.2	8.6	**86**	**86**	54
K	**122**	36.5	12.2	**122**	**122**	**139**
Mg	2.2	6.6	2.2	2.2	2.2	2.4
Ca	9.9	29.7	9.9	9.9	10	9.9
Fe	0.05 – 0.1	0.15	0.05 – 0.1	0.05 – 0.1	0.05	**0.05**
Adequate Oxygen	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**
pH	7.4 ± 0.2	7	7.4 ± 0.2	7.4 ± 0.2	7	7.4 ± 0.2
Temperature	22 ± 2	25 ± 1	22 ± 2			

DOC = Dissolved Organic Carbon ThOD = Theoretical Oxygen Demand SS = Suspended Solids

Table 4: Ranking Test Methods for Their Ability to Demonstrate the Biodegradability of Organic Substances

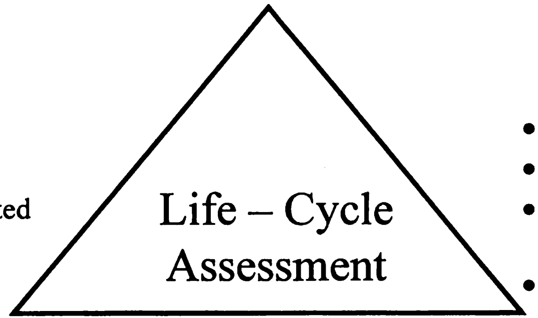
Test	Most Likely to Show Biodegradation (5 is best)[1]
OECD Screening / DOC Die-A-Way / CEC L-33-A-93	2-3
MITI / Manometric Respirometry	4-5
Closed Bottle	1
Modified Sturm	2-3
ASTM D-5864	4
ISO Headspace	5

1 – Based on a 5-point scale where 5 provides the optimal test conditions for demonstrating biodegradability and 1 provides the worst.

Figure 4: The LCA Evaluation Process

Inventory

- required energy, raw materials
- releases to air and water
- Amount of solid wastes generated



Improvement Analysis

- reduce energy & raw materials
- reduce waste emissions
- improve product design, processing & consumer use
- improve waste management

Impact Analysis

- environmental loadings
- ecological & human health impacts
- habitat modification, noise pollution

II. ENGINE LUBRICATING OIL EVALUATION FIELD TEST PROCEDURE

By: Bob Dittmeier, Ethyl Petroleum Additives, Inc.

DIESEL ENGINE LUBRICATING OIL EVALUATION FIELD TEST PROCEDURE
PREPARED BY
FUELS AND LUBRICANTS COMMITTEE
OF THE
LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

This field-test protocol only addresses how to run a field test, it does not address what additional requirements may be required by either the Original Equipment Manufacturer (OEM), the railroads, or from other power generation applications.

This procedure recommended by the Locomotive Maintenance Officers Association (LMOA) represents its judgement given the due consideration of the necessary limitations of a practical operation and in accordance with the aims and objectives of LMOA. LMOA assumes no responsibility for the affect of its reports, recommended procedures and practices and standards, or for the observance or non-observance by federal, state or local government agencies, or by manufacturers, of its standards, practices or procedures. It should be noted that findings and recommendations of LMOA in any case represented only its independent opinion arrived in accordance with its aims and purposes. LMOA does not warrant or guarantee the correctness of its opinion, or that its opinion will be accepted or recognized by any other person, organization or governmental agency. The recommended procedures of LMOA are in no way binding on its membership.

LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION
Company Representation
Fuels & Lubricants Committee
During 1974, 1975 and 1976

Alco Engine Co.
Amoco Oil Co.
Atchison, Topeka & Santa Fe Rwy.
Atlantic Richfield Research
Bessemer Lake Erie RR
Burlington Northern Inc.
Chessie System
Chevron Chemical Co.
Chicago, Rock Island & Pacific RR
Continental Oil Co.
Exxon Co.
General Electric Co.
General Motors Corp.
Gulf Research & Development Co.
Illinois Central Gulf RR
Louisville & Nashville RR
Missouri Pacific RR
Mobile Oil Co.
Norfolk & Western RR
Penn Central Trans. Co.
Reading Company
Saint Louis-San Francisco Rwy.
Shell Oil Co.
Southern Railway
Southern Pacific RR
Standard Oil Co. of Calif.
Texaco Inc.

The above list is retained to highlight those that were involved with creating the original document.

LMOA DIESEL CRANKCASE OIL FIELD EVALUATION PROCEDURE

Purpose and Scope

The purpose of this procedure is to provide a uniform method for conduct and reporting of field evaluation tests. The rationale is to determine if a new crankcase lubricating oil possesses the necessary characteristics to enable it to satisfactorily lubricate main power plant diesel engines, which are incorporated in railroad locomotives. It is intended that this procedure be used for the evaluation of lubricating oils containing new additive formulations not yet approved for commercial service. This testing may also include proven additives incorporated into base oil formulations of significantly different characteristics, e.g., Viscosity Index Improvers, Group I or Group II base stocks. It may also be used for products containing an additive formulation already in commercial service and under this condition, it would seem appropriate that the procedure be modified.

A successful lubricating oil field evaluation test requires the close cooperation of the railroad or company supplying the test equipment, the oil and/or additive company and the OEM. This cooperation should begin before the test is started, recognizing that a field evaluation of a new product always entails some risk.

The OEM's have historically screened new lubricating oils by the use of bench tests and/or stationary engine tests. It is expected that the OEM's will continue this process and will formally notify the appropriate oil and/or additive company that its candidate lubricant is, in their view, worthy of field test.

All the participants ultimately benefit from a new product, but it is appropriate that it be the responsibility of the oil and/or additive companies to arrange for a location to perform the test. All parties involved benefit from this testing by being able to evaluate the latest technology. The normal rules of warranty administration apply during the conduct of a test.

Performance Parameters

The lubricating oil under test is to be evaluated for its ability to provide:

1. Oil chemistry that is non-corrosive to engine bearing materials including silver, copper-lead and aluminum.

2. Adequate film strength to satisfactorily lubricate all internal engine components.

3. Deposit control in critical areas such as piston cooling cavities and piston ring grooves and lands.

4. Protection against corrosive wear within the power assemblies.

5. Sufficient dispersancy and detergency to maintain open oil passages, provide satisfactory oil filter life and control oil-related deposits.

6. A lubricant that will limit ash, carbon, sludge, or varnish deposits from developing on engine parts to any degree which would interfere with the engine performance.

7. Stability against oxidation; loss of alkalinity, dispersancy and detergency while providing reasonably long effective oil life.

Test Team

At the beginning of testing technical representatives of the railroad or the company supplying the test equipment, the oil and/or additive company and the OEM having field test responsibility shall be designated. Those designated should be present at the mid-term and at the final inspections of the engines involved in the test. A competing oil and/or additive company shall not be allowed to inspect engine parts or obtain used oil samples representing new oil performance except by written agreement of the oil and/or additive company conducting the testing. The same requirements apply to engine builders with respect to each other's equipment.

Operating Conditions

The following service conditions are known to affect lubricating oil performance in an engine and therefore are to be reported in the final evaluation of results.

1. Altitude
2. Tunnels
3. Ambient temperature
4. Fuel quality
5. Duty cycle
6. Maintenance practices including parts replacement, incidents of fuel or water contamination
7. Airborne contaminants - air filter c/o record
8. Oil change schedule - oil filter c/o record
9. Lubricating oil consumption
10. Interchange of locomotives.

Bracketed items would be considered as increased severity and would also need to be documented.

[Altitude 5,000 ft. or above.]

[Ambient temperatures in excess of 115°F. (Artificially created by tunnels.)]

[Fuel sulfur content of 0.5% or above.]

Fuel usage is a measure of duty cycle. During the course of the evaluation, the MWHr (megawatt hours) data from one of the units used in the test should be recorded.

Duration of Test

A standard test shall require the accumulation of a minimum of 100,000 miles and a minimum of 12 consecutive months so as to incorporate all seasonal climatic conditions. The test will be terminated at a shorter period if the test team agrees that the oil has failed. It may be run longer at the discretion of the test team. If for some reason beyond the control of the test team and aside from failure of the test oil, the test must be terminated before reaching the minimum timeframe, it shall be declared void.

Selection of Locomotives

A complete evaluation should include both EMD and GE locomotives. The evaluations may occur on different railroads. The locomotives selected should ideally be those of highest commercial BMEP (Brake Mean Effective Pressure) ratings available from each OEM. A variation from this goal requires a statement from the OEM that the evaluation in the substitute locomotive will adequately predict performance in the highest rated unit. In addition, Electro-Motive Division of GM includes the requirement of evaluating a minimum of two of their locomotives containing silver wrist pin bearings.

Each test oil should be evaluated in four to six locomotives manufactured by each OEM. Ten locomotives would be considered a maximum to operate on a test oil. All parties should be involved in decisions to operate a larger number of locomotives on the test oil. Two of the same class locomotives operating on the railroad's fleet lubricating oil are recommended as control units and will be treated in the same manner as those which are used for the test oil.

Parts Evaluated for Each Engine as Appropriate to Engine Type

Air box
Bearings (connecting rod only)
Cam lobes and camshaft
Top deck or rocker box covers
Crankcase
Crankcase covers
Heads (combustion face)
Cylinder liners
Valve and valvetrain
Piston and articulated pins
Piston pin inserts
Piston pin and articulated pin bushings
Piston ring groove and lands, crowns and undercrowns
Inlet ports
Piston rings
Intake and exhaust valves
Thrust washers

Test Inauguration

The engines used for both the test and control locomotives should be new or have been newly overhauled. The lubricating oil system external to the engine such as filters, cooler and the radiator system should be cleaned and inspected prior to start of test. A minimum of four pre-measured power assemblies on each engine shall be new or rebuilt to factory standards. Two of these power assemblies are to be applied to each bank of the engine. All piston ring side clearances on EMD are to be recorded.

Test Procedure

Locomotives should be load tested prior to the start of test to assure normal operation. A schedule of inspections shall be established for each test and include, as a minimum, six-month and end of test inspections. Under normal conditions it is not necessary to remove parts from the engines at the six-month inspection point.

Crankcase deposit ratings as well as top deck deposit ratings should be made in at least two cylinder locations at the six-month inspection.

At the six-month inspection, cylinders of GE engines are to be borescoped for evidence of piston ring sticking or cylinder scoring. This same evaluation is to be performed on EMD engines by "air box inspection". On EMD units, top ring side clearances are to be determined and recorded at this inspection.

Oil changes are to be made based on laboratory analysis or according to each OEM's condemning limits. The limits are to be those published by the engine manufacturer for this purpose unless agreed to by all parties prior to the test. A record of all lubricating oil changes is to be included in the final report.

A lubricating oil sample is to be obtained weekly if possible and analyzed by the oil and/or additive company. The analysis should consist of the following determinations as a minimum: viscosity at 40° C and 100° C, LMOA pentane insolubles, pH, Total base number (D4739), Total acid number (D664), and wear metals by an appropriate spectrometer.

Every effort should be made to prevent the mixing of the test lubricant with other lubricants. If at all possible, a supply tank complete with pump, hose and nozzle should be available at the major service point to facilitate proper oil addition. Where possible an onboard lubricating oil supply tank should be installed to allow test oil addition when away from the main terminal. Decisions on these points should be reached prior to the beginning of test. The oil and/or additive company should procure and analyze sufficient samples of the candidate lubricating test oil to establish if there is any degree of crankcase oil mixing. An organic or inorganic marker could be useful in tracking any contamination from the fleet oil.

A sample of diesel fuel from the onboard fuel tank should be obtained and analyzed at the start of test, the mid point and at the end of test. Tests should include gravity, centane index, sulfur, distillation; and these analyses should form a part of the final report.

A complete record of all parts removed and all service performed on each test engine and each control engine during the course of the evaluation shall form a part of the final report.

At the end of the evaluation, the four "test" power assemblies shall be removed from each engine and completely evaluated as detailed in the appendix.

Rating Methods

In general the methods used for rating engine parts will be those developed by the Coordinating Research Council, Inc. These methods are covered in "CRC Manual No. 18 (for deposits) and Manual No. 12 (for sludge)." It is not necessary to rate all of the engine parts in as much detail as covered in the CRC Manual. In general there are three types of ratings: Conditions, Deposits and Measurement. The most complex of these rating techniques are those associated with deposits. Considerable experience is required to obtain consistent results. Rating Symposiums are conducted periodically under the auspices of the Coordinating Research Council. The oil and/or additive companies normally employ individuals who are thoroughly experienced in judging the degree of deposits and who regularly participate in these programs. It is recommended that a qualified person, either from an independent lab or from the oil and/or additive company perform the end of test ratings.

The following defines the type of rating believed necessary for the conduct of an oil evaluation test. At the discretion of the test team, additional type ratings may be made.

Deposit Only

Air box, top deck or rocker box covers, crankcase, crankcase covers, heads (combustion face) and inlet ports.

Condition Only

Bearings, bushings, cam lobes, camshafts, valve mechanisms and pins.

Deposit, Condition and Measurement

Cylinder liners, piston and piston rings. Intake and exhaust valves and piston thrust washers.

Appendix A lists appropriate extractions from CRC Manuals No. 18 & No. 12.

Final Report

The oil and/or additive company will present a written report to the participating railroad and participating OEM. The railroad technical department and/or the OEM may cooperate in preparation of the report, but their participation shall not constitute an endorsement of the product.

The final report shall include tabulated wear and deposit ratings, illustrative photographs, lubricating oil analysis data and maintenance records as defined elsewhere. The following photographs representing typical conditions are

to be included. In addition any abnormal condition should be documented by photograph where appropriate.

Photographs

Connecting rod bearings
- Bearing surface and back

General
- Air box - left bank front and rear
- Top deck or rocker box, their covers and valve gear
- Crankcase main frame

Head
- Full fire face with valves in place
- Close up of two valves seats

Piston
- Side view close up full piston with rings
- Close up of rings lands without rings
- Top view of crown
- Undercrown
- Rings – detail of face and deposits present
- Silver insert bearing

Valves
- Close up of entire set after removal showing faces and stem up to weld joint

This document is the proposed procedure for field testing crankcase engine oil formulations. It does not address what is acceptable to the end user or OEMs.

APPENDIX A

Coordinating Research Council Inc. (CRC)
Suite 140
3650 Mansell Road
Alpharetta, GA 30022
678-795-0506
See Rating Manual # 18 (deposits)
See Rating Manual #12 (sludge)

III. DETECTING ABNORMAL WEAR OF AC TRACTOR MOTOR, PINION END, ARMATURE BEARINGS THROUGH LUBRICANT WEAR DEBRIS ANALYSIS

By: John Estes,
Union Pacific Railroad, and
Patrick Kilbane, PREDICT/DLI

Abstract

Repeated failures during operation of the AC traction motors used on locomotives owned and operated by Union Pacific Railroad demonstrated a need to employ condition monitoring techniques.

The utilization of analytical ferrography to detect abnormal wear in locomotive traction motors prior to failure proved to be an effective and accurate tool, resulting in the reduction of unexpected failures. Spectrometric analysis was conducted in conjunction with analytical ferrography to assess its ability to detect abnormal wear and to determine if any correlation between the two analytical techniques could be found.

Analysis of over 1,000 samples failed to produce any correlation between the two analytical techniques.

Traction Motors

The samples employed in this paper were collected from the motor, pinion end, and rotor (armature) bearing. These bearings consist of steel roller bearings, steel races, and a brass bearing cage (Figures 1 & 2). Lubrication for the bearings is achieved by drip. A reservior on the gear side of the bearing catches oil splashed by the gear set and drips into the bearing cavity. The brass bearing cages fail as a result of fatigue cracks propagated from the corner pocket of the bearing cage. A seal problem resulting in leakage has been identified and believed to be the principal cause of bearing problems due to lack of lubrication. The lubricant for these traction motors is a synthetic 460 oil. Typical used oil tests such as total acid number and viscosity showed normal results.

Introduction to Ferrography

Ferrography evaluates machine wear condition by the examination and evaluation of particles separated from used lubricant samples (oil or grease). Using ferrographic techniques, a trained analyst can identify wear-related failures at an early stage before collateral damage or failure occurs. Particles are separated from the lubricant in the following manner: A lubricant sample is diluted with solvent and allowed to flow down a low gradient inclined substrate (slide) while passing across a bipolar magnetic field. Wear particles are distributed down the length of the substrate between non-wetting barriers that have been painted onto the substrate's surface. Ferrous particles line up in strings that follow the magnetic flux lines. The largest ferrous particles are deposited at the entry end (see Figure 3) of the substrate due to magnetic force. The flow rate of the sample is such that nonferrous particles and contamination will randomly be deposited by gravity down the length of the substrate. When the sample flow is completed, a solvent "wash" cycle removes any lubricant remaining on the substrate resulting in a "ferrogram". After the ferrogram is dry, the wear particles and solid contaminants are adhered to the substrate and ready for examination.

A three-magnification biochromatic microscope is used to identify and examine the particles remaining on the slide. Particles caused by identified wear modes have distinctive characteristics, which reveal the wear mechanism at work. Wear particles can be classified by size, shape, concentration, and metallurgy. Many types of particulate contamination can also be identified. An experienced analyst can use these classifications and identifications to assess the machines' wear condition and make appropriate recommendations.

Analytical Procedures

Samples were collected from the traction motor gearcase. These samples were transported to the laboratory, heated to 65^{c}, homogenized and processed. Of the 2,249 samples analyzed, 1,278 samples were rated marginal (57%). The marginal ratings included recommendations that ranged from *"Keep this unit under observation"* to *"This sample is baseline CRITICAL, consider an oil change and inspection of this unit"*. Critically rated samples numbered 22 (1%), indicating *severe wear in this unit that requires immediate attention*. Since the focus of the failures is the brass bearing cap, any presence of copper alloy particles is sufficient justification to affix a marginal rating. Samples that contained copper alloy particles numbered 149 or (6.6%) of the total samples.

Identification of Analytical Thresholds

Particle Size Criteria:

Samples showing copper alloy particles larger than 20 microns are rated **MARGINAL**. Samples with copper alloy particles larger than 50 microns are rated **CRITICAL**. Iron particles of 100 microns or larger are indications of a **CRITICAL** condition.

Particle Concentration:

A rating of 1 to 4 is rated **MARGINAL**. A rating of 5 to 10 is rated **CRITICAL** (Figure 4).

Inspection Results

Inspections were performed initially to correlate ferrography results and physical inspections. Initially 32 motors were inspected with ferrography ratings of marginal or critical. No inspections were performed on normal rated motors (see Figure 5).

Correlation Between Spectrometric and Analytical Ferrography

1,100 traction motor samples were analyzed for potential correlation between ferrography and elemental analysis. Each sample was examined using ferrographic analysis techniques; in addition elemental analysis (spectro-analysis) was performed on these same samples.

Ferrography classified 759 of the 1,100 samples marginal or critical. Ratings reflect quantity of ferrous rubbing and abnormal wear particles, nonferrous rubbing and abnormal wear particles, and contamination present in each sample. Marginal recommendations ranged from "Monitor this equipment", "Consider an oil change", to "Consider inspecting this unit". Critically rated equipment accounted for 16 samples. Copper alloy particles were observed in 62 of the 1,100 samples analyzed. These samples were all rated marginal (48) samples or critical (14 samples).

Elemental analysis for copper and zinc levels ranged from 1 to 3,280ppm. Ferrography rated all of the abnormal elemental analysis results critical. However, not all equipment rated critical by ferrography was likewise rated critical by elemental analysis (Figures 6 & 7). This discrepancy is due to the insensitivity of elemental analysis to particles over eight microns in size. Two samples were rated critical by ferrography based on the presence of large copper alloy particles (30 to 50 microns in size). These samples averaged 95ppm in zinc and copper, therefore eluding detection by elemental analysis. There appears to be no direct correlation between the two analytical techniques.

Maintenance

Traction motors identified by ferrography as having abnormal wear conditions were taken out of service or monitored prior to a seal change. The cost of each traction motor is approximately $60,000, while a train delay may cost up to $100,000 per hour. Repairs resulting from the utilization of ferrography to identify problematic traction motors have reduced the average cost to between $750 and $1000 per motor (per Union Pacific). Used oil programs using ferrography to assess the severity of any wear problem can save money over the conventional used oil programs uses elemental analysis alone (see Appendix A).

Summary

The detection efficiencies of ferrography and elemental analysis are size dependent. Abnormal wear particles are designated as particles larger than fifteen microns in size. The inability of elemental analysis to detect particles larger than eight microns prevents identification of all possible abnormal wear conditions. Therefore, correlation between ferrography and elemental analysis was not possible.

Analytical ferrography proves to be an effective technique in the identification and assessment of abnormal wear. The onset of abnormal wear corresponds to the presence of copper alloy particles in the lubricant sample, which was verified, with visual inspection of the bearings. The detection of wear progressions, based on ferrographic guidelines is a valuable tool for prioritizing repair and maintenance schedules. Currently the percentage of samples rated marginal or critical has dropped from as high as 70% to 26%. This drop is associated with the new seal design being implemented on these motors. On-going evaluations of inspection data with ferrography were not available at this time. Amendments will be made when available.

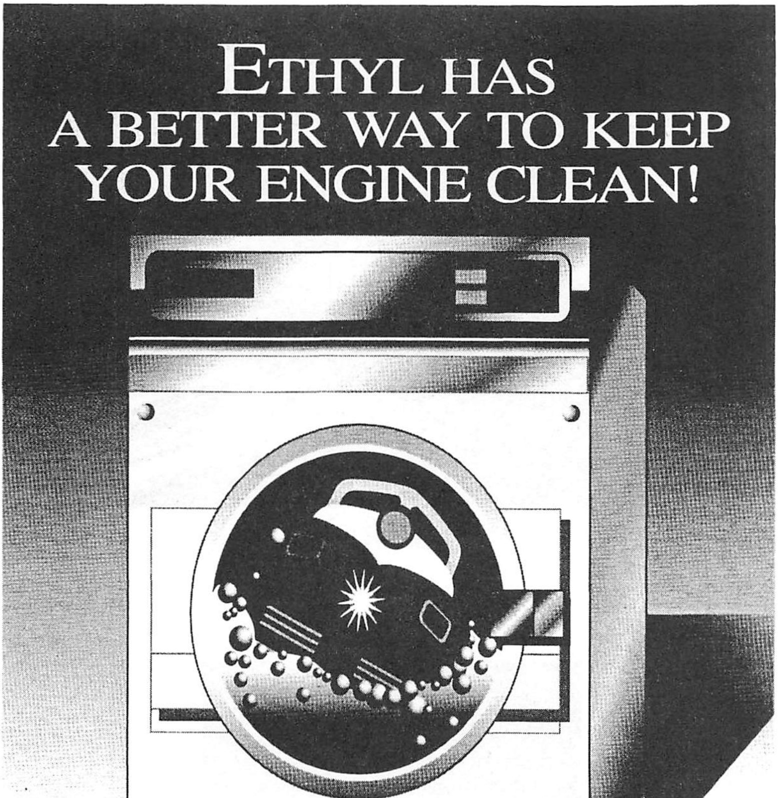
References:

1. Lockwood, F.E., Dalley, R. - Lubricant Analysis ASM International Volume 18 Friction, Lubrication, and Wear Technology, 1995

2 Seifert, W.W., Westcott, V.C. - A Method for the Study of Wear Particles in Lubricating Oils Wear, Volume 21, 1972, P27-42

3. Beck, J.W., Johnson, J.H. - The Application of Analytical Ferrography and Spectroscopy to Detect Normal and Abnormal Diesel Engine Wear SAE Special Paper 589, 1984

4. Dalley, R.J. - An Overview of Ferrography and its use in Maintenance Predictive Maintenance Seminar, 1991


ETHYL HAS
A BETTER WAY TO KEEP
YOUR ENGINE CLEAN!

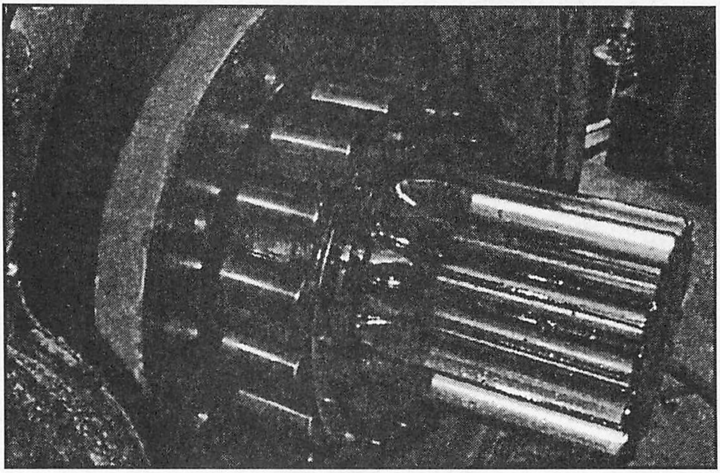


FIGURE 1

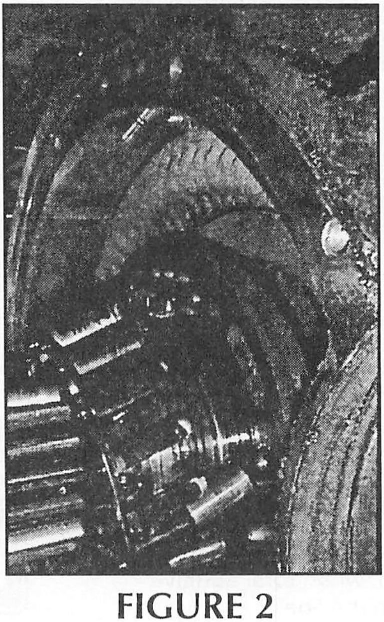
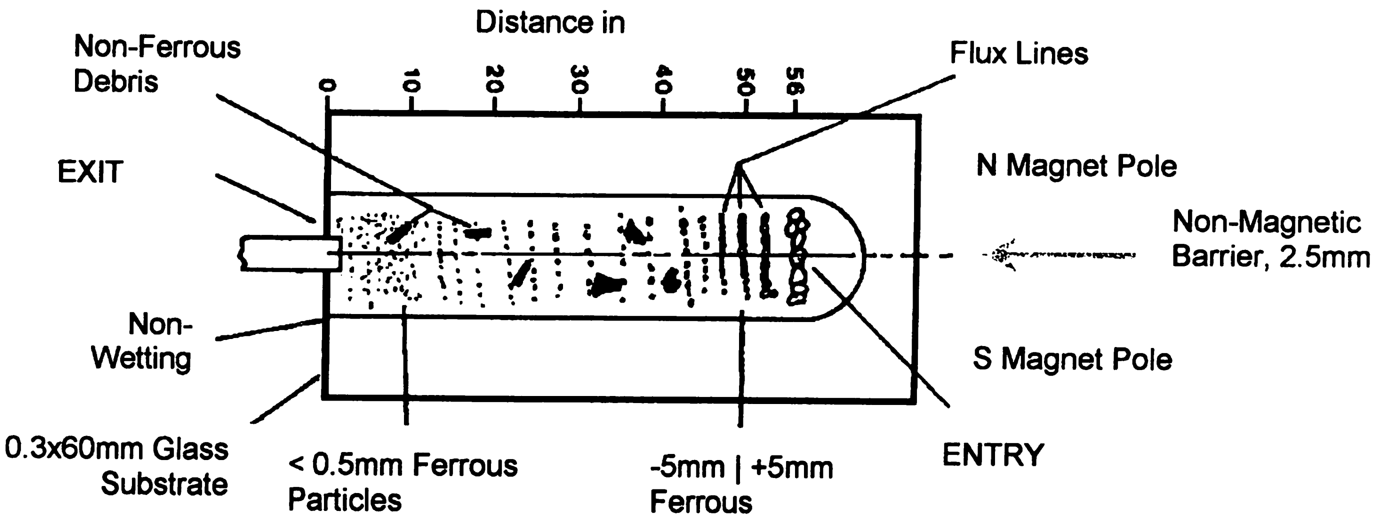


FIGURE 2



Distance in
Non-Ferrous
Debris
0
10
20
30
40
50
56
Flux Lines
EXIT
N Magnet Pole
Non-Magnetic
Barrier, 2.5mm
Non-
Wetting
S Magnet Pole
0.3x60mm Glass
Substrate
< 0.5mm Ferrous
Particles
-5mm | +5mm
Ferrous
ENTRY

FIGURE 3

FIGURE 4

Locomotive and Motor Number	Sample Date	Activity	Cage rubbing	Loose rivets	Outer Race Spalling	Inner Race Spalling	Roller End Wear	Excessive Clearance	Failed Oil Sample
104,4	2/5/99	Changed 2/21/99		X					X
108,2	2/4/99	6-wheel 2/23/99		X					X
109,2	2/12/99	6-wheel 3/3/99		X				X	X
109,1	2/12/99	6-wheel 3/3/99		X					X
109,6	2/12/99	6-wheel 3/3/99		X				X	X
111,1	2/14/99	Changed 3/10/99		X				X	X
111,1	2/14/99	Changed 3/10/99		X					X
120,6	2/16/99	Changed 3/1/99		X					X
120,3	2/16/99	Changed 3/1/99		X					X
124,1	2/22/99	changed 3/4/99		X				X	X
128,3	2/10/99	6-wheel 2/21/99	X						
143,3	2/27/99	Changed 3/9/99		X					X
150,4	2/5/99	Changed 2/25/99		X	X				X
156,2	2/14/99	Changed 3/3/99		X	X				X
207,2	1/11/99	Changed 1/23/99		X		X	X	X	X
208,5	2/13/99	Changed 2/27/99		X		X			X
216,2	2/5/99	Changed 2/21/99		X					X
220,2	1/2/99	Changed 3/4/99			X				X
244,5	1/29/99	Changed 2/13/99							X
244,6	1/29/99	Changed 2/13/99		X				X	X
290,1	2/20/99	Changed 3/3/99		X					X
290,2	2/20/99	Changed 3/3/99		X		X			X
298,2	2/23/99	6-wheel 2/25/99		X				X	X
298,3	2/23/99	6-wheel 2/25/99		X					X
301,5	2/8/99	re-wheeled 2/22/99		X				X	X
309,2	2/8/99	Changed 3/1/99		X		X		X	X
312,2	2/16/99	Changed 3/8/99		X					X
324,2	1/15/99	6-wheel 1/23/99		X				X	X
326,1	2/5/99	6-wheel 3/2/99		X		X			X
326,6	2/5/99	6-wheel 3/2/99		X					X
335,3	2/7/99	6-wheel 2/24/99		X				X	X
368,2	2/5/99	6-wheel 3/4/99		X				X	X

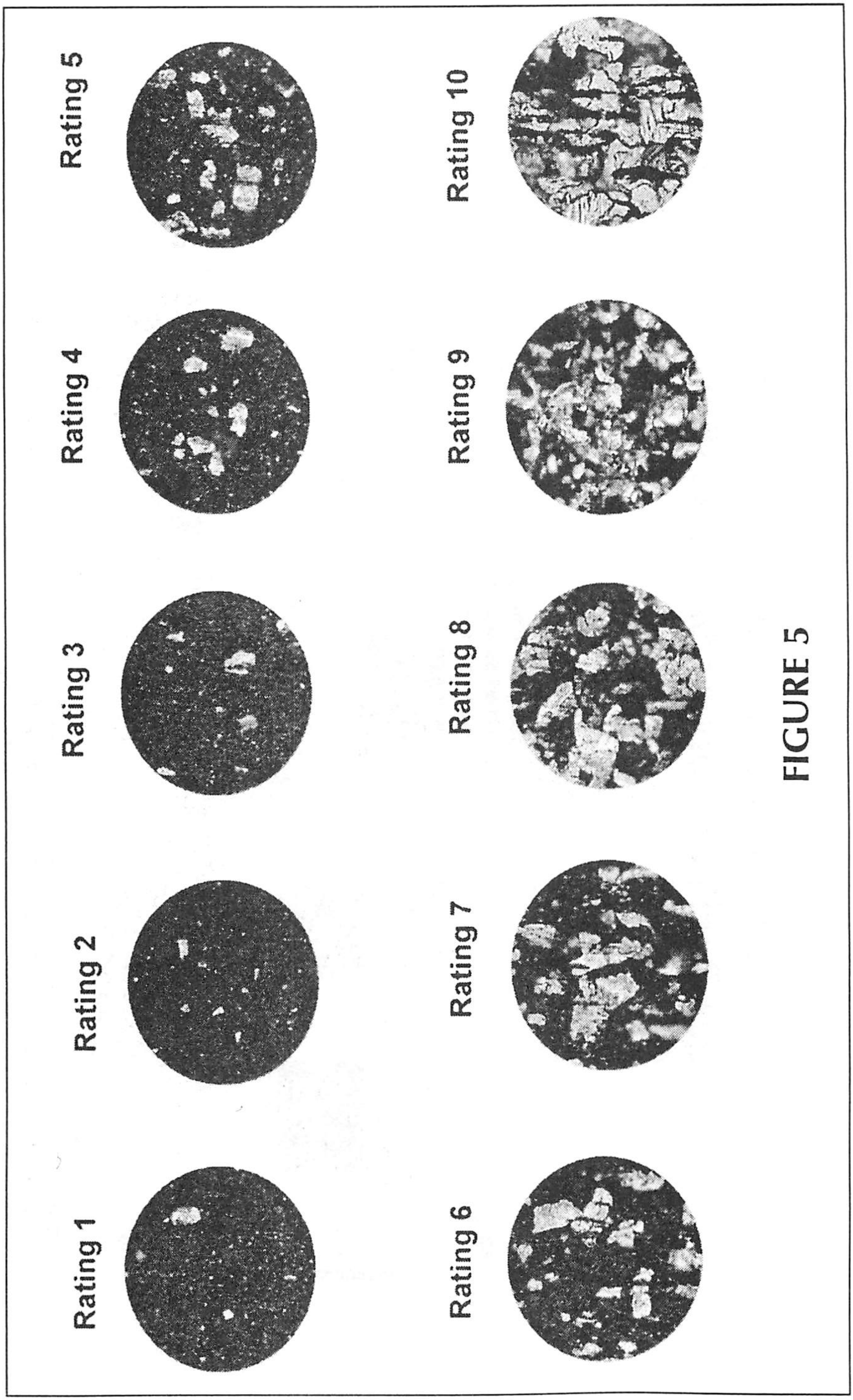

Rating 1
Rating 2
Rating 3
Rating 4
Rating 5
Rating 6
Rating 7
Rating 8
Rating 9
Rating 10

FIGURE 5

FIGURE 6

Copper Concentration and Wear Rating per Positive Copper Samples (62)

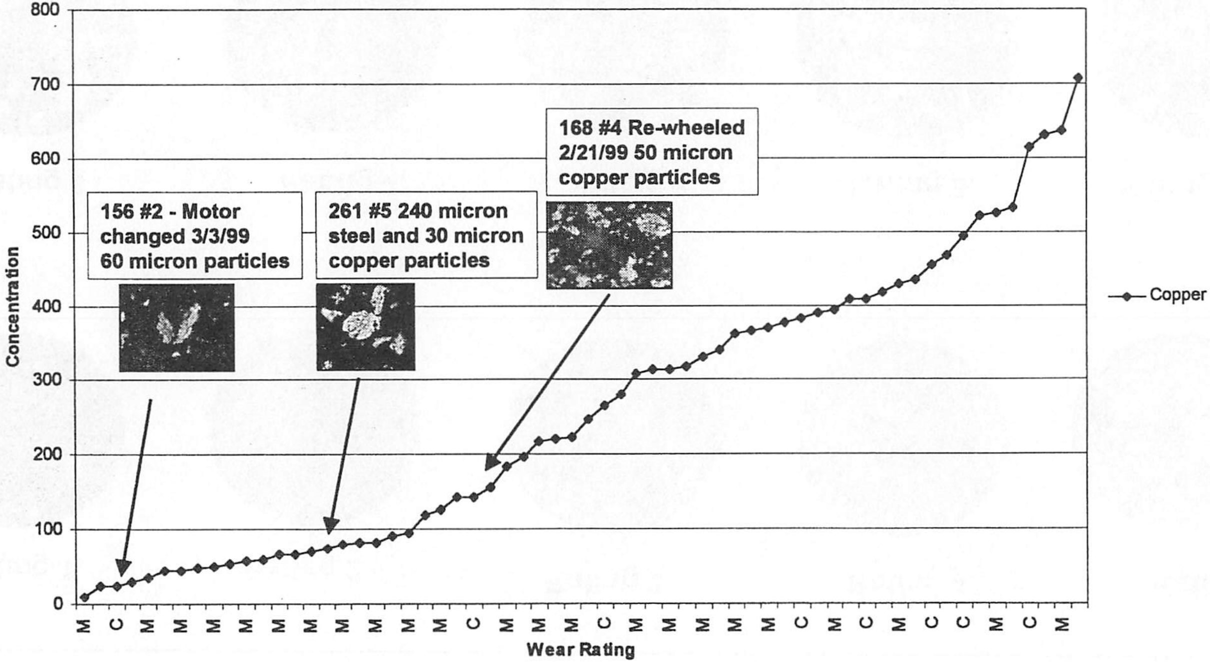
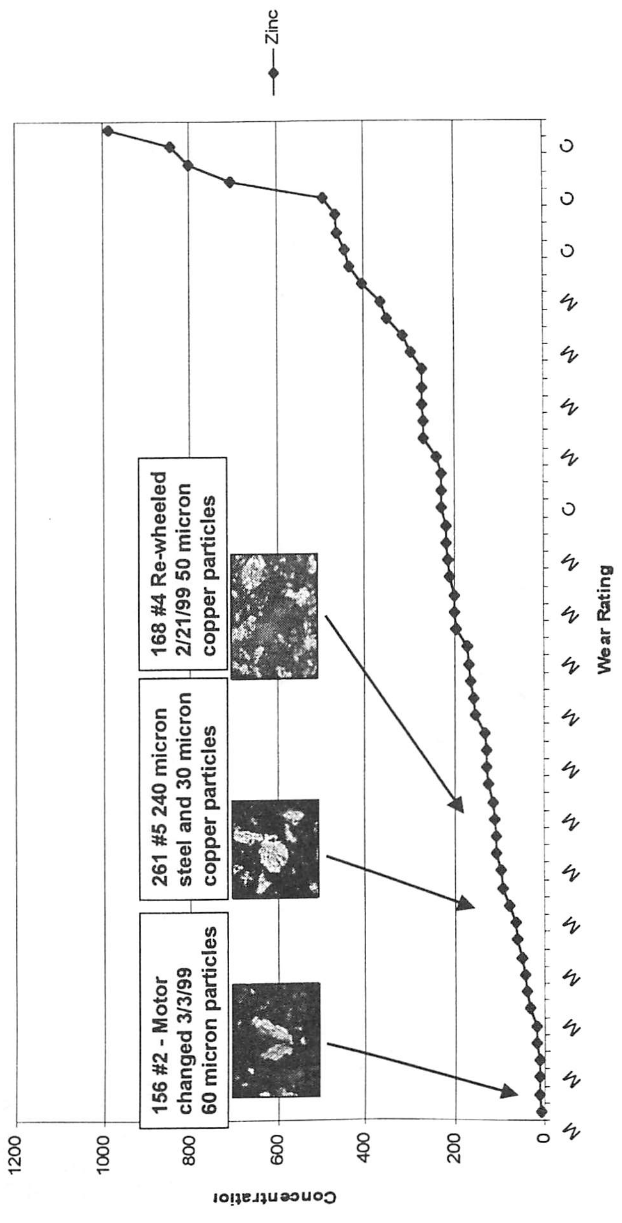


FIGURE 7

Zinc Concentration and Wear Rating per Positive Copper Samples (58)



APPENDIX A
Associated Costs

The numbers generated below represent data compiled form the correlation study of elemental analysis and ferrography. The total number of samples was 1,100. The following parameters are used to estimate the associated costs on the following pages.

No. of Samples per Parameter and Criticals Detected

Parameter	No. of samples	Percentage	No. of Critical (16)	Percentage of Criticals
Zinc at 100 ppm	318	29%	14	87%
Copper at 100 ppm	314	29%	13	81%
Zinc at 125 ppm	236	21%	14	87%
Copper at 125 ppm				
Zinc at 150 ppm	178	16%	11	69%
Copper at 150 ppm				
Zinc at 175 ppm	132	12%	11	69%
Zinc at 200 ppm	104	9%	11	69%

Associated Costs

Analysis Type	Number of Samples	Cost Per sample	Total Cost of Analysis
Ferrography	1,100	$35	$38,500
Immediate Inspection needed based on Analysis	16	$100**	$1,600
Total Cost for 1,100 samples	$40,100		

Analysis Type	Number of Samples	Cost Per sample	Total Cost of Analysis
Elemental Analysis	1,100	$6	$6,600
Inspection based on Analysis at Zinc 75 ppm*	370	$100**	$37,000
Total Cost for 1,100 samples	$43,600		

*Utilizing an inspection parameter of Zinc at 75 ppm will allow for 94% of all critically rated motors to be inspected and 81% of all samples containing brass particles.

** Low Estimate

Associated Costs

Analysis Type	Number of Samples	Cost Per sample	Total Cost of Analysis
Elemental Analysis	1,100	$6	$6,600
Ferrography Based on Zinc at 75 ppm	370	$35	$12,950
Immediate Inspection based on Analysis	15	$100**	$1500

Total Cost for 1,100 samples $21,050

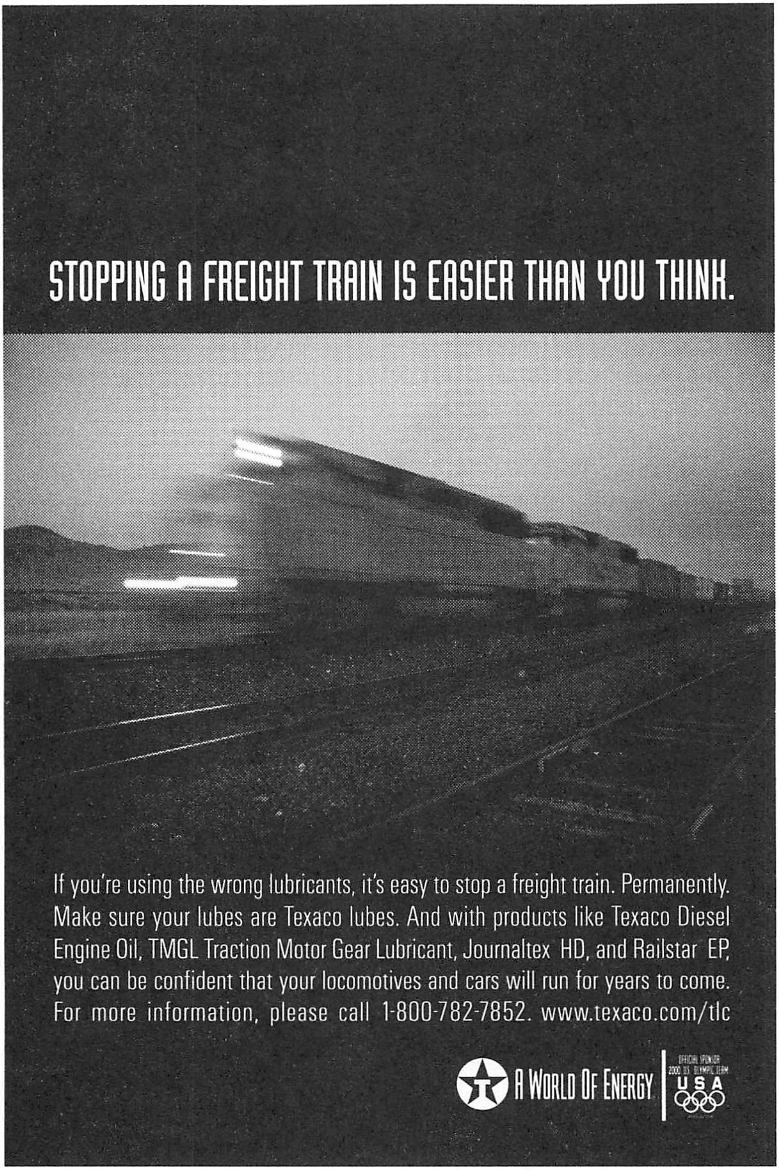
* Utilizing an inspection parameter of Zinc at 75 ppm will allow for 94% of all critically rated motors to be inspected and 81% of all samples containing brass particles.

Analysis Type	Number of Samples	Cost Per sample	Total Cost of Analysis
Elemental Analysis	1,100	$6	$6,600
Ferrography Based on Zinc at 200 ppm*	104	$35	$3,640
Immediate Inspection based on Analysis	11	$100**	$1100

Total Cost for 1,100 samples $11,340

* Utilizing an inspection parameter of Zinc at 200 ppm will allow for 69% of all critically rated motors to be inspected and 50% of all samples containing brass particles.

** Low Estimate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IV. FURTHER DEVELOPMENTS IN TOP-OF-RAIL LUBRICATION TESTING

By: Kenneth Davis,
CSX Transportation,
Sudhir Kumar,
Tranergy Corporation,
Greg Sedelmeier,
Equilon Enterprises

FRA and DOE sponsored the test of an on-board top-of-rail (TOR) friction modification system, Sentraen 2000TM, on CSX trains through ENSCO, Inc. between January and March 1998[1]. This test was a continuation of earlier studies reported by LMOA (Runyon and Kumar LMOA 1996[2]) and others (Runyon, ARM Wheel Rail Interface Seminar, 1999see 3).

The on-board top-of-rail friction modification system (TORS) tested is the first original system which was invented and developed by Tranergy Corporation in collaboration with Norfolk Southern Railroad and Texaco Corporation. The system provides an alternative to current on-board wheel flange lubrication systems which reduce the flange friction. The TORS presented here reduces the friction between top-of-rail and the wheel tread of the car wheels. This results in energy savings as well as reduction of lateral forces exerted on the rail. More details of the system and it's testing and development can be seen in a previous report [4].

The objective of this investigation was to conduct further tests of the TOR friction modification system in field service under the full range of train operating conditions, and possible system operating conditions, with respect to the following issues:

- Safety Related Issues
  - The effect of the friction modification system on train handling/speed control;
  - The effect of the friction modification system on braking, including stop distance and wheel slip;
  - The distribution of friction modifier (FM) under the train, including the amount of friction modifier remaining on the rails following a train passage and its influence on subsequent traffic;
  - The effect of the friction modification on the lateral curving forces.
- Performance Related Issues
  - The energy savings that can be expected from the use of the system for a range of typical trains in freight service;
  - The effect of the FM on the critical speed for truck hunting.

Train operation parameters were measured both with and without FM movements of CSXT's Stilesboro's 90 car coal trains between Corbin, Ky., and Cartersville, Ga. The consist traversed the test zone at typical operating speeds during the test with instructions being given to the engineers to avoid using special handling practices for the duration of the test.

The amount of fuel consumed and the electrical output of the locomotive's generators were recorded for the trip with and without FM. Mechanical energy was determined from force measurements made with an instrumented drawbar. Electrical and mechanical energy requirements were assessed in order to provide a point of comparison for fuel consumption measurements. Measurements of the electrical energy is an accurate means to determine the energy requirements associated with the movement of the train.

Tribometer readings were made at several locations prior to and after train passage for comparison of coefficient of friction measurements to determine the extent of FM remaining after train passage. Stop distance tests were conducted with and without FM conditions as traffic conditions permitted. Full service and emergency brake applications were employed for these tests.

The "dry", or without FM, rail condition was considered as a case where the TOR friction modification was not in use. Throughout the test effort, both wayside friction modification devices and wheel flange lubricators were fully operational. Of the three locomotives within the consist, the lead and the middle locomotives were applying flange lubricant continually in all tests. The trailing locomotive was equipped with the TORS, which applied lubricant from the trailing end only during tests designated as lubricated tests. *Differences in performance of the test train between the test run with and without FM were thus measured as a percentage above the levels obtained by using wayside and flange lubrication.*

The test zone was divided into twelve segments. This was done in order to aid in the analysis of the results - if results were compromised by weather conditions or train handling, the data from the affected segment could be disregarded without compromising results recorded in other segments. The end points of each of the segments were chosen such that the individual segments of the test zone had uniform terrain and similar track features.

Friction modification was achieved using a water-based friction modifier (FM) produced by Equilon. The water-based friction modifier (FM), top of rail friction modifier (TOR/FM), was formulated to complement the unique design of the TOR system application.

The TOR/FM behaves like a friction modifier for low slip or creep rates such as those experienced by rolling car wheels. However, it becomes a friction modifier agent producing 50% adhesion for high slip rates such as those experienced by braking. The proper application rate will allow the TOR/FM to be effectively consumed by the train without leaving any significant TOR/FM film behind which could interfere with the adhesion of the locomotive or the braking operations of the train.

The formulation contains a synthetic lubricant, along with glycol, and other additives. The TOR/FM was formulated to have a high wetting ability on the rails with a moderate to low viscosity (approximately 17c.St at 40°C). In addition, it contains no solids or heavy metals and is ashless. It is friction reducing, durable, and can perform effectively over a wide range of temperatures from -17°F to 165°F. An extreme colder weather version (-50°F) of the TOR/FM is also available. Initial sample candidates were screened for performance in a laboratory rail simulator test developed by the Illinois Institute of Technology (IIT). The IIT laboratory rail simulator (LA4000) was designated as the key laboratory instrument used in evaluating a new TOR/FM.

The basic composition of the TOR/FM was established in late 1993, just before the first field test demonstration of the lubricant in the prototype TOR/FM applicator system. Over the last six years the TOR/FM has been improved in regards to both its high and low temperature properties without compromising the integrity of the original composition. The most recent upgrade to the base composition of the TOR/FM was made in 1997, and it was commercialized in 1999. Extensive toxicity studies on the long-term environmental effects of TOR/FM were undertaken over a one-year period ending in August 1995. The TOR/FM was subjected to studies determining acute dermal toxicity, acute oral toxicity, primary ocular irritation, primary dermal irritation, acute toxicity to rainbow trout, acute toxicity to sheepshead minnow, toxicity to freshwater green algae, acute toxicity to daphnids, acute toxicity to mysid shrimp, the potential for biodegradation in water by carbon dioxide evolution, and leaching characteristics. The results of these studies showed that the TOR/FM was practically non-toxic in virtually every category tested and had some degree of biodegradability in time limited tests. These tests typically did not exceed one month in duration.

The Argonne National Laboratory (ANL)[5] and Penn State University[6] have recently completed studies through funding by the U. S. Department of Energy (DOE). The objective of the efforts by ANL was to identify degradation by-products (volatile and semivolatile) of the TOR/FM while also investigating the effects of vertical load, speed, and angle of attack on the friction force, as well as consumption time of the lubricant. ANL used sophisticated methods of gas chromatography and mass spectrometry to analyze and characterize the volatile by-products. The results of this series of studies showed that the TOR/FM contains none of the compounds considered hazardous by the EPA.

The Penn State studies centered on conducting tests to establish volatility and residue forming tendencies of the TOR/FM as well as conducting preliminary thermal and oxidative stability tests of the TOR/FM. The testing included performing the Penn State microoxidation test that is used to measure volatility and deposit forming tendencies of the TOR/FM. Evaporation tests were used to indicate whether or not the TOR/FM would leave behind a residual film, and pressure cylinder tests were conducted to determine if sufficient volatile products were generated by the TOR/FM during the test. The basic conclusions of the Penn State studies were that (1) unless heated to very high temperatures (300°C or more), the TOR/FM does not leave a residual film, (2) any liquid residue that could accumulate in the soil, should biodegrade, and (3) no environmental problems with the TOR/FM decomposition products were detected during the analyses. In summary, the TOR/FM offers a new and higher level of environmental compatibility among rail lubricants.

Observations made during the tests and analyses of the test data lead to the following conclusions:

- *Train Handling*: The use of the TOR system did not appear to negatively affect either train handling or speed control. This was evidenced by consideration of the average speeds, notch dwell times and the number of throttle position changes through comparable test zone segments. Interviews with personnel associated with the test confirm this finding. The locomotive road foreman in charge of tests, Mr. Lane, reported that he likes the system due to improved train handling, including a smoother ride.

- *Braking Performance*: Braking performance was found to be safe for the FM rate employed during this series of tests. Stopping distances were approximately the same with and without FM rail conditions for full service and emergency braking of loaded and empty trains. This was evidenced by measured distances as well as the same distances corrected for grade and power application. Full service brake applications showed a decrease in stopping distance when employing the TOR friction modification, with average reductions on the order of 200 feet. It should be emphasized that these particular results pertain to these tests and that reductions of this magnitude are not necessarily universal. There was no occurrence of wheel slip during any of the 13 braking tests conducted.

- *FM Distribution and Consumption*: Results from top of rail tribometer surveys were mixed, with some surveys showing no change in friction coefficients measured on the rail following the passage of the test train and some showing a decrease in measured friction coefficients. On a few occasions, a thin film could be felt by touch of a finger on the rail head after the test train had passed. While several decreases of friction coefficient, ranging between 0.03 and 0.30, were measured during the surveys, friction coefficient measurements made at the designated curve location revealed no significant difference between the changes in friction due to the passage of normal revenue trains and changes in friction corresponding to the passage of the test train employing the friction modification system. Based on measurements made at the curve site that focused on normal revenue service trains, average friction coefficient measurements ranged between 0.37 and 0.56 before the train passage and between 0.27 and between 0.21 and 0.48 after train passage. In comparison, measurements made at the same location for trains employing TOR/FM ranged between 0.31 and 0.51 before the passage of the trains and between 0.27 and 0.45 after the passage of the trains. Engineers operating pusher locomotives used for the fifteen mile 1% grade found the operation of the locomotives to be quite normal when assisting the test trains using the TOR/FM. Subsequent trains did not report anything unusual throughout the test zone; however, systematic reports from subsequent trains were not gathered.

- *Energy Savings*: Performance related issues focused largely on energy expenditures with savings being determined using a variety of methods. Energy savings for a round trip of the test train ranged from 4.20% to 11.11%, depending on the method of evaluation used. The average energy saving for a round trip, found by averaging the results from different methods, was determined to be 7.83%. There was a 7.74% saving in fuel consumption realized when results from comparable test segments were combined for a round trip (i.e. by disregarding results form segments where the train was operated in significantly different manners.) It should be kept in mind that electrical energy results were based upon two locomotives. It must be emphasized that differences in performance of the test train between the runs with and without FM were determined as a percentage above the levels obtained by using wayside and flange lubrication.

Information related to the following issue was not observed during this series of tests:

- *Wheel/Rail Interaction*: An evaluation of the effect of the TOR/FM on curving forces based on this series of tests was not possible. This was due to the employment of wayside lubrication in the vicinity of the instrumented curve and data acquisition system problems. No evidence of truck instability was observed during the tests and, therefore, no conclusion could be drawn regarding the effect of the TOR/FM on the critical speed for truck hunting. During the series of tests, speeds were restricted to 40 MPH, a speed below that necessary to develop hunting under either "dry" or with FM rail conditions.

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FURTHER DEVELOPMENTS IN TOP-OF-RAIL FRICTION MODIFICATION TESTING

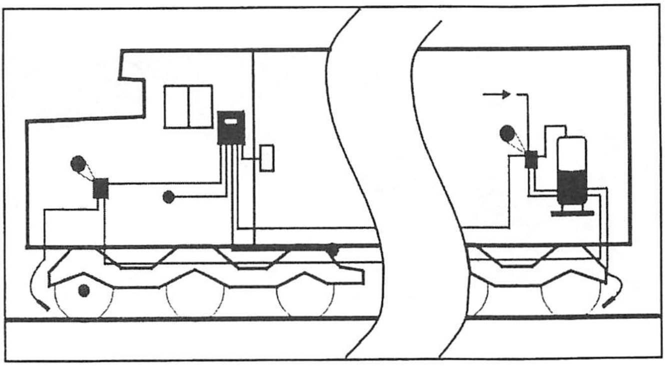
by:
Kenneth Davis CSX Transportation
Sudhir Kumar Tranergy Corporation
Greg Sedelmeier Equilon Enterprises

LMOA Meeting
September 2000

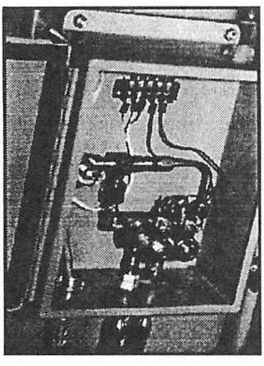
WHAT IS SENTRAEN 2000™?

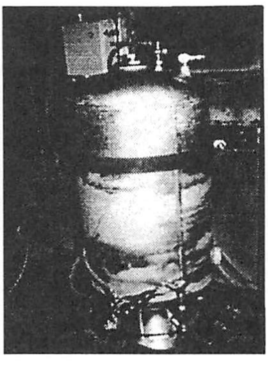
- Sentraen 2000™ is a friction modification system that applies an environmentally safe, consumable friction modifier (FM) on both rails after the last axle of a locomotive.
- The quantity of FM applied is precisely calculated and controlled such that it is consumed by the time the train has passed.

INSTALLATION LAYOUT OF TOR SYSTEM

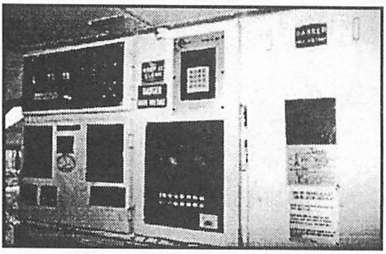


SOLENOID BOX & TANK

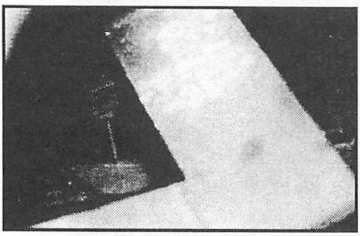


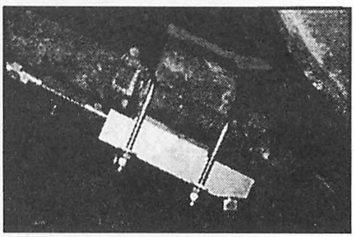


COMPUTER CONTROL & CURVE SENSOR



FM JET ON RAIL & NOZZLE HOLDER





FACTORS THAT CONTROL FM APPLICATION

- Train Speed
- Weight of Train
- Locomotive Position/Orientation in Consist
- Automatic Brake Status
- Track Curvature
- FM Temperature

CURRENT PAPER

- Top of Rail Friction Modifier (TOR)
- Testing on CSX revenue trains conducted by ENSCO, Inc. under the sponsorship of Federal Railroad Administration (FRA) and U.S. Dept of Energy (DOE)

OBJECTIVE

- Test the TOR system in field service under a range of operating parameters to study Safety and Performance related issues.

SAFETY RELATED ISSUES

Effects of the system on:

- Train handling/speed control
- Braking stop distance and wheel slip
- Subsequent traffic due to any FM residue on rails after train passage
- Lateral curving forces

PERFORMANCE RELATED ISSUES

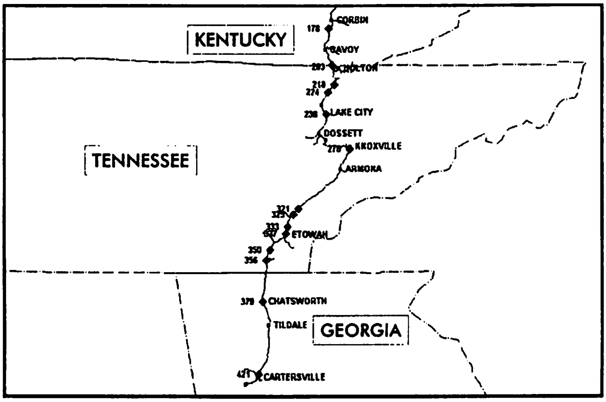
- Energy savings
- Effect on truck hunting

BASELINE CONDITION & IMPROVEMENTS

- The dry or baseline condition was considered one in which both Wayside and Flange lubricators were fully operational
- When the TOR system was turned on, performance improvements were measured as a percentage above the levels obtained by using wayside and flange lubrication

MAP OF TEST ZONE

CSXT Stilesboro 90 Coal Car Train Route - 12 segments



TEST MEASUREMENTS

- Fuel consumed
- Mechanical energy through an instrumented drawbar
- Electrical energy
  - Calculated through locomotive notch dwell times
  - Measurement of current and voltage in the motors providing electrical energy
- Tribometer readings before and after FM train
- Stop distance during full service and emergency braking

FRICTION MODIFIER

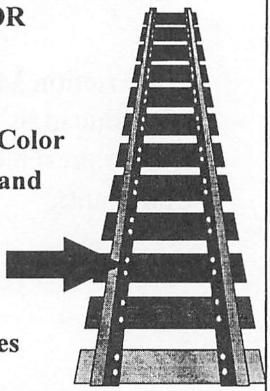
The Friction Modifier (FM) called "Railstar TOR" is produced by Equilon Enterprises, LLC. Details will be presented by Greg Sedelmeier of Equilon Lubricants.

PROBLEMS WITH TRADITIONAL MEANS OF RAIL LUBRICATION

- **Applicator Maintenance**
- **Excessive Grease Usage**
- **Loss of Traction due to lube migration**
- **Environmental & Safety Concerns**
- **<u>High Lateral Creep Forces (*Root Cause*)</u>**
  - **Rail/Wheel Wear (possible Gage widening)**
  - **Increased Friction**
  - **Excessive Fuel Consumption**
  - **Increased Maintenance Costs**

EQUILON FRICTION MODIFIER/ TOP OF RAIL LUBRICANT CHARACTERISTICS

- A Water-Glycol fluid known Railstar TOR
- Applied directly to Rail Crown
  and consumed at Wheel/Rail Interface
- Clear and Bright Fluid with Teal Green Color
- High Wetting ability with good mobility and durability
- Viscosity @ 40 °C = 17.5 cSt
- Environmentally Friendly; No Solids
- Usable over a wide range of Temperatures



FRICTION MODIFIER - TOR LUBRICANT DEVELOPMENT & FIELD TESTING OVERVIEW

- 1993
  - Basic Product Composition Identified
  - Used in First Conceptual Field Test (Dec 93)
- 1994-1995
  - Enhanced Low Temp Properties of FM/TORL
  - Addition of Rust Inhibitor
  - Extensive Toxicology Testing
  - Successful Field testing of the first prototype TOR system with FM/TORL

FRICTION MODIFIER - TOR LUBRICANT DEVELOPMENT & FIELD TESTING OVERVIEW (CONT.)

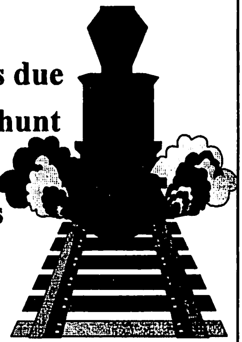
- 1996
  - Patent granted for formulation
  - Revenue Service testing of full system by NS
- 1997
  - Developed improved current formulation
  - Initial Revenue service testing of full system with current formulation
  - First series of tests at AAR-TTC

FRICTION MODIFIER - TOR LUBRICANT DEVELOPMENT & FIELD TESTING OVERVIEW (CONT.)

- 1998
  - Testing of product by
  - Revenue Service testing of full system by
  - Second series of testing at AAR-TTC
- 1999
  - Commercialization of FM/TORL
  - Initial Revenue service testing of full system by Union Pacific

MAJOR BENEFITS OF USING THE FM/TORL WITH THE SENTRAEN 2000 SYSTEM

- Improved Fuel Savings above that of conventional rail lubricants (5-20%)
- Potential Reduction in Derailments due to a decreased tendency of cars to hunt
- Increased Rail Wear Life
- Reduced Track Maintenance Costs
- Increased Train Productivity
- Reduced Loss of Shunting Signal



CONCLUSIONS

Train Handling

- Using the TOR system with "Railstar" TOR-FM did not appear to negatively affect either train handling or speed control.
- Interviews with personnel associated with this aspect of train handling confirmed that there was improved train handling, and a smoother ride.

CONCLUSIONS

Braking Performance

- Stopping distances were approximately the same with and without FM for full service and emergency braking of loaded and empty trains.
- Full service brake applications showed a decrease in stopping distance while using TOR/FM, with average reductions of the order of 200 ft.

CONCLUSIONS

Adhesion Coefficients and Subsequent Train Performance

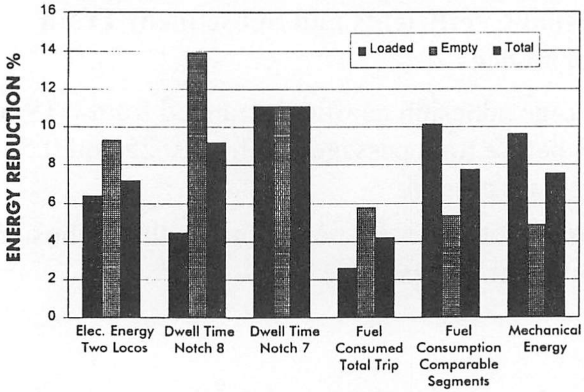
- Average adhesion coefficient ranged from 0.19 to 0.68 before train passage and from 0.25 and 0.53 after train passage
- Subsequent trains did not report anything unusual throughout the test zone

CONCLUSIONS

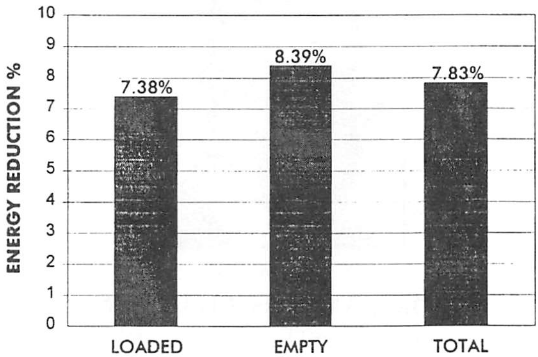
Energy Savings

- The average energy savings for a round trip, found by averaging the results of different methods was determined to be 7.83%
- Results from comparable test segments showed a 7.74% savings in fuel consumption

ENERGY REDUCTIONS
Using Various Methods



AVERAGE ENERGY REDUCTIONS
Various Methods



CONCLUSIONS

Wheel/Rail Interaction

- Evaluation of the effect of TOR FM on curving forces was not possible due to the closeness of wayside lubrication to instrumented curve and data acquisition problems
- No evidence of truck instability or hunting

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

TUESDAY, SEPTEMBER 19,2000
9:00 A.M.

Chairman
BOB REYNOLDS, CHAIRMAN
Locomotive Electrical Specialist
Canadian Pacific Railway
Calgary, Alberta

Pre-Convention Presentation: Southern & Southwestern Rwy. Club

July 21, 2000
St. Augustine, FL

Vice Chairman
DAVE PERKINS
Electrical Project Manager
Montana Rail Link
Missoula, Montana

COMMITTEE MEMBERS

R. Bartels	Mgr.-Electrical Systems	Via Rail Canada	Montreal, PQ
D. Becker	Design Engineer	Electro Motive Divn.	LaGrange, IL
J. Chessario	Program Manager	GE Transportation	Erie, PA
J. Estes	Manager-Electrical	Union Pacific RR	No. Little Rock,
D. Freestone		Alaska RR	Anchorage, AK
K. Gazarov	Mgr-Elecrical Engineering	CSX Transportation	Jacksonville, FL
K. Gilbert	Director-Loco. Sales	Alstom	Montreal, PQ
D. Haffner	Director-Diesel Locos.	Amtrak	Beech Grove, IN
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PERSONAL HISTORY

Bob Reynolds
Locomotive Electrical Specialist
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. His hobbies are electronics and hiking in the Canadian Rockies.

I. CUSTOM ELECTRONICS AND THEIR APPLICATIONS

By: Ron Bartels
VIA Rail Canada

1. Introduction

A lot of well-built and well-engineered electronics products are available for use on locomotives today. They can be simple diode assemblies, complete locomotive logic, excitation, and wheelslip control systems, or anything in between. They perform a wide range of functions such as suppressing voltage spikes, regulating voltages, displaying speed, recording data for accident investigations, and controlling the main generator excitation or air brake systems, just to mention a few. On top of that, these products are also generally quite reliable.

This paper is not about all the electronics products for locomotives that are available today. It is about the electronics products that are not available for purchase from any supplier, but are custom made to fill a particular need. It also describes one of the custom products that VIA Rail is currently testing on one of its locomotives for eventual fleetwide implementation.

2. Why Custom Electronics?

The main reason for buying custom electronics products is to meet specific needs that cannot be met by using or adapting products that exist or are in development. These needs may be due to special operational or climactic conditions on a particular railway, an obsolete product whose function is not obsolete and that needs to be replaced, or a vision that requires using technology that is not commonly used by railway suppliers.

3. Advantages

There are enough advantages in having electronics products custom-made to justify the concept, in many but not all cases.

3.1 The Right Product

The biggest advantage in a custom product is knowing that it will perform all the desired functions and meet all requirements of the project, without having surplus features that cost money but are not needed. This is particularly true when the device is expected to monitor and control a variety of parameters that are not necessarily related, such as VIA's locomotive module, which will be described later. This advantage applies in cases where the custom product is designed to replace an obsolete product or to meet a new requirement. If it is replacing an obsolete product, it also presents an idea opportunity to design out any of the undesirable characteristics that the old product may have had.

3.2 Cost and Availability (obsolete products)

Products become obsolete for two main reasons: either the product or its replacement parts are no longer available or lead times become too long, or the old technology becomes prohibitively expensive to maintain. Replacing an obsolete product with a modern custom-made product using up-to-date technology will almost always reduce the cost of spare parts and replacements, and at the same time, solves the problem of parts availability.

3.3 Employee Involvement

Although it is not a tangible benefit, the railway employees, who are involved in defining developing, testing, and finally installing a custom product will inevitably become very involved in the process. They will have a better understanding of how the system works, which can help speed up troubleshooting. Also, the lessons they have learned throughout their career will help make it a better product, in terms of features, performance and maintenance requirements, more so than if it was a standard purchased item. In the past when we have had custom products made for VIA, the fact that the railway employees were directly involved in their development was a big reason for the success of those products.

4. Disadvantages

Along with the advantages, there are some disadvantages to buying custom electronics.

4.1 Cost

A custom-made electronics device may not have a huge market, especially if it is designed to meet a very specific need. Because of that, it will normally cost more than a mass-produced item. The development costs will represent a bigger percentage of the total cost of the product than for an off-the-shelf device. Also, production costs will be slightly higher because of the smaller quantities and reduced economics of scale. This has to be taken into account at the justification phase of the project. In many cases, these extra costs can be reduced by a well thought out design using proven modern technologies. In some cases, the supplier may be able to reduce the cost by reusing part of the design on other products and only applying a portion of the total development costs on the custom product.

4.2 Demands on Technical Personnel

Making a custom electronics product work and preparing for fleetwide installation requires a lot of effort from the personnel in the technical group of the Equipment or Mechanical department. They have to provide information to the supplier, participate in design reviews, and install and test prototypes, much more so than when installing or adapting an existing product. There is also the possibility that they will have to prepare for retrofits, either hardware or software, to correct

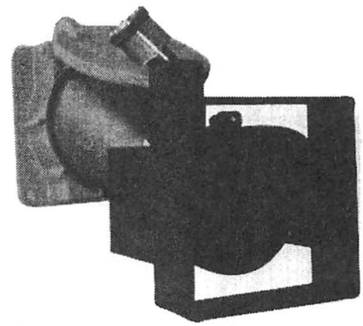
Model LM-1
The Locomotive Marker Light

FRA APPROVED
RED FLASHING LIGHT

PLUGS INTO THE
MU RECEPTACLE AND
BEGINS FLASHING
IMMEDIATELY!

POWERED BY THE
LOCOMOTIVE'S BATTERIES

LIGHT WEIGHT EASY TO
PLUG IN AND TAKE OUT
CAN BE LOCKED IN PLACE



USED AT THE REAR OF THE TRAIN:

The #LM -1 Locomotive Marker Light simply plugs into the MU receptacle to provide a flashing red light for the rear of locomotives working as pushers or helpers. It also can be used on locomotives operating singly or on Tenders or Slugs. The light is powered by the locomotive MU connection and therefore requires NO separate batteries to cause inventory, maintenance, and disposal problems. The light is housed in a high impact Lexan Case and has a red lens plus a visor for improved visibility during daylight hours. The housing is surrounded by a steel guard and the assembly is mounted on a modified MU connector.

ADVANTAGES

While locomotive headlights may be used in this type of operations, the locomotive Marker Light has distinct advantages :

- Headlights are confusing.
  Crews, track workers, and vehicle drivers cannot tell which way a train is moving.
- Headlights bother the vision of engineers on oncoming trains.
- Can be more easily seen in bad weather such as rain and snow storms, fog, and on overcast days.
- Up to 4 mile visibility range.

SPECIFICATIONS:

Light:	High Impact Lexan Housing with Red Lens & Visor. Steel "Surround" Guard.
Bulb:	GE #1141, 18 W 5000 hrs. at 15% duty cycle; 100 candela.
Weight:	10 lbs.
Warranty:	2 years (with the exception of bulb)

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071096

problems that are noticed only after a number of units have been installed.

5. Improving the Chances of Success

5.1 Do You Need Custom Electronics?

To improve the chances of success of the project, and assuming that funding is available, the first thing to do is determine if you really need a custom product. Begin by checking with suppliers of railroad electronics to see if there is already a product in existence or in development that meets or is close to meeting the needs of the project. If so, a custom product is probably not needed.

If no product exists that meets the needs of the project, the best thing to do is inquire at other railroads to see if they have the same needs. If more than one railroad has the same or similar needs, then it would be easier to convince one or more suppliers to create a product that meets those needs. When it becomes obvious that you are the only railroad with a specific need in an electronic device, then custom electronics is the best solution.

5.2 Definition of Needs

It is very important to define the needs of the project very closely in writing, in terms that both railway and supplier personnel can understand. If the requirements change or grow during the project, the changes must be documented as well. The best way to ensure that both parties understand each other well is to have face-to-face meetings, or design reviews, and document the discussions. Because words on paper can easily be interpreted in more than one way, this will ensure that everyone involved interprets them in the same way.

5.3 Definition of Responsibilities

The responsibilities of the railway and the supplier must be very clear, particularly for the production run. The scope of supply is often different at the prototype stage than at the production stage. During the development and prototype stages of the project, the relationship between the railway and supplier personnel can become much like a partnership where they work together very closely, usually more than during production unit delivery. During the prototype stage, one of the partners may absorb some unexpected costs such as a connector or cable harness to simplify the paperwork. Sometimes this is cheaper than formalizing these cost details. However, these details must be specified clearly for the production units. A $300 unexpected cost on a prototype is not likely to break the budget but if it is repeated on 300 units, the effects are much greater.

Another important item to consider is the supply of user and maintenance documentation and any special test equipment, if applicable. It is worthwhile even to specify the type of information that is expected in the documentation because interpretations of the contents of different types of manuals vary a lot from one organization to another.

5.4 Design Ownership

The issue of design ownership must be included in the contract between the railway and the supplier. If the design belongs to the supplier, it becomes simply a matter of managing the warranty, spares, and repairs for the railway, once installations are complete. Otherwise, if it belongs to the railway, agreements can be made with the original supplier, or other suppliers, to benefit from potential future sales of the product or of products that are based on it. These benefits can be in the form of royalties or lump sum payments.

5.5 Finding the Right Supplier

The supplier who will design and build the electronic equipment has to have extensive experience in designing and building electronic devices for the railroad industry. Very few companies without this specific experience will succeed the first time in designing a reliable electronics product for locomotive applications. The supplier also has to have technical personnel that can be dedicated to the project. Otherwise, although the project may eventually be a technical success, it will take much longer than expected to complete.

6. VIA's Locomotive Module

One custom electronic system that is currently being designed for VIA is call the Locomotive Module. Its name doesn't describe any of its functions because it performs several functions that are, in many cases, unrelated. Initially it began with a specific purpose that could not be met with any existing products on the market. Once it was decided that the project would go ahead, it grew considerably when we realized what could be accomplished with modern technology at a reasonable cost.

In order to understand the origin of the locomotive module, some background is required. VIA has no short or medium term plans to replace its existing cars or locomotives. To improve the availability of our equipment, we have decided to retrofit a train monitoring network using Lonworks® technology to provide better troubleshooting information. At the same time, we are gradually replacing unreliable and obsolete control and monitoring systems, mainly on our passenger cars, with new microprocessor-based Lonworks® compatible systems. The systems on each car "talk" to a car binding module (or car module) which links them together. Any fault information generated by one of these systems on a car is transmitted to the car module via the car network. The car module then sends this information via the train network to the locomotive module.

The locomotive module was created mainly to be able to link all the cars together and provide a central point for communicating train-related faults to a pre-determined remote location. It is actually a series of five separate modules linked together via the locomotive network, with one of the modules acting as a link between these five modules, the car modules, and the outside world. See Figure 1 for an illustration of how the network control systems, the car modules and the locomotive module communicate amongst each other and to remote locations.

6.1 Primary Functions

The original purpose of the locomotive module was to function as a:

1. Binding module for any new Lonworks® compatible systems on the locomotive;

2. Train network binding module, linking all the car module together;

3. Remote communications link for the train. All train faults will be communicated by cellular and/or satellite telephone to a telephone, pager or computer;

4. Speed signal source for the train. Some systems on the passenger cars need ground speed signals. With a central source we will be able to eliminate distributed speed signal sources, i.e. axle generators or doppler speed sensors;

5. Signal source for trainline continuity monitoring. A high frequency (<100kHz) sinusoidal signal will be superimposed on the head end power control trainlines to be monitored by the car modules. If a car does not receive the signal, we will know at which car the trainline is incomplete. Presently, we only know when the trainline is incomplete but not where. With trains approaching 30 cars in length with four HEP cables between the cars, it can take a long time to find a trainline continuity problem. The feature will save a lot of time in finding the defective connections or cables.

Since the heart of a microprocessor-based system was already going to be installed just to perform the primary functions, adding other important features could be done at a smaller incremental cost. We therefore decided to use the locomotive module also to improve the interface between the operating crew and the locomotive, improving the information available to the Maintenance department, and eliminate unreliable or maintenance-intensive features of the F40 locomotive.

6.2 Crew Interface/Information

The following features were added to improve the crew interface with the locomotive and the information available to the Maintenance department:

1. Locomotive warning panel. The existing warning panel, which consist of 20 LED indicators, has a high failure rate and does not provide any more information than an illuminated LED. It will be replaced by an electroluminescent display that will show text messages with the type and severity of alarm and on which car or locomotive it is happening. It will also have the ability to give pre-programmed instructions to the crew for various types of alarms. One of these warning panels has been in service since May, 2000, with excellent results. See Figure 2 for a view of the display with a sample of alarm messages that can be displayed.

2. Event recorder download capability. The warning panel portion of the locomotive module will be permanently connected to our future event recorders to allow remote downloading from any location with a telephone connection.

3. Global Positioning System (GPS). The GPS will allow us to know the exact position of our trains, have a back-up for the train speed signal, and provide a position stamp to all alarms that occur.

4. Printer output. Currently there is no use for it. It is there in case VIA decides in the future to send train orders to locomotive crews that they can print out in the locomotive cab.

6.3 Maintenance Aids - Monitoring

We will be monitoring the following items to indicate when a device is out of specification or trending towards failure:

1. Dynamic brake ground fault detection. Currently, if there is a high voltage ground fault in the dynamic braking circuits, we don't know until we test with a megohmmeter. This feature will continuously measure the integrity of the insulation of the dynamic brake circuits when they are in operation and send two types of alarms: one when the insulation is deteriorating and a more severe one once it has failed.

2. Motoring/braking (MB) motor current. On an EMD F40 passenger locomotive, the motoring/braking transfer switch gets a lot of use because of the blended braking. With more than a minimum reduction on the automatic brake, the dynamic brakes supplement the air to reduce wheel heating and wheel and brake shoe wear. If the transfer switch motor assembly fails, usually the

locomotive is disabled unless the transfer switch can be manually repositioned. The purpose of monitoring the current is to predict that the motor or contact block is degrading and change it out before it fails.

3. Companion alternators (CA5) output voltage. Locomotives have been found with CA5 alternator voltages that are about 20% too low. If the output voltage of the CA5 alternator is too low, the cooling fans will draw too much current and overheat. To prevent this, the CA5 output will be monitored and an alarm will be posted if it is too low.

4. Main generator bearing temperature and vibration. Main generator bearing failure can lead to extensive damage to the AR10 alternator. We will be acquiring both bearing vibration and temperature on the AR10 bearing on the prototype to determine which is the more dependable method. A decision will be taken on the production units once we analyze the data.

6.4 Maintenance Aids - Control

The locomotive module will control the following functions, for the reasons explained below:

1. Compressor unloader. A pressure transducer to control the compressor unloader will replace the compressor control switch. The transducer will never need adjustment and provides more information than just a switch.

2. Low main reservoir pressure alarm. An alarm will be posted on the locomotive warning panel in the cab when main reservoir pressure drops below a programmable set point. This alarm will use the same transducer as the compressor unloader function.

3. Engine temperatures - fans, shutters. A temperature transducer that never needs adjustment will replace the temperature switches. Instead of switching on the fans at pre-determined temperatures, the objective is to operate the engine in the same temperature range all year round.

4. Blowdown timer. The electric blowdown timer (EBT) function will be replaced by a timed output on the locomotive module. The existing timer module will be removed.

5. Rated load timer. The rated load time delay relay (RLTD) function will be replaced by a timed output on the locomotive module. The existing time delay relay will be removed.

6. Winterization time delay. This is a new 30-minute time delay function to coincide with replacement of the inertial filter screens with moisture

separators. We will disable the winterization feature and only use it as back-up if the inertial filteration system is plugged. Every 30 minutes, the system will revert to normal to check if the inertial filteration system has unplugged itself.

6.5 Troubleshooting Tools

Some troubleshooting tools will be provided to help diagnose difficult or intermittent problems:

1. Alarm log. The alarm log will store a snapshot of all measured parameters at the time of an alarm, as well as for a period before and after the alarm.

2. Built-in datalogger. A built-in software-configurable and password-protected datalogger will allow regular recording of any parameters monitored by the locomotive module. This will be useful for intermittent problems and for gathering information to help make informed decisions.

Both of these features require generous amounts of memory. This is not seen as a problem because the locomotive module will have 16 megabytes of RAM, about half of which will be used, and will be expandable to at least double that amount.

In addition to having spare memory capacity, there will be spare input and output capacity to allow monitoring and controlling other parameters as our needs evolve in the future.

7. Conclusion

In the particular case of the VIA locomotive module, with its Lonworks® compatibility and multitude of functions, a custom electronics system was the only way to meet all the requirements listed above. There are no products available that even closely resemble it, without having many more features that are not required. We are prepared to devote the effort required to make it work and the cost information we have so far is encouraging. We will also benefit tremendously from the elimination of unreliable and maintenance-intensive parts and from the information that will be available to the Equipment Maintenance department. At VIA, we are confident that for the locomotive module, custom electronics was the right approach.

Acknowledgements

I would like to thank Andre Milot, Bill Barclay, Martin Gendron, and Michel Blais of the VIA Rail Equipment Maintenance department, without whom this paper could not have been written.

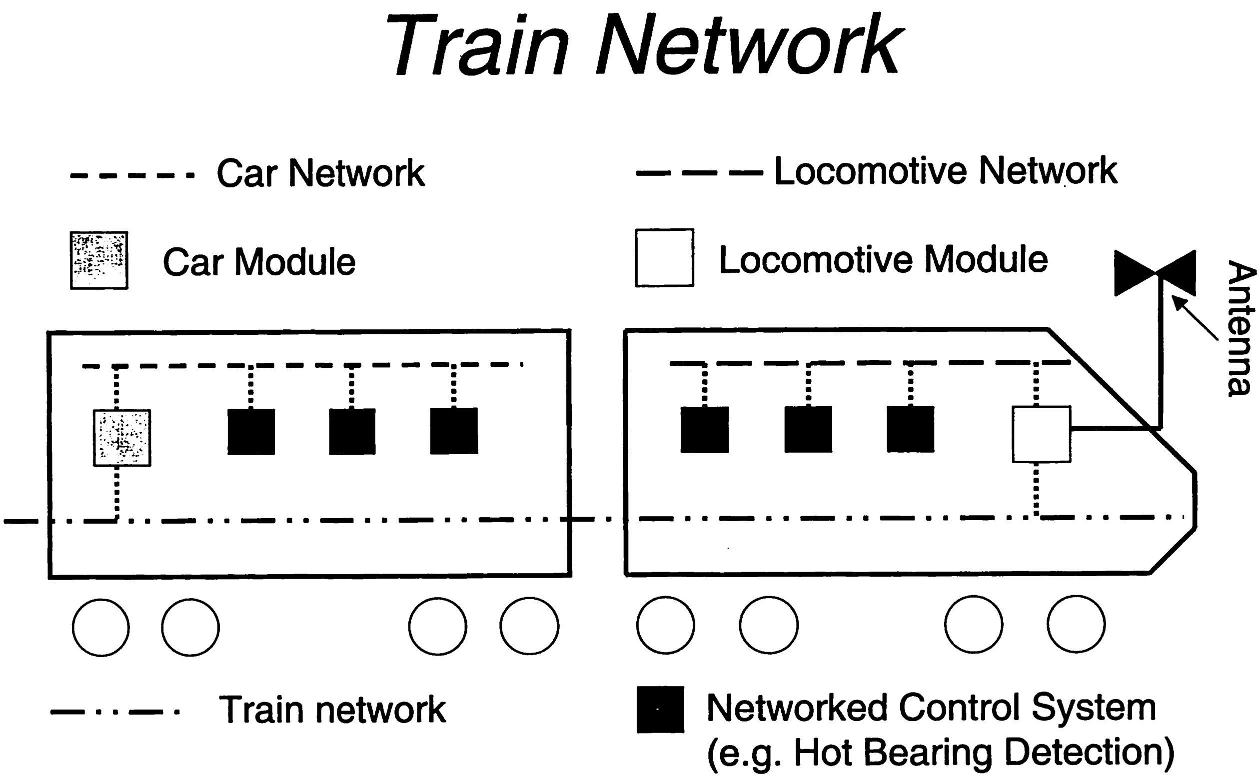


FIGURE 1 TRAIN NETWORK

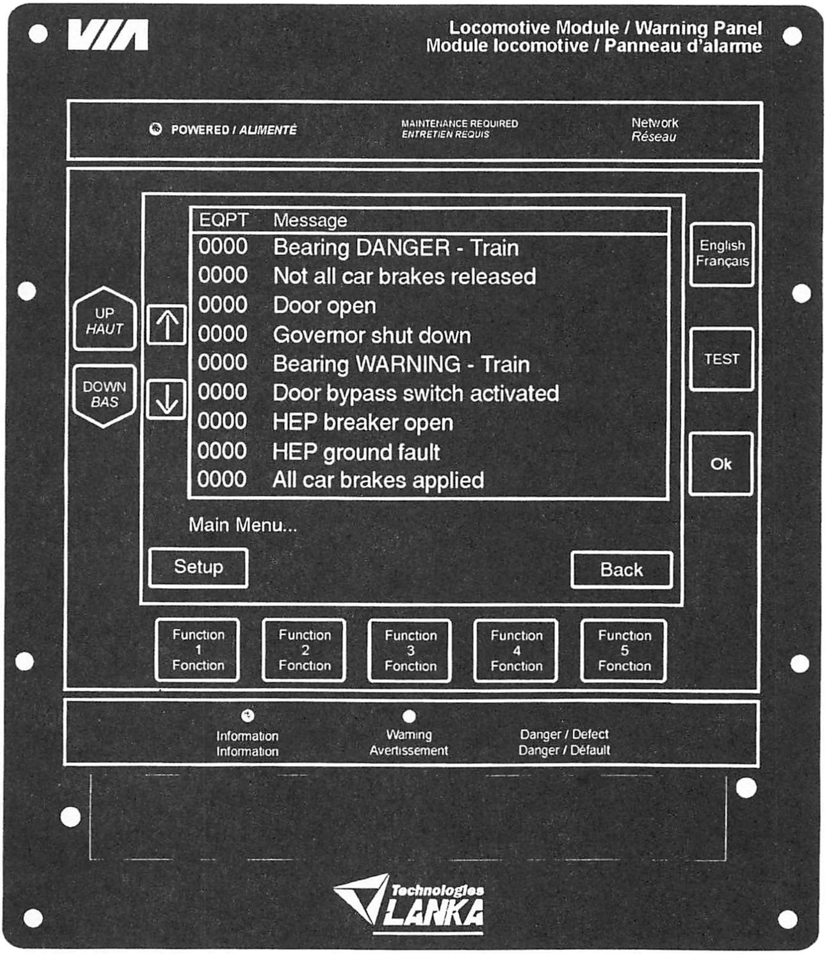


FIGURE 2 LOCOMOTIVE WARNING PANEL

II. LOCOMOTIVE WIRE UPDATE

By: Dave Perkins,
Montana Rail Link, Inc.
Missoula, Montana

Without a doubt, the most important and frequently overlooked component in today's locomotive is its writing. While the "wiring" is not a component by definition like traction motors, brake grids, power assemblies or other similar devices, it can be thought of as the link by which many of the other locomotive components are connected. If this link is "weak", then failure can result. Just one wire failure for any reason can stop a locomotive dead in no time at all.

Locomotive Wire Environment

Wire used in locomotives is subject to some of the worst conditions possible. It must be tough, flexible, operate under a wide range of temperatures, resistant to grease and oil, water resistant, and highly flame retardant. In addition, locomotive wire is expected to have a long life and be somewhat reasonably priced. While there are many types of wire on the market that will meet some of the above mentioned conditions; only certain versions of crosslinked polyolefins currently meet all of these conditions.

Several wire manufacturers make crosslinked polyolefin insulated wire; however, Exane® as made by the Rockbestos Suprenant Cable Corp. is the current O.E.M. standard for both EMD and GE locomotives.

Locomotive Wire Criteria

1. Tough-Locomotives operate in a heavy industrial, high vibration environment. While some parts of the wiring system in locomotives are protected in cabinets and conduits, other sections such as traction motor feeds are exposed and unprotected from physical protection and abrasion. If the insulation is not tough enough to hold up to this exposure, an open exposed conductor would be the result creating a number of unwanted and dangerous conditions.

2. Flexible-Locomotive wire must be somewhat flexible to easily make the tight bends that it is required to make inside cabinets, boxes, and conduit fittings. It must also have flexibility to hold up to continuous vibration. If locomotive wire is too stiff, vibration can cause a failure. Sometimes the copper conductor can break under the insulation and this condition will not be at all visible making it difficult to troubleshoot. Locomotive wire flexibility is maintained through the use of type ASTM B 172 and B174 stranding along with the flexibility of the crosslinked polyolefin insulation.

3. Wide temperature range-Locomotives operate over an

extremely wide ambient temperature range. They operate in winter climates that can go as low as -45° C (-50°F). They also operate in summer climates that can be as high as 50° C (122°F) in the hot deserts. In addition to the ambient temperatures, temperatures in certain areas of a locomotive can get much higher than 50°C due to all the heat generated within the carbody by the prime mover, air compressor, and various electrical components.

4. Resistant to Oil and Grease - No matter how clean a locomotive is kept, there will always be places where the wiring will come in contact with various oils and greases. Various petroleum-based liquids chemically attack many products used for wire insulation. Over time, the insulation will break down and lose its resistive insulating ability. Some insulations will even swell up, turn into a gel type material, and even fall off the conductor. Traction motor feed cables are especially prone to grease and oil damage due to their open exposure.

5. Water Resistance - Many areas of locomotive wiring systems are subject to water, whether intentional or not, and where exposed, even to soap compounds. Many insulation compounds get saturated with water and the resistive value of the insulation breaks down to the point where the insulation has actually failed. Today, since many railroads or their contractors use high-pressure washers to wash their locomotives, water and even soap tend to adhere to the wiring at many locations. Locomotive wiring must be a highly water resistant over a large temperature range to assure long reliable service.

6. Flame Retardant - It is imperative that locomotive wiring be highly flame retardant. Should the wire become exposed to a severe overload such as in a direct short situation or become exposed to open fire or flame it must not be capable of sustaining a fire by itself. If it did, massive fire damage and/or severe personal injury would be the result. Locomotive wire must also be classed as low smoke to minimize toxicity to humans.

7. Long Life - Since the life span of the typical locomotive is 25 to 50 years, the wire used in it should, under normal conditions, also last that long. Rewires and major wiring repairs are expensive in terms of both material and especially labor. In addition, unit downtime must be considered while the unit is out of service for repairs.

8. Reasonable Price - There is no doubt that any special wire made to fulfill the seven criteria listed above will cost more than

any common automotive, building, or general purpose wire on the market. However, where long life is required, overall reliability will usually outweigh the additional cost factor.

To sum up the above criteria, a good locomotive wire must stand up to day to day heating and cooling cycles, be oil, grease, and water resistant, flame retardant, stand up to vibration, provide long life, and not be too costly. Crosslinked polyolefin, and especially Exane insulated wire, meets or exceeds all of the above criteria and has done so for almost 30 years.

History of Locomotive Wire

In the very early days of the diesel electric locomotive, builders used what was commonly known as textile braid over rubber insulated wire. It quickly became apparent that this insulation was not very oil resistant and soon, in the late 1930's, neoprene began to be used as the insulation material.

Neoprene was a drastic improvement over textile braid insulated wire but there was still room for improvement. Hypalon slowly came into the picture to replace neoprene due to its better stability. As the nation's railroads dieselized and many of the early units were experiencing electrical failures, it became apparent that the insulation was breaking down for not one, but several reasons. They were oil, grease, and water saturation, heat damage (cracking and meltdown) and general limited life. It was obvious that a better wire insulation was still needed.

In early 1970, EMD contacted the then ITT Suprenant Cable Corp. to help solve the problem with wire insulation failures. Within a period of about 18 months, a wire with crosslinked polyolefin insulation given the trade name "Exane" was developed. A short time later, Exane became EMD's standard for most power and control circuit wiring. Somewhat later, in the 1980's, GE began using Exane for most of its locomotive wiring too.

What Exactly is Crosslinked Polyolefin Insulation?

Crosslinked Polyolefin wire insulation can be defined as a special thermoplastic material that through the cross-linking of the molecular structure becomes thermoset when exposed to high-energy radiation. Once this material goes through the cross-linking process, the result is an insultation material that has much greater resistance to heat and superior physical strength. A perfect combination for locomotive wire.

Important Definitions:

1.Polymer - A large molecule built up by repetition of many smaller chemical units.

2. Polyethylene (part of the polyolefin family of compounds) - Consists of a long chain of units each made with one carbon.

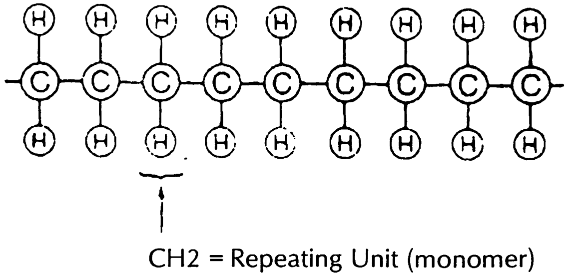


FIGURE 1. PORTION OF A POLYETHLENE MOLECULE MADE OF REPEATING UNITS OF CARBON AND HYDROGEN.

atom with two associated hydrogen atoms (Figure 1). An actual polyethylene molecule is approximately 5000 units in length. Polyethylene actually consists of many random molecular chains with no chemical bonds existing between the chains.

3. Thermosplastic - Polyethylene after it has been heated and the chains are free to slip and flow with a relatively small outside force.

4. Cross-linking - The covalent or chemical bonding which take place between the polyethylene molecule units after being subject to irradiation.

5. Irradiation - A process of bombarding the insultation with high-energy electrons. In the case of polyethylene molecules, the irradiation energy will eject a hydrogen atom which then removes a neighboring hydrogen atom, forming molecular hydrogen gas (H_2). The vacant sites on the adjacement polymer chains then combine to create a crosslinked chain as illustrated in Figure 2.

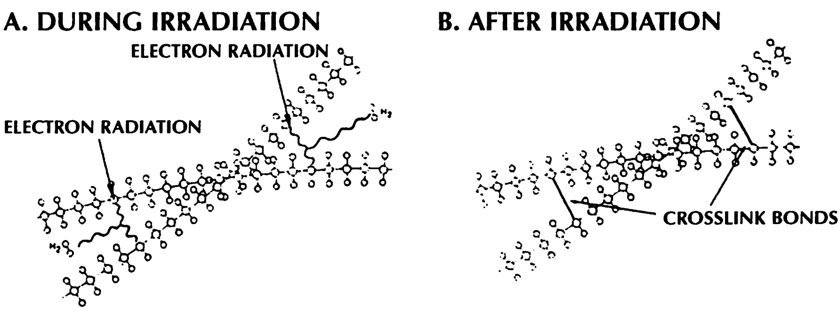


FIGURE 2: TWO RANDOM POLYETHYLENE MOLECULES DURING AND AFTER IRRADIATION CROSSLINKING.

Benefits of Crosslinking from the Irradiation Process:

1. Higher tensile strength
2. Improved abrasion/cut through resistance.
3. Better crush resistance
4. Soldering iron resistance
5. Resistive to stress cracking
6. Improved fluid resistance
7. Slightly better flame retardance
8. No change in electricals
9. Slight decrease in flexibility
10. Greatly improved high temperature mechanicals (increase of about 50° C)
11. Better overload characteristics.

How Exane Wire is Manufactured

Exane insulated wire is manufactured by similar methods as most thermoplastic wire except for the irradiation process. The conductor used for Exane locomotive wire is soft annealed tinned copper of adequate stranding to maintain flexibility. Typical stranding for #12 wire is 37/27. Stranding for 535 MCM 1325/24.

The conductor is run off the pay-off reel and is fed through the extruder where polymer pellets are fed into a hopper, heated to a point where it will allow the polymer to be extruded onto the copper conductor, then immediately cooled by water while it runs through a cooling trough. The wire then proceeds around a capstan, through a spark tester then reeled on the take-up reel. This reel is then taken to be run through the irradiation process where it is unreeled, run through the electron beam scanner and then re-reeled. After this process is complete, the wire goes through whatever testing is necessary and then to the warehouse for shipping.

Testing of Exane Wire

Exane wire is usually manufactured to one of two standards. One is DAA 1069A while the other is DAA 1093. EMD uses DAA 1069A and this is the most common specification used in locomotives. Listed below are typical tests that Exane wire must pass in order to meet the DAA 1069A specifications.

Mechanical Strength Tests

1. Physical properties - unaged (tensile strength elongation)
2. Physical properties aged - same as #1 above except cable has been in over 68 hours at 158°C
3. Tension set (pull apart 2 inch to 4 inch)

4. Crush resistance

5. Abrasion resistance

6. Impact resistance

High Temperature Tests

1. Heat resistance (96 hours at 175°C)

2. Insulation resistance (168 hrs at 158°C)

3. Insulation resistance as #2 above then cold shock at -40°C

4. Heat shock (225°C 1 hour)

5. High temperature test (8 hours at 225°C)

6. Long term heat resistance (500 hours 200°C)

7. Heat distortion (150°C 25% distortion limit)

8. 125°C Penetration test (10 minutes weight on edge of chisel)

9. Hot oil resistance test

Insulation Resistance and Stability Tests

1. Voltage withstand 5 min. after 6 hours in water at 6KV

2. 100% dielectric test

3. Insulation resistance in water (24 hours in water)

4. Insulation resistance (125°C air 2 megabhms/1000 ft. or higher)

5. Insulation resistance long term moisture

6. 90°C capacitance stability

7. Long term water absorption (16 weeks 90°C)

8. 5% salt water test

Electrical Overload Tests

1. Electrical overload single conductor (3 minutes)

2. Bundle overload (center wire of 7-wire bundle)

3. Current temperature cycle test (535 MCM cable 8 hours on 16 off 1,100 amps 25 times)

Flame Tests

1. Flame retardant test - vertical wire test (flame out in 3 seconds)

2. 70,000 BTU ribbon burner flame test (#8 and larger only)

3. Smoke generation

Flexibility Tests

1. Low temperature cold bend test (-55°C)

2. Low temperature cold shock (flex at -40°C)

3. Room temperature cable flexibility

Other Miscellaneous Tests

1. Two inch strip test
2. Minimum thickness - (90% of nominal)
3. Ozone resistance test
4. Relative humidity test (95% humidity 120 hour exposure)
5. Mineral spirits and fuel oil test (100-hour exposure swelling limit 10%)
6. Moisture absorption
7. Corrosion test at 175°C
8. Acid generation test

Exane has passed all of the above tests upon initial production runs for each given size. After the initial qualification tests, periodic re-evaluations are made at 2-year intervals. In addition, lot acceptance tests are done based on footage of cable produced and wire size. Laboratory tests can't always duplicate actual field conditions, but the DAA 1069A specifications pretty well cover most situations diesel locomotive wiring would typically be subjected to and then some.

Locomotive Wire of the Future

With the horsepower race of two major locomotive builders in full swing, both builders are always looking for improved products. Higher horsepower means higher voltage and current in locomotive power circuits. Rockbestos Suprenant Cable Corp. is currently working on an improved Exane insulation which will result in smaller wire O.D.'s, yet maintain all of the physical and electrical characteristics Exane is currently known for. In addition, higher temperature ratings are being pursued so that existing copper conductors, when designed and installed in the right applications, can handle higher current without the need to upsizel them. This is aimed at both reducing needed space for power wiring and cost savings too. Rockbestos Suprenant Cable Corp. is expecting to release an improved version of Exane with a temperature rating of 150°C in the near future.

Conclusion

Most of the North American rail industry has used Exane or other crosslinked polyolefin insulated wire with excellent results for almost 30 years. It is used in brand new locomotives, older locomotives that have gone through extensive rewiring and for repairs for all locomotives. Montana Rail Link uses Exane wire in all rewires and repairs to its fleet of 120 locomotives with excellent results.

III. INTEGRATED AIR BRAKE & DISTRIBUTED POWER UNDER EMD FIRE SYSTEM

By: Robert Reynolds, Canadian Pacific Railway

This paper presents a description of the integrated air brake and distribution power system found on new EMD 6000 horsepower locomotives equipped with their Functionally Integrated Railroad Electronics, known as the FIRE system. We will discuss:

- the use of distributed power on Canadian Pacific Railway,
- the hardware components of the system,
- the software which links all the hardware components together,
- what's involved in training crew and mechanical personnel and
- the maintenance performed on this system.

Distributed power is not a new concept on the railway. We have been using distributed power on Canadian Pacific since 1969. Distributed power permits the operation of long heavy trains over steep grade territory. The use of distributed power has greatly expanded over the past several years due to the use of newer, higher horsepower locomotives.

Typically on CP we operate heavy bulk trains with two AC locomotives on the head end and one in the mid-train position. Depending on the territory we also have an application with two head end units and one remote unit on the tail end of the train. Although we only run at this time with one remote locomotive in the train, the system is capable of distributing up to four remote locomotives within the train. There is a possibility of combining two empty coal trains from the shipping port back to the staging yard where they will be split up into two trains for return to the mines.

In addition to motoring and dynamic braking, distributed power also provides quicker application and release of air brakes and is particularly helpful in cold weather when it can be more difficult to charge extended length trains. We run bulk trains with the minimum required horsepower and on the steepest grades train speed is down to about 12 mph. The system can be set to have the remote follow the throttle and dynamic brake settings of the lead unit, or the engineer can independently control the remote unit as desired. The equipment permits each locomotive to be set up as the lead controlling locomotive or as a remote locomotive. There is a slow speed control option that we use that permits a remote locomotive to assist when loading at coal mines.

When coal trains arrive at the port for unloading, the port takes over control of the train through a tower control system. We have been studying the use of tower loading equipment at the mines. This would enable the mine to take control of the train when it arrives at the mine. Presently the loading operation is disrupted because of train crew changes. At the time of writing we are about to test the use of distributed power on heavy mixed freight trains on steep grades through the Rocky Mountains.

We began using Harris Locotrol I in 1969, then worked with this supplier developing Locotrol II in 1983, Locotrol III in 1992 and in 1995 took delivery of Locotrol IV on GE AC4400 locomotives. Since that time we acquired more GE AC units as well as EMD SD 90 locomotives and the most recent acquisitions are equipped with GE Harris Locotrol Electronic Brake, called LEB, which uses the locomotive display screens instead of a dedicated console. All our locomotives equipped with Locotrol IV or Locotrol LEB are fully capatible. In other words, a lead locomotive equipped with Locotrol IV can operate with a remote locomotive equipped with Locotrol LEB or vice versa.

EMD created the FIRE system in 1998. The purpose was to provide the operator with information displays and controls and be integrated to the locomotive control system, air brake system, perform event recording, crew alert function and be the man-machine interface with distributed power. The major components used by distributed power system are:

- Two locomotive display screens, each housing a Pentium™ processor,
- A GE Harris Integrated Processor Module,
- A relay interface module,
- A data radio package,
- Electronic air brake system.

The locomotive display screens provide locomotive operating data to the engineer. One display provides basic operating information such as speed, air brake status, end of train status, etc. The other screen is used to display distributed power remote locomotive data. We worked with the manufacturer to make the wording and screen layouts as much as possible the same as on our other systems. It is important to have consistency in the user interface. This makes operating the equipment much easier for the locomotive engineers.

The integrated processor module handles the distributed power logic. It receives commands from the FIRE screen and returns status information. It controls the data radios, interfaces with the electronic brake system for pneumatic control, monitors the status of MU trainlines on the lead unit, and controls the MU trainlines on the remote unit.

The relay interface module has two roles depending on the mode the locomotive is operating in. On a lead locomotive the relay interface module is sensing the status of the trainlines and on a remote locomotive the system controls the trainlines through this module. An important function of this module is emergency brake control. Although emergency brake is commanded by software there is also a direct hardware backup occurring at the same time as the software.

The data radio module is used to handle messages between the lead unit and the remote unit. On a remote unit, it sends status of the remote to the lead unit. On CP, we use a frequency of 140 MHz whereas in the US, railroads use 450 MHz. There is message repeater equipment to ensure data communications in long tunnels. The system performs routine data communications checks every 20 seconds and can operate through intermittent loss of communications. In the event of an extended communication interruption, the remote unit will stay in the last commanded state. However, if the locomotive engineer applies a brake application, the remote unit will idle down if it was operating in throttle mode. If it was in dynamic brake mode it will stay in that to assist with train braking.

As an aside on radio communications, we worked with Wabtec in 1999 to test a wire line distributed power system used with ECP - electronically controlled pneumatic brake system. Communication over the wire line was excellent and of course it does not require tunnel repeater equipment.

Our new EMD 6000 HP locomotives are equipped with an electronic air brake system which performs all of the air brake functions similar to the 26L pneumatic brake equipment. An internal fault log aids troubleshooting the electronic brake equipment, and changing modules quickly performs repairs.

It used to be said that hardware integration was a way to reduce the quantity of system components and if a function had to be changed, it was simply a software revision. We quickly learned that there is no such word as 'simply' on a locomotive, especially when it comes to software. The software is becoming so complicated that it almost makes you want to go back to the old stand-alone boxes! A communication network links all of the above hardware and the software performs the logic in each of these functions and passes data and commands from one component to another.

Revising software in one component if not done properly can cause a detrimental effect in another component. Software testing is very involved, lengthy, and you need to test for the various unexpected hardware faults, tripped breakers, communication losses between modules, etc. System software design also involves different manufacturers working together to make sure that functions operate as per requirements. Different railways have different requirements and this adds to the complexity of software design for the manufacturers.

Wouldn't it be nice if every cab were identical? Although we try to make new cabs the same between builders, it is very difficult again because of different railways having different requirements and each builder tries to keep his basic design standard. This makes training of personnel somewhat difficult because of different cab designs, display layouts, control layouts, etc. The training of crews and mechanical personnel is very important for a safe operation. We provide crews with on the job familiarity with new equipment, operating manuals, and road manager supervision. Mechanical people that test and troubleshoot this equipment are given training and manuals.

The maintenance of this highly sophisticated equipment is directly related to reliability and efficiency. We have contracted the maintenance of new locomotives to the locomotive builders. The maintenance contracts also include component replacements so we do not have to stock costly spare parts. The reliability of the electronic equipment as well as all other locomotive systems is continuously monitored. Road defect trends are brought to the attention of the locomotive builder for resolution.

If a crew encounters a problem with this equipment on the road, they call in to a central locomotive specialist. The specialist tries to suggest remedies such as cycling circuit breakers to get the train back in service. If this does not help, then the train is either assisted over the grade or into a siding and the locomotives are changed out. Once defective units are at a shop, an event logger is downloaded which greatly assists in troubleshooting problems. This equipment is inspected during the 92 day periodic. This inspection covers the secure mounting of hardware, proper fastening of connectors , condition of antennas and a review of the fault logs. A five year inspection should be performed, consisting of the removal of all hardware for cleaning and testing.

In conclusion, we have presented a brief overview of the new distributed power system operating under the EMD FIRE system. It is possible in the future that hardware will be integrated further resulting in fewer components and better reliability. Of course, if we ever want to make a change, it is **simply** a software revision! Thank you.

IV. CARBON BRUSHES - A FRESH LOOK

By: Robert P. McCaffrey, National Electrical Carbon Products, Inc.

Carbon brushes have been in electric and diesel-electric locomotives for over 100 years, and they still perform a very important role in locomotive performance.

Most of the new developments today are in the area of AC locomotives, which do not use brushes in the traction motors. However, brushes will be an important factor for a long time to come. Consider that the vast majority of locomotives currently in the fleet have DC traction motors; and the OEM's are still building more DC locomotives than AC locomotives. Union Pacific is currently taking delivery on the first of 1,000 DC locomotives, and other roads are also receiving new DC locomotives. Also, AC locomotives have brushes in the alternator, and in grid blower motors.

The bottom line is that brushes, and their maintenance, will be an important consideration for railroads for the foreseeable future.

Brushes have many important functions:

- They carry the load current to or from the stationary part of the machine to the rotating part of the machine,

- They assist in commutation,

- They help protect the commutator,

- They can act as a window to the motor, and help us understand what is happening inside the motor.

The reversal of current in the armature coils of a DC machine is called commutation. This take place hundreds of times per second, depending on the rotational speed of the machine. Each time the current is reversed, a significant voltage and current spike is induced from the current collapsing inside the coil. If this spike is not suppressed, sparking, usually at the brush edges, will result. The brush helps to suppress this current through its resistance, and design.

The action of a brush carrying current to the commutator, or slip ring, causes a film to form. This film, only microns thick, provides a protective barrier to the copper, and acts as a lubricant between the brush and the copper. Brush grades must be selected that will provide the proper filming characteristics. Figure 1 shows an EMD commutator with a normal film.

Examining brushes can give us clues to:

- Poor commutation,
- Commutators with high runout,
- High bars on the Commutator,
- Defects in the brush holders and,
- Foreign material contamination.

Poor commutation is characterized by sparking at the edges of the brushes. This sparking can leave residues on the edges of the brush, and can erode the carbon if severe. Commutation is affected by numerous factors, including brush holder location or neutral position and use of an appropriate brush for the application. The magnetic characteristics of the motor, including interpole windings, will also affect commutation. Figure 2 illustrates residue from sparking on the edge of a brush caused improper neutral position.

If a commutator is significantly out of round, brushes are subjected to high vibration. This vibration will cause frayed shunts on traction motor brushes. High TIR is also indicated by high polish on the sides of the brushes. Figures 3 and 4 show shunt fray and side polish on an EMD traction motor brush caused by an out of round commutator.

One or more high bars in a commutator will cause chips at the edge of the brush. In more severe cases it will cause wafers to break completely. Figures 5 and 6 illustrate brushes severely chipped from high bars.

Defects in brush holders often show up as a brush condition. A ridge at the bottom of the brush can indicate excessive brush holder height. Scoring on the brush indicates burrs in the brush holder. Sparking underneath the brush may indicate low spring tension. Spring finger marks not centered on the pad may indicate bent or out of line springs, or in some cases, incorrect finger placement. Figure 7 shows fingers improperly placed on the edge, rather than the center of the pad. Figure 8 shows off center marking on the pad from defective springs.

Training shop personnel to recognize commutator and brush distress can result in significant savings to railroads, and prevent road failure. Brush manufacturers frequently offer training classes for railroad personnel that can be presented on site.

It is important to select the correct brush for the application. Factors that must be taken into account are the resistivity of the carbon, the filming characteristics and the strength of the material. Construction factors such as the number of wafers and the type of clip or pad are also important. OEM brushes and some independent brands are well proven in locomotive applications.

There are literally thousands of different brush grades available, each with different characteristics. However, only a small number of grades are commonly used in locomotives.

While brushes are a very old and established product, they are not a static product. There are ongoing efforts in grade development and brush construction, such as the addition of edge chamfers.

Grade development, with the goal of obtaining superior life and better commutator protection, is an ongoing process with all brush manufacturers. One of the keys to developing better brushes is the ability to field test on Class I railroads, which follows extensive laboratory testing.

Brushes are now available from both locomotive OEM's with corner chamfers. This allows the brush to seat more rapidly on a worn commutator, and prevents brushes from seating only on the corners of a worn brush path. The chamfers therefore eliminate a large area of no contact under the main area of the brush face. This reduces sparking and the possibility of flash over. Figures 9 and 10 show traction motor brushes for EMD and GE traction motors with edge chamfers.

In conclusion, the following main points are most important:

- It is inevitable that carbon brushes will be an important locomotive maintenance item for the foreseeable future.

- The training of maintenance personnel can reduce costs significantly by recognizing and correcting detrimental motor conditions before they result in failure.

- Manufacturers continue to improve brushes through grade development and construction improvements such as the use of edge chamfers.

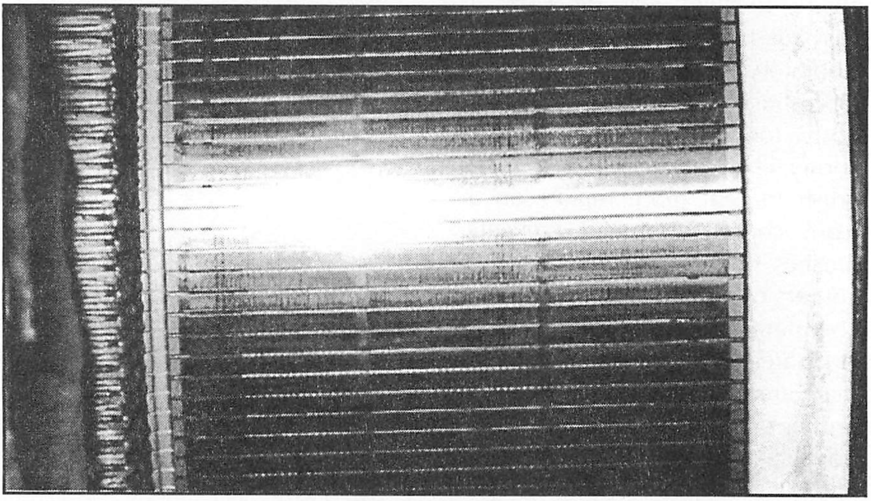


FIGURE 1: EMD COMMUTATOR WITH NORMAL FILM

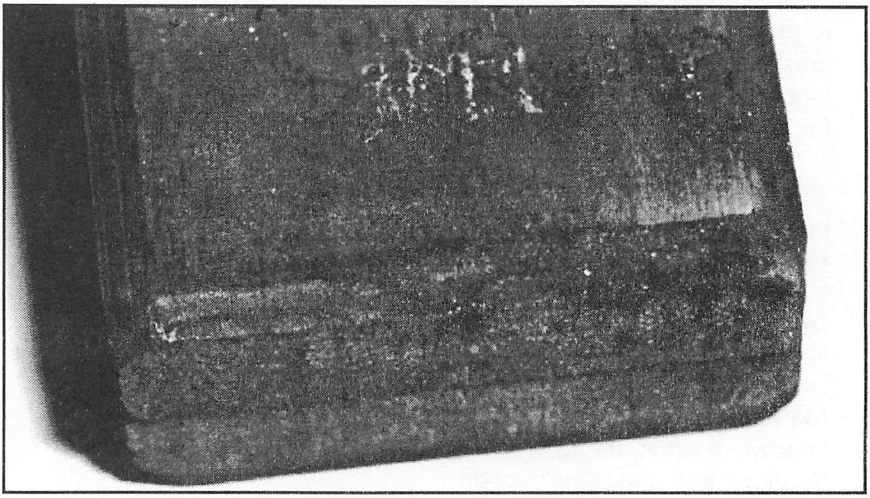


FIGURE 2: COPPERY RESIDUE ON BRUSH EDGE FROM SEVERE SPARKING

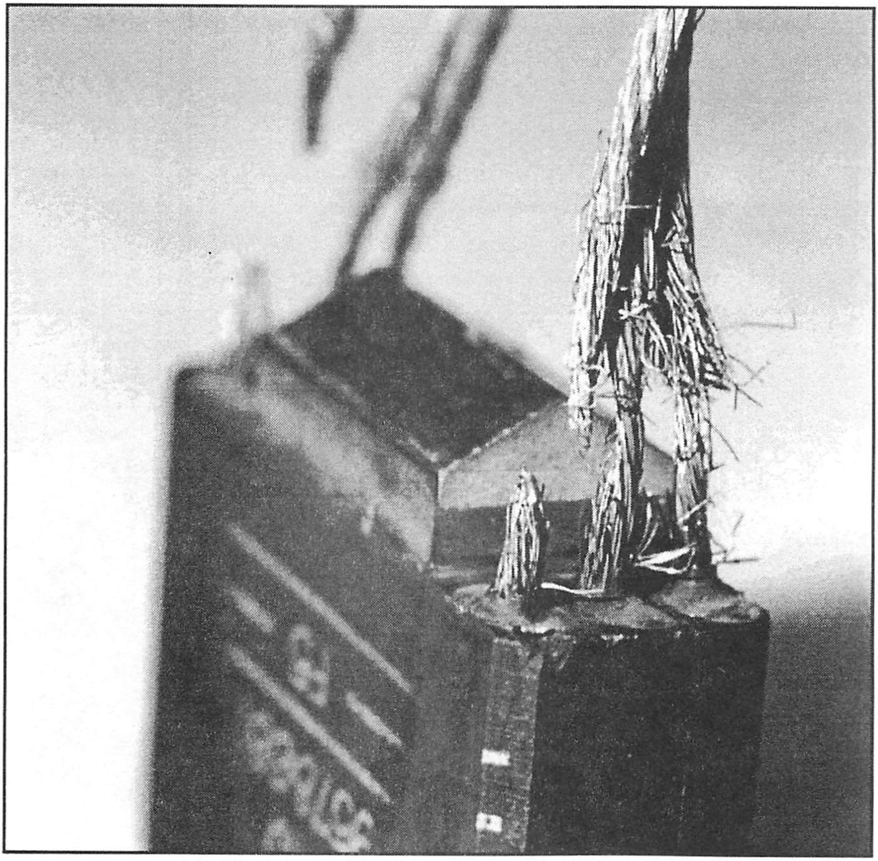


FIGURE 3: FRAYED SHUNTS FROM COMMUTATOR WITH HIGH TIR

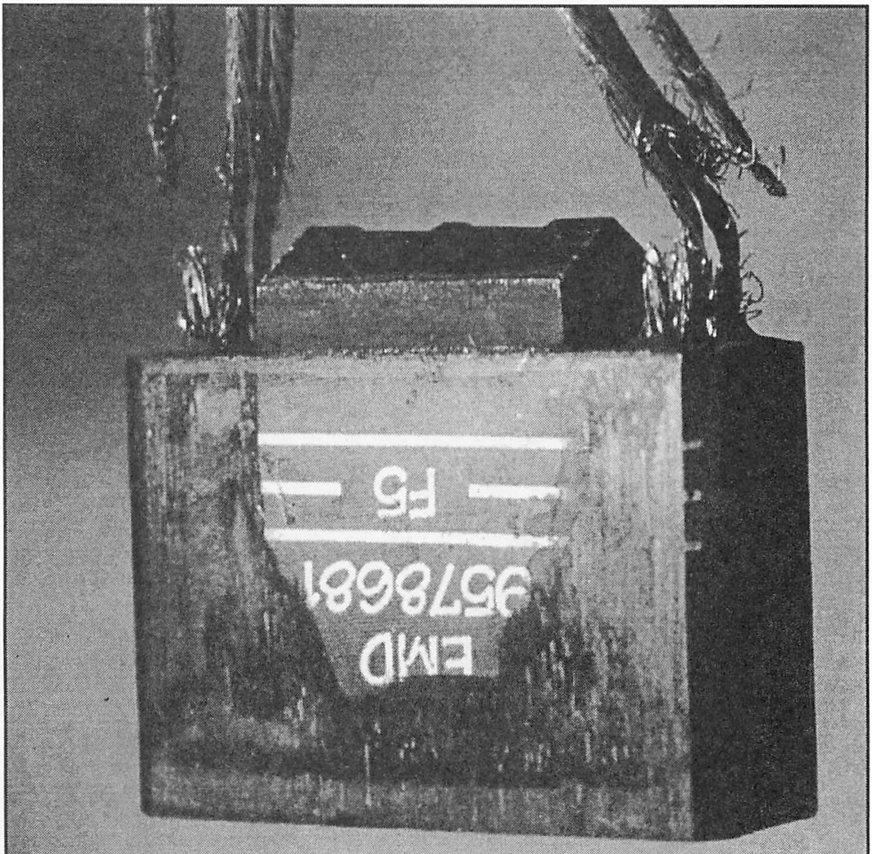


FIGURE 4: BRUSH WITH POLISHED SIDES FROM COMMUTATOR WITH HIGH TIRD

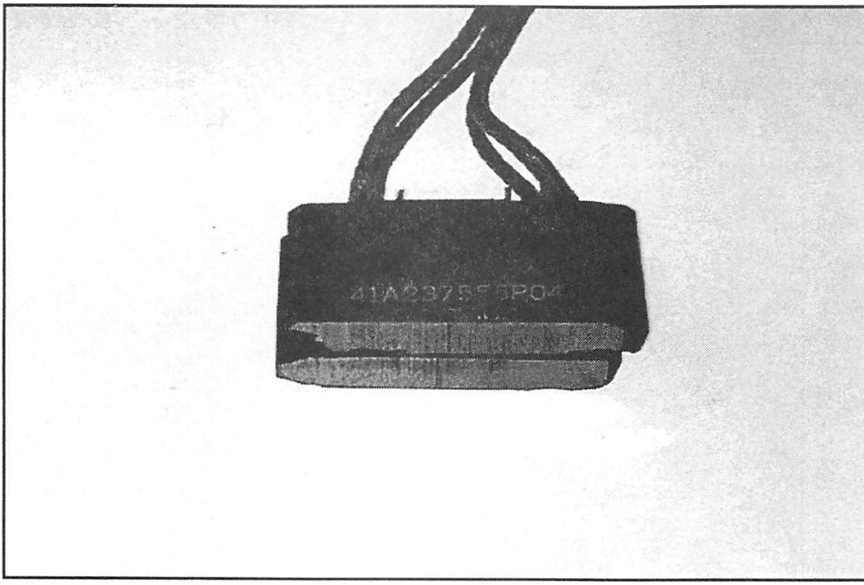


FIGURE 5, BRUSH WITH EDGE CHIPPING FROM HIGH BARS

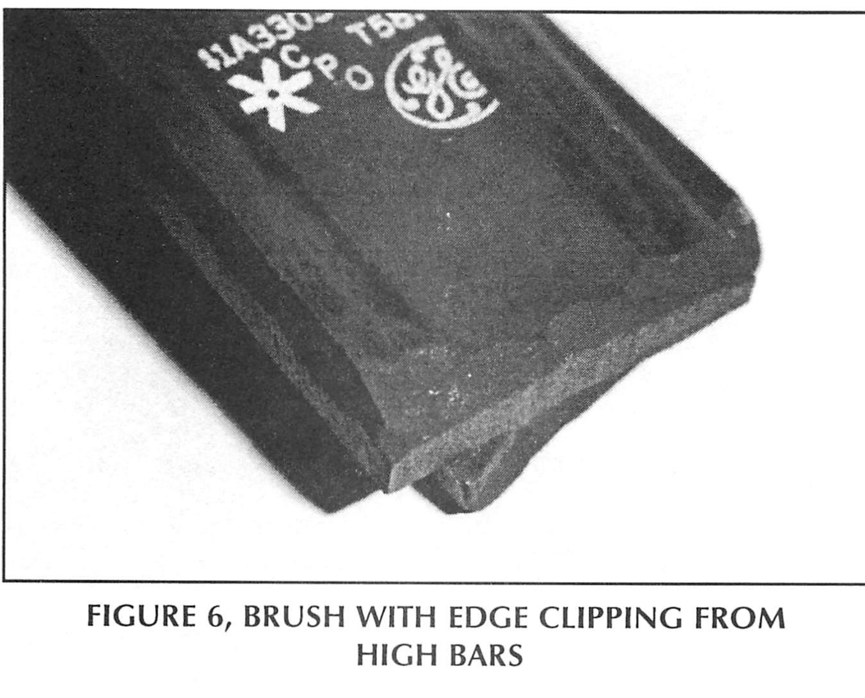


FIGURE 6, BRUSH WITH EDGE CLIPPING FROM HIGH BARS

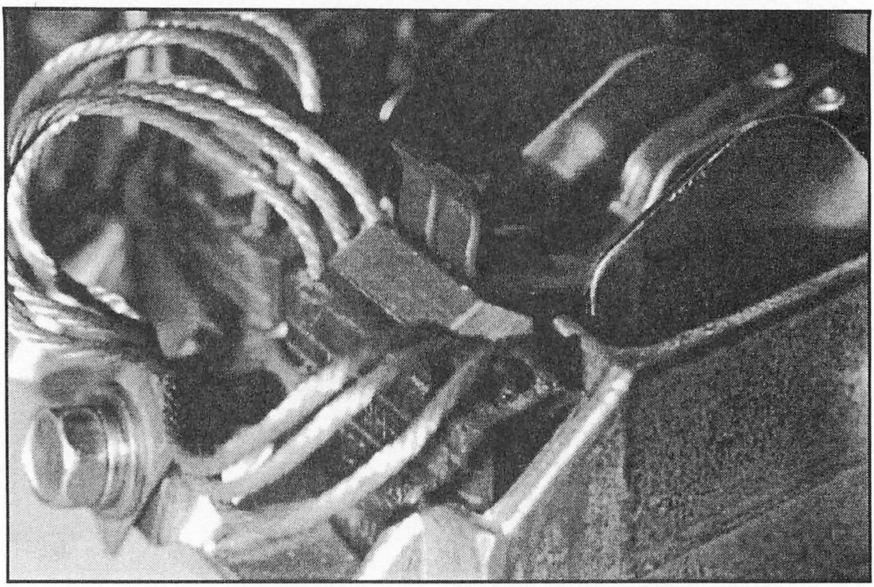


FIGURE 7: IMPROPERLY PLACED SPRING FINGERS ON EMD TRACTION MOTOR BRUSH

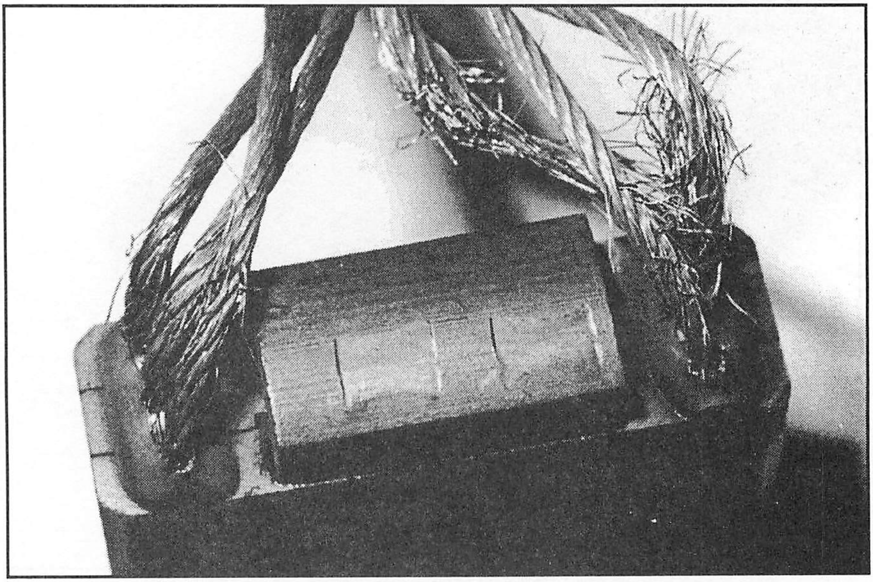


FIGURE 8: BRUSH WITH OFF CENTER SPRING MARKS FROM DEFECTIVE SPRING FINGERS

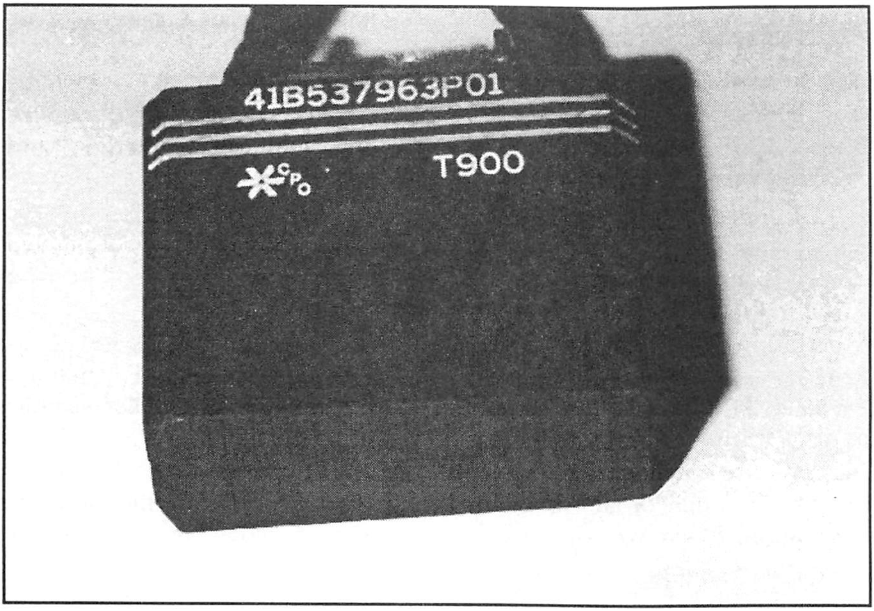


FIGURE 9: GE TRACTION MOTOR BRUSH WITH EDGE CHAMFERS

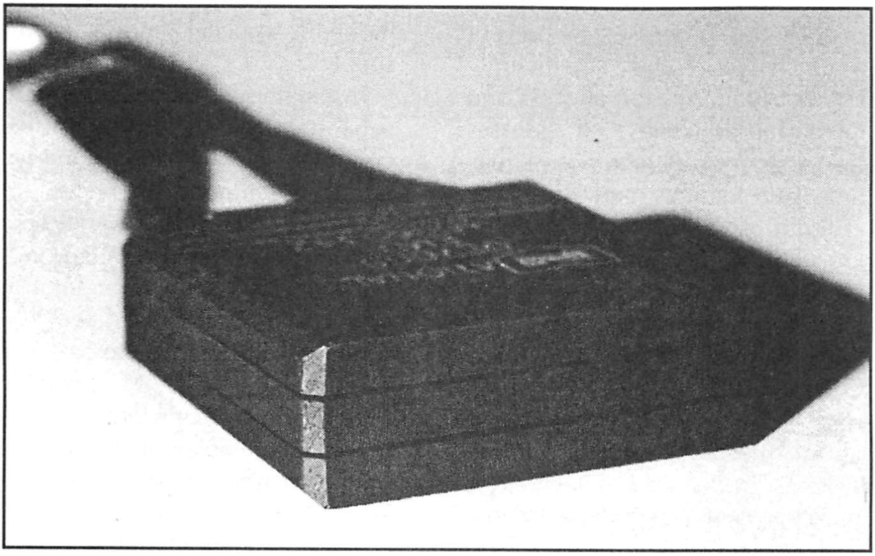


FIGURE 10: EMD TRACTION MOTOR BRUSH WITH EDGE CHAMFERS

V. RM&D - WHAT IT IS, WHAT IT DOES

By: John Estes,
Union Pacific Railroad
&
John Chessario,
GE Transportation Systems

Introduction

This paper will discuss Remote Monitoring and Diagnostics, or RM&D, as applied to Union Pacific's AC4400 fleet. RM&D improves the overall operating performance and productivity of the fleet through proactive failure prevention. First we will review what the system is, in terms of hardware and technology, then explain its operation and benefits.

Background/System Overview

What is RM&D? It is a service that combines hardware, software, people and processes to prevent road failures and significantly improve train mission success and railroad productivity. It assesses the operation of locomotive real-time and detects and diagnoses conditions before they impact locomotive performance. The system consists of on-board locomotive hardware to gather and manage data, a satellite communication path to transmit data from a remote locomotive, and off-board data analysis systems, tools and resources to make proactive recommendations that prevent locomotive failures and speed repairs.

The system was designed to:

- Improve service quality
- Benefit from GE Systems Engineering and Field Service Engineering knowledge and expertise.
- Automate analysis of data and information received from a remote locomotive.
- Provide access to on-board locomotive data while the train is in operation.

Next we'll explore the hardware and technology that enables the process.

On Board Hardware

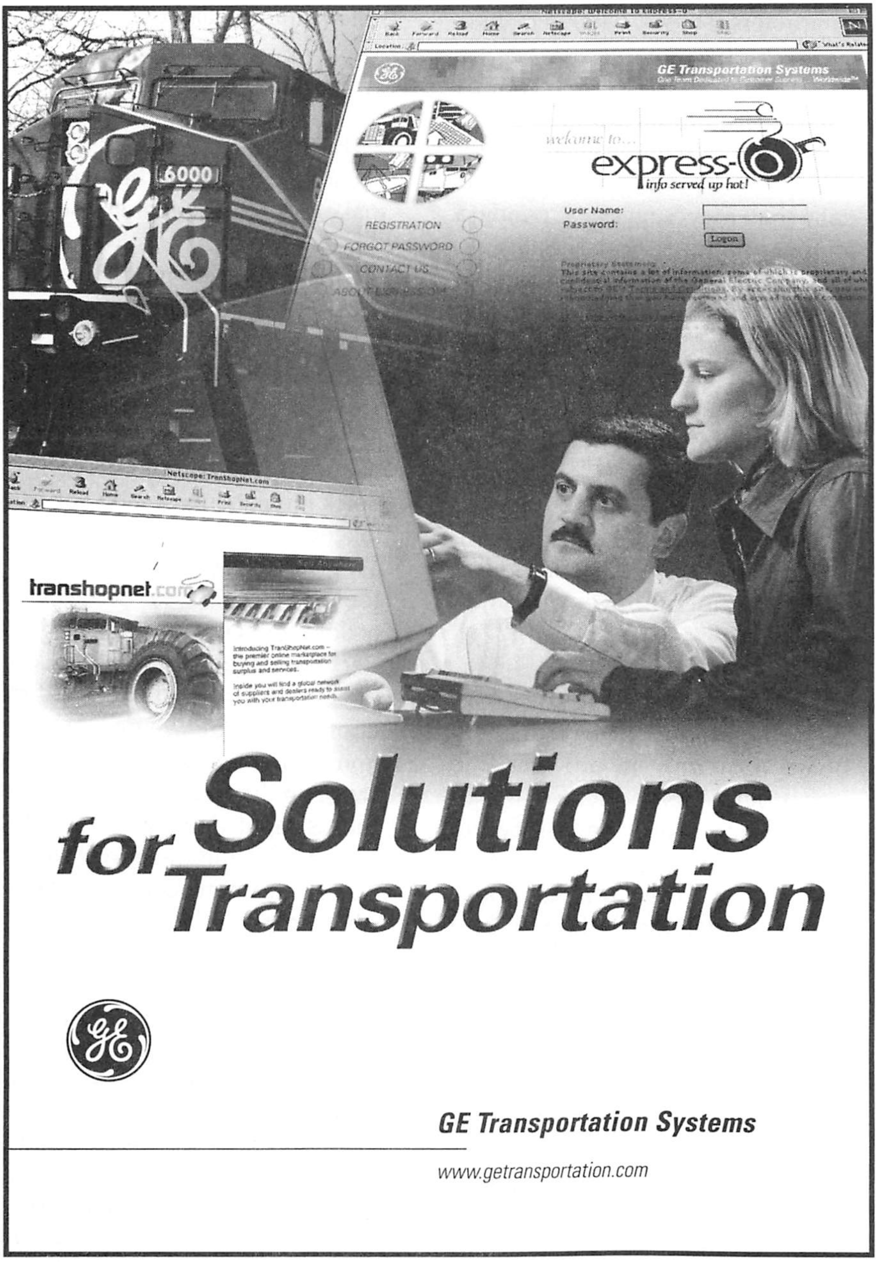
The service communication equipment on board consists of the OBM, or on-board monitor, a satellite communications antenna, modem, amplifier and a power supply.

The system is independent and separate from the locomotive control system - a failure of the on-board equipment will have no impact on the normal operation of the unit. The RM&D system does not interfere with the locomotive system or require any intervention on the part of the operating crew. The exchange of dynamic information from on-board to off-board is completely transparent to regular locomotive operations.

System Details

<u>**On-board**</u>

The core of the on-board data system is the OBM. Examples of


GE Transportation Systems
welcome to...
express-
info served up hot!
User Name:
Password:
Logon
REGISTRATION
FORGOT PASSWORD
CONTACT US
6000
transhopnet.com
for Solutions Transportation
GE Transportation Systems
www.getransportation.com

data collected by the OBM are: fault logs and data packs, monitor parameters, sensor data, and third party systems.

Communication

Data are continuously analyzed. The OBM is programmed to send data that may suggest a pending fault condition that could be prevented, and to recognize critical fault conditions and initiate a call to the Monitoring and Diagnostics Service Center, or MDSC, located in Erie, Pa. Regularly downloaded data, along with the current locomotive location, are transmitted through satellite to the off-board system. The system can maintain a link with any locomotive operating throughout North America.

Off-board/Analysis

The heart of RM&D is the off-board system - it provides the infrastructure for the state-of-the-art diagnostic tools necessary to collect and analyze the data. Experts at the MDSC make recommendations on how to best service units to minimize service delays and reduce repair times for each particular case.

Conclusions/Actions

Prevention and intervention are the primary functions. The system works around the clock to monitor mission critical parameters and provide predictive and proactive recommendations. The objective is to provide notice of an impending performance restriction or event and enable the railroad to take corrective actions that avert potential road failures.

Trending, Fault Analysis and Recommendation

The key to success is to accurately analyze the data and make a proper recommendation. On time delivery of information is the key to preventing road failures. Automated analysis tools developed with the rigor of Six-Sigma allow the system to address any situation, ranging from total prevention of a problem before it occurs to recommendation for quick repairs once a fault has been logged.

Once the experts review the tool's output, they propose an action if necessary.

Recommended actions are input directly into the customer's train control system where they can immediately respond. These take shape in the form of an "RX" code that is input directly to the UPRR Locomotive Information System or "LIS". All open recommendations are also posted on a secure web site.

Repair Recommendation

Each recommendation contains standard information about the locomotive such as road number, date and time of the case, and a problem description. Codes are used to indicate the priority of the case and the estimated repair time, ranging from less than one hour to greater than three hours. The most logical repair location is then coordinated based on the severity of the repair needed and the estimated repair time.

Based on the recommendation, parts, materials and training instructions may be delivered to the repair site. The train can arrive at the run-through and be greeted by a service technician equipped with the necessary parts, tools and appropriate maintenance, safety and training instructions to quickly and accurately complete repairs during the train's scheduled dwell time.

Web Based Data

Figure 1 shows an example of a recommendation that has been posted to the web. The advantage of the web site is that it allows for more detail than is currently available on the UP LIS system. Repair recommendations, unit history and custom reporting features are all available. It offers easy web access to system users with the proper security and privileges.

Recommendation Actions and Closure

Shown in Figure 2 is a repair recommendation in the form of an "RX" code that is seamlessly integrated into UPRR's LIS, or Locomotive Information System. There data are available to maintenance facility personnel in advance of in-bounding the locomotive.

The fault data and suggested repairs are loaded by the MDSC staff. UPRR repair facility mechanics then enter the actual repair made into UPRR's LIS system.

After the maintenance recommendation has been closed and the train continues on its route without delay the MDSC monitors the locomotive's condition to ensure the problem has been corrected. This feedback loop enhances the recommendation accuracy and ensures that cases are properly closed.

Potential Benefits

Remote monitoring allows existing fault data to be integrated into the repair process in a controlled and systematic way. It removes the need for mechanics to attempt to interpret sometimes complex and seemingly conflicting information. Instead, the mechanics can focus on targeted and specific actions designed to isolate and repair a failure.

This allows scarce technical resources to identify failures or potential failures, determine appropriate repairs, and plan repair assets. It forces fault data to be addressed, coordinated and implemented more systematically. The results are reduced mission failures, reduced down time, and reduced maintenance costs.

Example 1

In this example, we see a unit that began to log faults on January 3. A case was opened and MDSC personnel determined that a failure was likely in the next 48 hours.

A recommendation to inspect

and replace the #6 traction motor speed sensor was made and an RX code was loaded into the TCS system.

When the unit arrived at the run-though track the speed sensor was repaired in less than an hour and the case was closed.

Troubleshooting was minimized, a road failure was avoided, and the unit was kept in service.

Example 2

In this case a unit approaching 80% load pot phoned home before a fault was logged. A recommendation to change the fuel filters was made and transmitted via the RX code.

When the unit arrived the troubleshooters verified that the fuel filters were plugged and changed them out.

The system predicted an impending restriction and issued a preventative action before a fault occurred. Once again a road failure and an unscheduled shopping were avoided.

Key Considerations

There are several key considerations when comparing remote monitoring alternatives.

First, what data do you want and how often do you want it? Too much data can actually increase downtime. Too little means missing needed repairs. On-board computers can simply transmit raw data, transmit data upon fault triggers, or be programmed to trend and filter data. How "smart" does on board equipment need to be?

Second, how do you want to transmit these data? Today, you can use satellite, cellular, digital messaging, proprietary or a combination. Not all options are available in all areas. Costs vary widely. These are not the only data being transmitted. Remote monitoring requires relatively low bandwidth. Modern locomotives have numerous communication channels and remote monitoring can be integrated with other communication needs.

Third, where and how will you warehouse these data? This is a significant cost. These are not the only data being collected. Fault data are being monitored from a variety of locomotives. These data must be integrated with other data such as AEI tag data, GPS data, repair history, train schedules, and scheduled maintenance requirements. These data need to be accessible using standard tools.

Finally, how will the data be integrated? On-board data must be filtered and then integrated into the repair process. GE RM&D provides a turnkey solution for DASH 9 and AC4400 locomotives because it not only remotely monitors the data, but more importantly provides the diagnosis for corrective actions to quickly return units to service.

Cost Drivers

On-board equipment is one obvious cost driver. Communications costs, data warehousing, system integration and staffing costs are also significant cost factors. Does the system support a technology migration path for future expansion? The total cost of the system must be considered when comparing alternatives.

Future Wants

In the future remote monitoring should be more integrated into the locomotive control systems. All the various locomotive and crew data should be transmitted to and from all locomotive platforms using standard communication channels. These data should be formatted in a standard open format and stored in ODBC compliant databases. And finally, it should be able to support future services without significant additional hardware and communication investment.

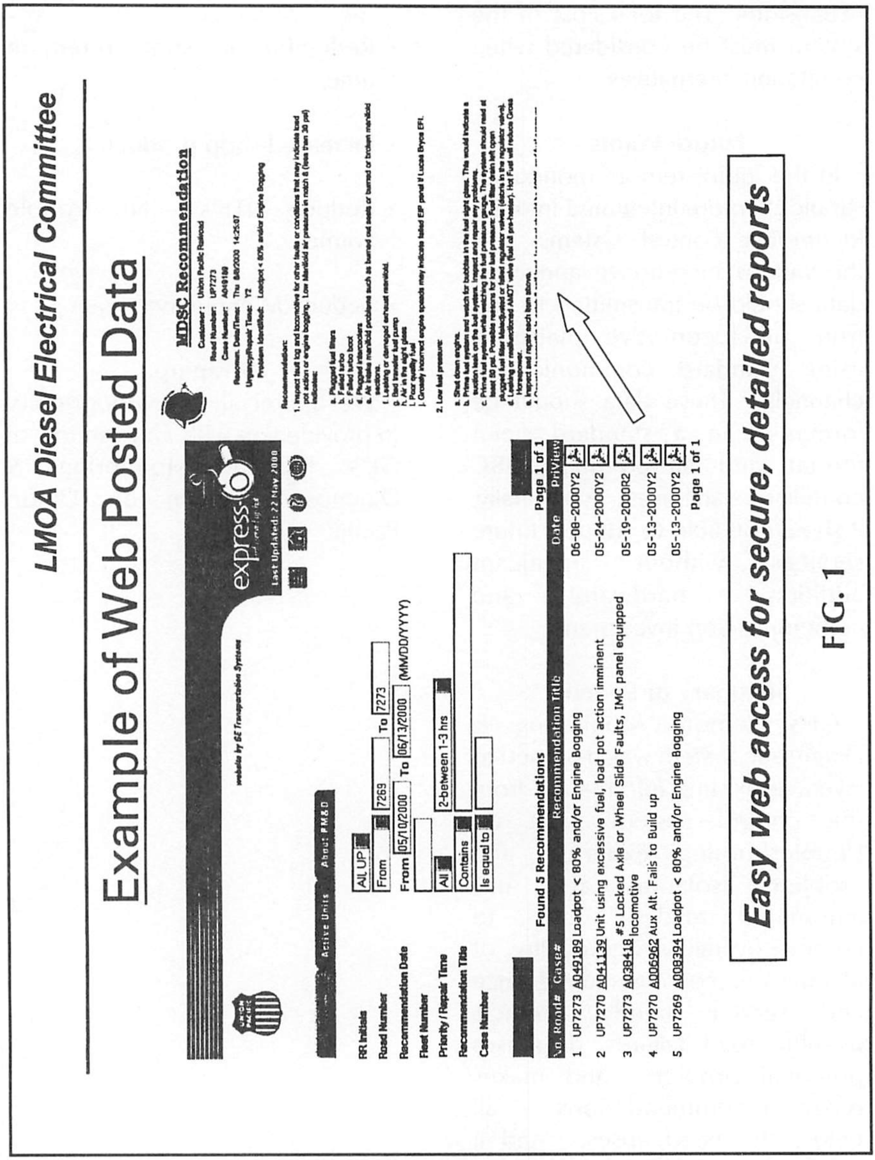
Summary of Benefits

GE's Remote Monitoring & Diagnostic System was designed to leverage existing information from the control system, built on troubleshooting expertise and problem isolation and use automated analysis tools to improve overall service quality. It identifies upcoming maintenance and service needs, predicts possible road failures, diagnoses potential problems and makes repair recommendations - all before the need arises. And it includes expansion capability for future services. Benefits include:

- Road failure prevention,
- Improved locomotive availability,
- Improved mission success,
- Reduction in shop retention time,
- Increased shop productivity,
- Reduce NTF's - No trouble Found,
- Reduce Maintenance costs.

Wrap-up

We appreciate the opportunity to provide you with an overview of GE's Remote Monitoring & Diagnostic System on Union Pacific.


LMOA Diesel Electrical Committee
Example of Web Posted Data
website by GE Transportation Systems
express
Last Updated: 22 May 2000
Active Units
About PM&D
RR Initials
Road Number
Recommendation Date
Fleet Number
Priority / Repair Time
Recommendation Title
Case Number
All UP
From 7269 To 7273
From 05/10/2000 To 06/13/2000 (MM/DD/YYYY)
All 2-between 1-3 hrs
Contains
Is equal to
Found 5 Recommendations
Page 1 of 1
No. Road# Case# Recommendation Title Date PriView
1 UP7273 A049189 Loadpot < 80% and/or Engine Bogging 06-08-2000Y2
2 UP7270 A041139 Unit using excessive fuel, load pot action imminent 05-24-2000Y2
3 UP7273 A038418 #5 Locked Axle or Wheel Slide Faults, IMC panel equipped locomotive 05-19-2000R2
4 UP7270 A006962 Aux Alt. Fails to Build up 05-13-2000Y2
5 UP7269 A008394 Loadpot < 80% and/or Engine Bogging 05-13-2000Y2
Page 1 of 1
MDSC Recommendation
Easy web access for secure, detailed reports
FIG. 1

What Does A Shop See?

INITIAL/NUMBER: UP 007266 CASE ID: TSA034344 WHITE 2 CLOSED
OPENED DATE : 2000/05/11 02:13 MODIFIED DATE : 2000/05/11 20:16 OMNL342
INCIDENT DATE : 2000/05/11 02:13 RECOMMENDED DATE: 2000/05/11 02:13 Y6
CLOSED DATE : 2000/05/11 20:16 FINAL FAILURE CD: 5806
SVC PLACEMENT: 2000/05/11 18:00 SVC RELEASE : 2000/05/11 18:45 SVC: NP162

EXCESSIVE FUEL VALUE, LOAD POT ACTION IMMINENT

IN SHOP RECOMMENDATION:
< >1. CHK FOR LOW FUEL PRESSURE, PLUGGED FUEL FILTERS OR OPEN FUEL DRAIN
< >2. POP TEST, CHK FOR CYL NOT FIRING. CHK FOR BROKEN WIRES, BAD FUEL
PUMPS/INJ.
< >3. LOAD UNIT N8 CHECK FOR INCORRECT ENG. SPEEDS, POSSIBLE EGU
< >4. PERFORM HAPEMAN FUEL PUMP TEST.
< >5 SEE DETAILED RECOMMENDATION.

CLOSEOUT COMMENTS:
C/O FUEL FILTER

FIG. 2

LMOA Diesel Electrical Committee

Situation

- Unit Began Logging Faults on 01/03/2000
- GE Downloaded Fault Log on 01/04/2000 (Routine Daily Download) and Opened Case at MDSC
- **Failure Likely in Next 48 Hours**

Recommended Action

- Inspect Speed Sensor #6, Cabling, Connections, Repair Defects, Check Mounting
- If No Visual Defects, Replace SS#6
- Repair Time < 1 Hour (Run Through)
- Recommendation Loaded into TCS (Rx Code) on 01/04/2000

Action Taken

- Unit Arrived at North Platte West Run Through on 01/06/2000 at 08:00
- **SS#6 Changed at Run Through in < 1 Hr.**
- Case Closed in TCS on 01/06/2000 at 14:19 After Repair Validated via Download by GE

Implications

- **Road Failure Avoided**
- **Repair Implemented < 1 Hr. Without Shopping Unit**
- **No Manual Intervention by GE, Only Required Loading Recommendation in TCS**

Kept Locomotive On The Train, Saved Troubleshooting Time

EXAMPLE 1

LMOA Diesel Electrical Committee

Situation

- Unit on empty coal train headed to the Powder River Basin
- Anomaly detection suggests unit is approaching 80% load pot faults
- RM&D center in Erie knows problem exists before unit logs a fault

Recommended Action

- GE experts craft recommendation based on anomaly detection
- GE loads recommendation into UP mainframe remotely from Erie using jointly designed RX Code
- UP RF desk at HDC notified to coordinate repair

Action Taken

- Unit arrives at NP EBRT and UPRR technicians assigned to keep units 'On-Train' coordinate & execute repair. Replaced fuel filters per recommendation
- Repair validated through remote download in Erie
- Can tell 'real time' whether repair effected actually fixed problem

Implications

- **Road Failure avoided**
- **Loco dwell < 1 hr**
- **Unscheduled shopping avoided**

Predictive Maintenance in Action - Fixing Locos Before Faults Occur

EXAMPLE 2

VI. AN ALTERNATE ADHESION SYSTEM

Prepared by
Bill O'Neill
ZTR Control Systems

The continuous advance of new technology has allowed modern day locomotive control systems to offer customers better control and improved overall tractive effort than their earlier counterparts.

However, this does not mean that the older fleets need to remain stagnant with respect to taking advantage of these technological breakthroughs. On the contrary, some of these exciting advances are also applicable to older fleets and offer real benefits by improving their productivity as well. So I would like to suggest that the old adage, "You can't teach an old dog new tricks", does not necessarily apply here.

ZTR Control Systems has developed a product called "BOA" (an acronym for "Bolt On Adhesion") that offers some of this retrofittable new technology. This particular excitation wheel slip control system was designed to maximize the amount of tractive effort the locomotive can utilize under all weather and rail conditions, while requiring minimal operator intervention.

The design of this particular system takes into consideration the importance to customers of being able to easily and quickly install this type of equipment.

FIG. 1

As shown in Figure 1, the system consists of a main control panel, voltage and current transducers, a battery field isolator, a battery field supply, governor port pressure switches and manifold, as well as preassembled harnesses.

The system also includes critical documentation such as installation instructions (based on your locomotive model), a maintenance and service manual, and monitoring and diagnostics software.

The BOA controller is a smooth, very fast, high resolution microprocessor based system that has demonstrated its ability to provide superior excitation control in both power and if applicable, dynamic braking. This control system was designed for operation in the harsh railroad environment and has routinely demonstrated its ability to do so.

The main controller interfaces a central processing unit with a variety of I/O modules that perform both general and highly specialized functions. The designers of the BOA system set out to provide the end user with significant improvement in useable tractive effort without requiring the use of probes or axle generators.

As the performance charts indicate, (Fig. 4) this design goal has been attained.

The system can be retrofitted to either switcher or road locomotives. It will work with either main generator or main alternator equipped locomotives. Additionally, it can be applied to either four or six axle units and can be optionally equipped to handle the wheel slip detection and correction functions involving slug applications.

Some proven benefits the BOA system has provided its users to date include:

- Noticeable and consistent improvement in usable tractive effort under all weather conditions.
- Smoother excitation control.
- Dynamic braking control (Optional).
- More efficient train handling.
- Does not require the use of probes or axle generators.
- Solid state replacement of load regulator.
- Improved locomotive reliability.
- Superior wheel slip/slide detection and correction.
- Automatic main generator short term overload protection.
- Automatic traction motor short term current thermal overload protection.
- Easy Installation.
- Powerful diagnostics and inquiry software.

Using Figure 2 as reference, in general terms, here is how the BOA system works. It relies on the engine governor to tell it the amount of load the engine can handle for each given throttle position. Instead of using the load regulator to regulate the amount of excitation being called for, the BOA system's manifold assembly senses the engine governor's request to either increase or decrease excitation. (In fact, the load regulator can be removed from the locomotive, as it is no longer needed with this system.)

A signal from the manifold pressure switches is sent to the main control panel, where it is processed and sent out to the battery field isolator. The battery field isolator converts the signal and sends it to the battery field supply, which will control the current flow through the battery field. Optionally, dynamic braking excitation control can also be handled by the BOA system.

The system achieves its superior tractive effort performance because of the methodology it incorporates to detect and correct differential or simultaneous wheel slip or slide situations.

In Figure 3 two series parallel circuits are depicted, each with two motors connected in series. Had this unit been a road locomotive that makes transition into full parallel, it would of course require additional current transducers for motors #3 and #4.

The voltage transducers are connected across each traction motor's armature. The current transducers read each series-parallel circuit. The BOA system continuously monitors the circuits for any and all abnormalities in each of these five areas:

First: each traction motor's voltage rate. (DV/DT).
Second: the amperage rate of change in each traction motor circuit. (DA/DT).
Third: traction motor armature voltages (Delta V).
Fourth: traction motor circuit armature amperages. (Delta A)
Fifth: traction motor voltage and amperage ratios.

The system monitors all of these areas to detect differential wheel slip or slide. A simultaneous slip is detected using the traction motor voltage rate of change or DV/DT.

If a wheel slip or slide is detected, correction is made in up to three stages, depending on the severity of the condition. During the first stage, battery field excitation is cut back based on the severity of the slip. This cut back repeats continuously until the wheel slip or slide is under control.

If after a predetermined period of time, the activation of stage one does not sufficiently reduce the wheel slip or slide; the sanding circuits are activated.

If the system detects sanding circuits are activated and the battery field has been reduced to zero, yet a detectable wheel slip or slide is still present, the shunt field is dropped out.

Having described the functionality of the system, let's now turn our attention to Figure 4, which summarizes the BOA's performance during testing conducted against a typical GP9 system. Both systems were tested on the same locomotive. CP Rail test personnel using their instrumented test car carried out the tests.

In summary, BOA has demonstrated that its quick response in detecting wheel slips or slides, complimented by its ability to only reduce the power as required, can provide the end users with the ability to get more productivity out of their locomotives.

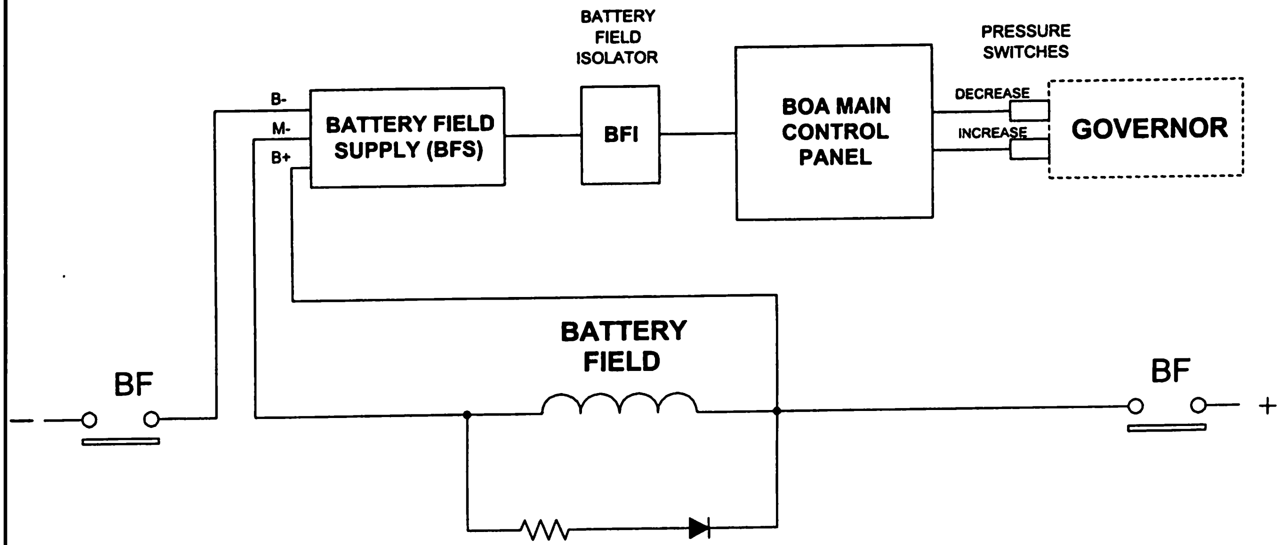


FIG. 2
Typical circuit after modification

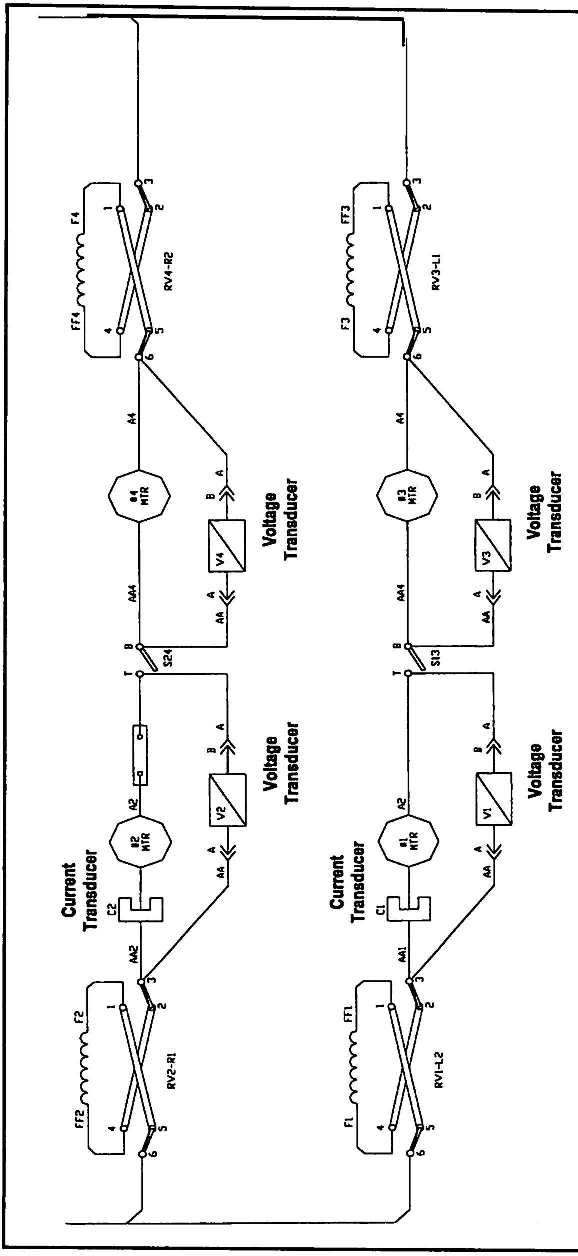


FIG. 3
BOA transfer application

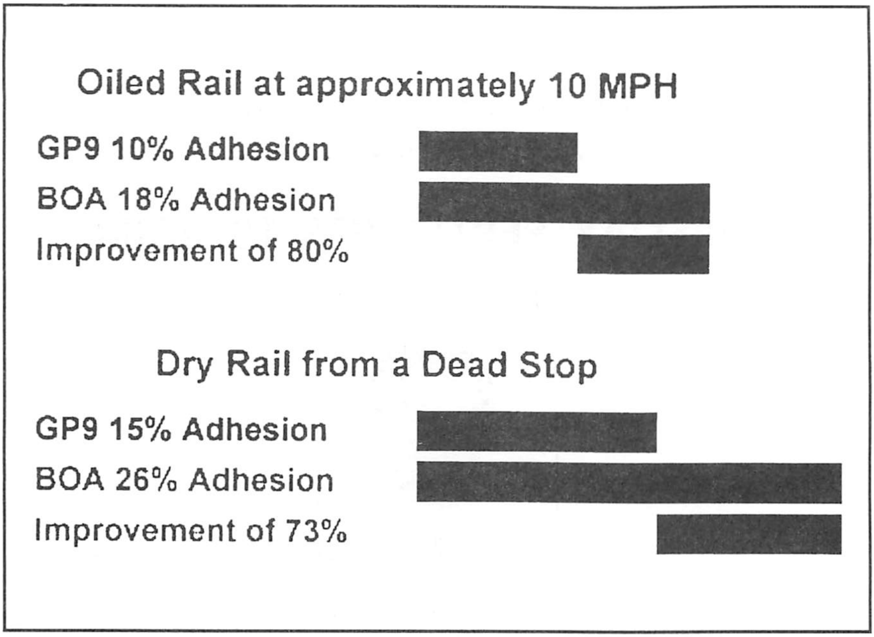

Oiled Rail at approximately 10 MPH
GP9 10% Adhesion
BOA 18% Adhesion
Improvement of 80%
Dry Rail from a Dead Stop
GP9 15% Adhesion
BOA 26% Adhesion
Improvement of 73%

FIG. 4

REPORT OF THE COMMITTEE ON NEW TECHNOLOGIES

TUESDAY, SEPTEMBER 19, 2000
10:45 A.M.

Bruce Butts, Chairman
Manager - Corporate Accounts
National Electric Carbon Products, Inc.
Naperville, IL

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

COMMITTEE MEMBERS

A. Mercier	Director	Alstom	Montreal, PQ
A. Oser	Product Development	GE Transp.	Erie, PA
R. Parent	Sr. Mech. Rel. Spec.	CN/IC Rail	Montreal, PQ
C. Prudian	Technical Prop. Manager	Electro Motive Div.	LaGrange, IL
D. Robey	Director-Loco. Engineering	CSX Transp.	Jacksonville, FL
C. Wills	Senior Engineer	BNSF Railway	Topeka, KS

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. His current position is Manager, Corporate Accounts. He and Corinne, who have been married for 27 years, live in a far Western suburb of Chicago.

I. FIRE: EMD TURNS UP THE HEAT ON RAILROAD ELECTRONICS INTEGRATION

By: Craig R. Prudian
Technical Proposal Manager
Electro-Motive Division
General Motors Corporation

Back in the "good old days" of diesel-electric locomotives, things were much simpler than today. We were pretty happy, as long as locomotives made traction, compressed air and could stop predictably. Yet, since the 1970's, there has been a steady progression of supplemental functions available to increase productivity of locomotives and/or reduce their operating costs. Along with locomotive-related productivity features, later add-ons were increasingly targeted to the global issues of overall train movement and transportation efficiency.

At first, adding these functions was pretty much a non-event for the locomotive builders. All that needed to be done was to provide space in the locomotive, 74 volts through a circuit breaker and maybe a tie-in to the air system. The functions and interfaces were treated as "black boxes" that had to figure out for themselves how to co-exist with the locomotive environment. But, highly touted as technology is, it can create a wealth of new headaches. For that same technology that works to make difficult tasks simple, also serves to make some easy ones excruciatingly difficult. As shown in Figure 1, a major issue for the locomotive builders soon became "how do we put all this stuff in a cab, and still make a package that actually delivers all the promised benefits?" The railroads, to their credit, held the locomotive manufacturers' feet to the fire, in order to ensure some semblance of ergonomic integration of these features. Yet the sheer proliferation of these ancillary functions was making it nearly impossible to present them in a way that an operating crew could deal with them all.

So, in the late 1980's, early cab integration was introduced. The vision was taking shape - focusing of all the cab functions to a central point, and providing a rational man-machine interface. But as most of the industry knows, the vision sounded better than it worked. Indeed, technology could be used to harness all of these disparate functions and present them in a coordinated fashion. But... the technology (and full railroad consensus) wasn't fully ready to undertake this challenge. The early ICE (EMD's Integrated Cab Electronics) and IFC (GETS' Integrated Function Control) applications did provide a common man-machine interface, but fell well short of full cab integration. The **intended** benefits were lower overall costs through integration, simpler application of new features, and increased reliability. It is true that some positive movements have taken hold. For instance, now the locomotive builders have an increased stake in the integration of these features, as we must insure their reliability, as part of a complete locomotive offering. Some increases in crew efficacy are being shown, as these devices are now more consistent in their method of application and use. Yet as today, we are not quite realizing the full intended vision.

The Past:

In the beginning... or the earliest days of integration of cab functions, OEMs were able to bring some increases in crew efficacy, simply by adopting a consistent display format. They have also taken an increased stake in the integration of these features, insuring their reliability as part of a complete locomotive offering. Yet, both major locomotive manufacturers have been perceived to be slow in bringing full cab integration to market, because after seven years of effort, no further significant integration took place! Why was this so? Fundamentally, the architecture prevented further integration. There were no universal standards for integrating functions. What resulted at the end of this period was:

- Black boxes that kept all of their functions except for displays, which are consolidated;

- Way too much duplicate hardware, software and support equipment (power supplies, as an example), and

- Point to point serial interfaces, which made data sharing a real headache.

Needless to say, reliability expectations were not being achieved, pointing to a real need for new breakthroughs. Through it all, the specification efforts were also lacking. Although the industry had spent a lot of time and effort developing a comprehensive interface specification, known as Locomotive Systems Integration or LSI, the functions that each system was to perform were not covered.

So there were some lessons to be learned. What EMD discovered was:

- New specifications were critically required. LSI was just not enough.

    - LSI defined the interface BETWEEN the systems, but did not address how they are supposed to function.

    - Integration problems were rampant because of LSI protocol misinterpretation and/or misapplication.

- Out of this, perhaps the biggest lesson of all emerges. The value of total cab integration is tied, not to the way we package features, but how many features can be combined into a coordinated package.

The Next Generation:

So, where do we proceed from here? Let's review the original purposes for integrating cab functions. This is what EMD kept hearing from our customers:

- "Keep it simple"; make it easy to understand and use,
- Increase reliability; combine the duplicate functions,
- Decrease overall locomotive cost,
- Provide interoperability, including interchangeability of equipment.

For the most part, the development efforts of the past were not very efficient. EMD's major concern (in fact, over half of system development effort) was getting the tricky interfaces right and developing communication software. What made matters worse, was that each supplier had his own CPU, memory, I/O and software designs.

As a result, EMD was not able to deliver new functions to market quickly. The technology was just not in place soon enough to be useful to the industry when these systems were being developed. But, as we all worked with the technology we had, technology kept forging ahead. A new breakthrough was imminent, and technology finally delivered in a number of ways.

Key Technology Advancements Enabling Software Integration

First, the industry developed low cost general purpose CPUs, with:

- Integrated memory management unit (MMU). More on this, later...
- Integrated floating point units,
- Integrated cache management, and
- Higher performance and low cost.

Other factors included:

- Strong multi-tasking operating systems with full MMU support,
- Inexpensive memory and storage sub-systems.
- Object oriented analysis and design methodologies,
- The Department of Defense embracing of commercial off the shelf (OTS) methodologies.

How does this technology help the rail industry? EMD brainstormed and leveraged expertise to specify and develop the next generation of cab electronics solutions, focused specifically on functionality. What has emerged, is a cab electronics platform that provides generic computing capabilities to handle features seen now and for the

future, all while addressing customer concerns. Some of the specific assets of this new system includes:

- Enabling of 3rd party software integration,

- Backward compatibility with LSI compliant equipment,

- Elimination of duplicate hardware,

- Elimination of complicated and unnecessary interfaces.

This platform is what EMD proudly refers to as **FIRE™ - Functionally Integrated Railroad Electronics.**

The installation of FIRE in the cab is clean and ergonomically effective. All black box functions and other interfaces are applied in the locomotive short hood - out of sight of the operating crew. Likewise, the FIRE computers are nowhere to be seen... the computers themselves reside directly behind the display screens (Figure 2). They are packaged with the screens, but are not functionally tied to them. For instance, if a screen fails, the computer will continue to run, and process data as it normally would. The remaining screens would be reconfigured to display all operating data, and the locomotive will be able to continue as a lead unit. Likewise, if the computer were to fail, the remaining computers will take on the extra processing duties, again allowing the locomotive to continue on.

Figure 2 also shows a typical #1 display screen. The format is in keeping with the latest industry direction, this being necessary to allow the crews to become comfortable with the system in the quickest possible timeframe.

EMD's strategy addresses customer concerns. Specifically, it can be broken down into four major elements:

- 1. Keep it simple,

- 2. Increase reliability,

- 3. Reduce cost,

- 4. Provide interoperability, along with interchangeability.

Keep it Simple

To promote simplicity at a system level, EMD has and will continue to:

- Promote open architecture by using railroad industry specification,

- Aggressively develop/support industry specifications,

- Incorporate functions at systems level,

- Focus on improving crew productivity through improved ergonomics.

Increase Reliability

To increase system reliability,

EMD worked to first, minimize the amount of hardware and number of connections required. Second, the FIRE architecture was developed to be reliability-driven. Third, EMD implemented a rigorous testing and structured introduction plan, consisting of:

- HALT Testing, which is a method used to test the system to failure - This test method provides knowledge and understanding of weaknesses in the system so that they can be effectively eliminated,

- A formal risk assessment/field introduction plan,

- Extensive use of the EMD integration lab. This step ensures proper communications and functionality between cab electronic systems for every locomotive configuration, before the features are installed in the locomotive.

With the integration lab (Figure 3), EMD is able to evaluate the FIRE system in a locomotive, complete with all the expected inputs. EMD's integration lab (I-Lab) offers a unique cab electronics test setting, consisting of a full set of every cab electronics system applied to our locomotives today. This provides us the ability to test all cab electronics hardware and software simultaneously for proper communications as well as functionality. In this way, every cab electronics configuration can be qualified in the lab, prior to production and field application, ultimately providing higher reliability and thus greater locomotive availability.

The following list is representative of the functions that the integration lab is now configured to emulate:

- Dynamic AEI tag
- Alerter - (internal to FIRE)
- Cab signals
- Integrated distributed power
- Electronic air brake (NYAB and Wabco)
- EM2000 (locomotive control system)
- HOTD and EOT (head of train and end of train devices)
- Event recorder - (internal to FIRE)
- Event recorder radio download
- FIRE (functionally integrated railroad electronics)
- Fuel monitoring
- GPS (global positioning system)
- MCP (mobile communications package).

Decrease Overall Locomotive Cost

The next element in EMD's strategy is to decrease costs from both a capital and operational standpoint. A sure way to further the effort is to utilize an open architecture and develop standards for systems integration. This should increase competition among EMD's suppliers, and not leave EMD captive to added costs and complexity of proprietary systems.

Integration savings are clearly indicated, as well. Elimination of duplicate hardware will help both the cost and the reliability picture. The focus on features promises increased value to the railroads. In turn, customers will find that they are only paying for the incremental functionality, and not unnecessary additional hardware. Utilizing OTS hardware and software will also benefit the industry by encouraging the use of proven systems, increasing speed to market and making integration an easier task.

Interoperablility

EMD developed a platform that supports a "Plug and play" concept, which allows a drastic reduction in the dependency on specialized hardware: "plug and play" simplifies the system by using a standardized set of hardware. Functions are added or deleted by simply changing the software that activates them.

Customer Benefits

All of EMD's efforts serve to provide the following specific customer benefits:

- A system that supports industry standards,
- A platform for software integration,
- Reliability,
- Expandability,
- Speed to market,
- Decreased capital and operational costs.

Technicals:

EMD has applied the above concepts to architecture, hardware and software. This section will look a little way under the surface of FIRE, to show the foundation in place to provide the advancements that EMD has brought to the fore. Let us first take a look at two approaches to system architecture. Figure 4 shows an older concept of how features were integrated into the computers that oversee and handle them. As the figure is a bit busy, let's build the system up step-by-step.

The backbone of the system is a communication link, known as the network bus (center). Computers are added, which provide the brainpower to handle all of the functions needed. Next, a number of internal processes are inserted (center block of processes). These processes are designed to be movable (able to be handled by either computer). If one computer goes out, the other one can take over to provide the functionality. The remaining functions that have interfaces are so specialized that they cannot be easily shared across the network bus. Each of these needs to be assigned to a dedicated computer. If the computer overseeing these functions goes out, the function is lost. Clearly this is not the best arrangement for maximizing the reliability of the system. A more effective way is required.

In order to optimize the application of cab functions, a different method of thinking is required. This is what led to FIRE's targeted architecture, as seen in Figure 5. With this new arrangement, a common bus (Ethernet and/or LonTalk) is used for the entire system, which is external to the FIRE computers. Instead of hard connections from each black box directly into the FIRE computer, each of the functions interfaces to the communication bus. Logic for each of the external functions is now implemented as a software module within the FIRE system.

With this configuration, if one of the FIRE computers fails, true redundancy is attained, with the remaining computers automatically handling the functionality that was normally controlled by the now-failed unit. All network resources, including flash disk, PC card (PCMCIA) and sound, are available to each computer. An "object-oriented" software architecture is utilized to keep sub-functions modular and independent from one another.

Reliability maximization drove the development of FIRE systems and interfaces. With the decision to use a software integration methodology, computing is now consolidated and entire classes of interface problems are eliminated! Simply stated, where there is no extra hardware, there are no failures as a result of it. Additionally reliability is achieved with the standardization of communications hardware, interface protocol, connectors and wiring. EMI is much easier to control, as EMC is easier to attain due to fewer disparate parts and pieces to integrate.

Because the FIRE architecture obviates the need for card level integration, the following advantages are immediately evident:

- The entire system data and resource capability is fully available to all ancillary functions,

- The decoupling between subsystem functions provided by FIRE allows it to be used in safety-critical applications, and

- FIRE provides a totally open locomotive integration platform, so that all vendors can "play", using an internet-like system architecture.

To understand what is meant by "software integration", a concrete example will be used to provide some illustration. Distributed power is a good test case. Figure 6 demonstrates how functions were added before, in a hardware-intensive mode. The first item normally identified when adding distributed power is the external hardware - in this case, a specialized communication package (DP radios). Next, a unique interface card is needed, which takes the inputs and oversees the interface to the computer's communication bus. In many cases, this card is so function-specific that it does not fully comply with all the "rules" for interface to that bus. Lastly, operating software is required. This is usually not part of the overall system, but local to the added card. This makes it most difficult to access this function during routine maintenance or troubleshooting.

With the FIRE system, a new way to implement functions is introduced. The hardware employed is standardized to the maximum extent possible, and doesn't change as new functions are added. In this case, a universal, LSI compliant communication package is employed for all communication functions (Figure 7). To implement distributed power, all that is required is to add the distributed power software to the computer and configure the man-machine interface. The communications package is now configured for distributed power, with no extra hardware.

One of the next issues then has to be: just how will suppliers be able to produce features and functions in a form that interfaces directly with the FIRE system? In order to accomplish this, EMD is providing a FIRE developer's kit for their use. The FIRE developer's kit allows 3rd parties to create FIRE applications, so that they will work within FIRE, right out of the box. This kit includes:

- NetCore C++ class library with HTML based documentation,

- Sample FIRE applications,

- Debugging tools and basic simulators.

In order to encourage third parties to effectively develop their product in a FIRE compatible format, EMD has made the kit available for no charge. As of this date, the kit has been distributed to all key cab electronics suppliers currently on record.

Safety Critical Functions

Safety critical functions have traditionally been kept separate from normal locomotive control. For instance, cab signals have always been pretty much "stand-alone", with a minimum of interface to all other electrical apparatus. They have even needed to use separate dedicated conduits for a lot of wiring. But recent thrusts in integration have made this approach more and more impractical. The control system must have a way to handle and process safety-critical functions. Some of the essentials that must be met when engineering a safety-critical system are that they must use established design, validation and verification methodologies. Safety critical functions must maintain fail-safe operation in light of any type of hardware, software or interface defect. To this end, full utilization of a memory management unit (MMU) is key.

One of the important factors in providing safety-critical functions is the ability to keep processes separate from one another in the computer, to minimize the possibility of contamination of one process by another. Let's look at the world and how it was before memory management units, or MMU's were around. Figure 8 shows two processes that use information from memory locations specific to each. But sometimes, processes need to share information from common memory locations. Existing systems would allow multiple process to use common memory buffers. At this point, the problem becomes obvious; one process, in the course of its execution, can corrupt another that shares the same memory location. In this example, Board B has direct access to memory on Board A. Thus, Board B is able to corrupt the system.

The new FIRE system allows no process to directly access the physical memory. An MMU is employed to create a firewall between processes (Figure 9). This protects memory from undesired coupling and potential corruption.

Another key element to a bulletproof safety-critical system is the operating system chosen for the tasks. The candidate operating system must meet a stringent list of technical requirements just to be considered by EMD. General guidelines have been established for the selection of OTS operating systems in safety critical applications. Meeting those criteria, FIRE's operating system requirements are also based on the NASA guidelines.

EMD has evaluated candidate operating systems, based on the following criteria:

- Availability of tools and OTS software,
- Software license costs,
- Memory footprint,
- Network, display and general device support,
- Knowledge and user base,
- Rail industry trends.

The results are shown in the Table, below:

As the table shows, the two top candidates, based on EMD's evaluation, were Windows NT and QNX. Both operating systems have a similar micro-kernel architecture, which keeps the

Data from 1996

Operating System	Windows NT	QNX (Photon)	QNX (X)	LynxOS (X)
Tools and OTS Software	10	3	5	5
License Cost	7	5	3	3
Memory Footprint	2	8	4	3
Device Support	8	6	6	3
Knowledge and User Base	8	5	6	4
Rail Industry Trends	0	4	6	0
Overall Rating	**35**	**31**	**30**	**18**

operating system simple and easy to maintain, but are optimized for different applications. QNX is optimized for hard real time control at the cost of software integration protection. EMD chose Windows NT embedded, as it is optimized as a robust and reliable software integration platform. Embedded NT utilizes the core of Windows 4.0, specifically:

- Kernel,

- Security subsystem,

- TCP/IP networking,

- Device support (PC card, sound, serial),

- Windowing subsystem.

This operating system offers all the features needed for today, and expandability of FIRE well into the future.

Conclusion

The march of technology is offering us many opportunities. The railroad industry is likewise demonstrating the need for advanced systems to help them transport its cargo (freight or passengers) more swiftly, safely and cost effectively. The introduction of FIRE to streamline the man-machine interface to the locomotive allows the operating crew to become a more intimate part of the transportation loop (Figure 10). EMD is committed to applying the latest in proven technological advances to our locomotives, in order to simplify the task of managing a train. What was presented here is a small portion of our vision for a locomotive truly integrated into a transportation infrastructure. EMD has gathered some positive feedback, has even higher hopes for this product and trusts that, as customers get more familiar with the FIRE platform, we'll together find even more new and innovative ideas to apply to this product to best focus it for their specific needs.

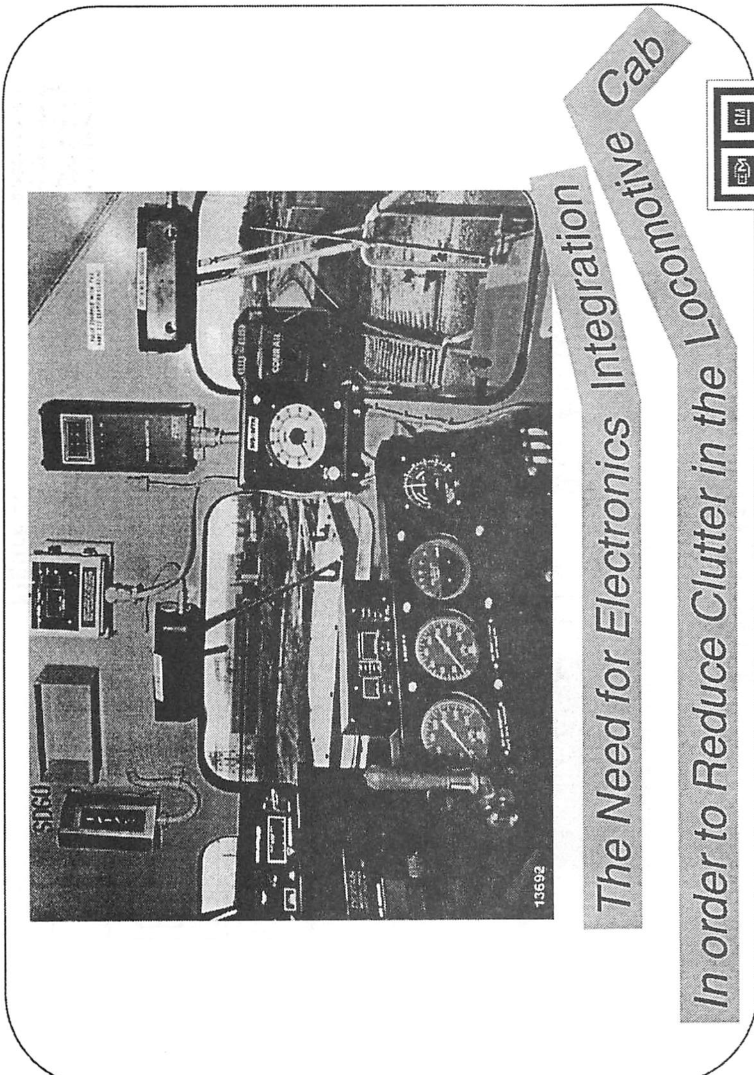

The Need for Electronics Integration
In order to Reduce Clutter in the Locomotive Cab
13692
ELECTRO-MOTIVE

Figure 1.

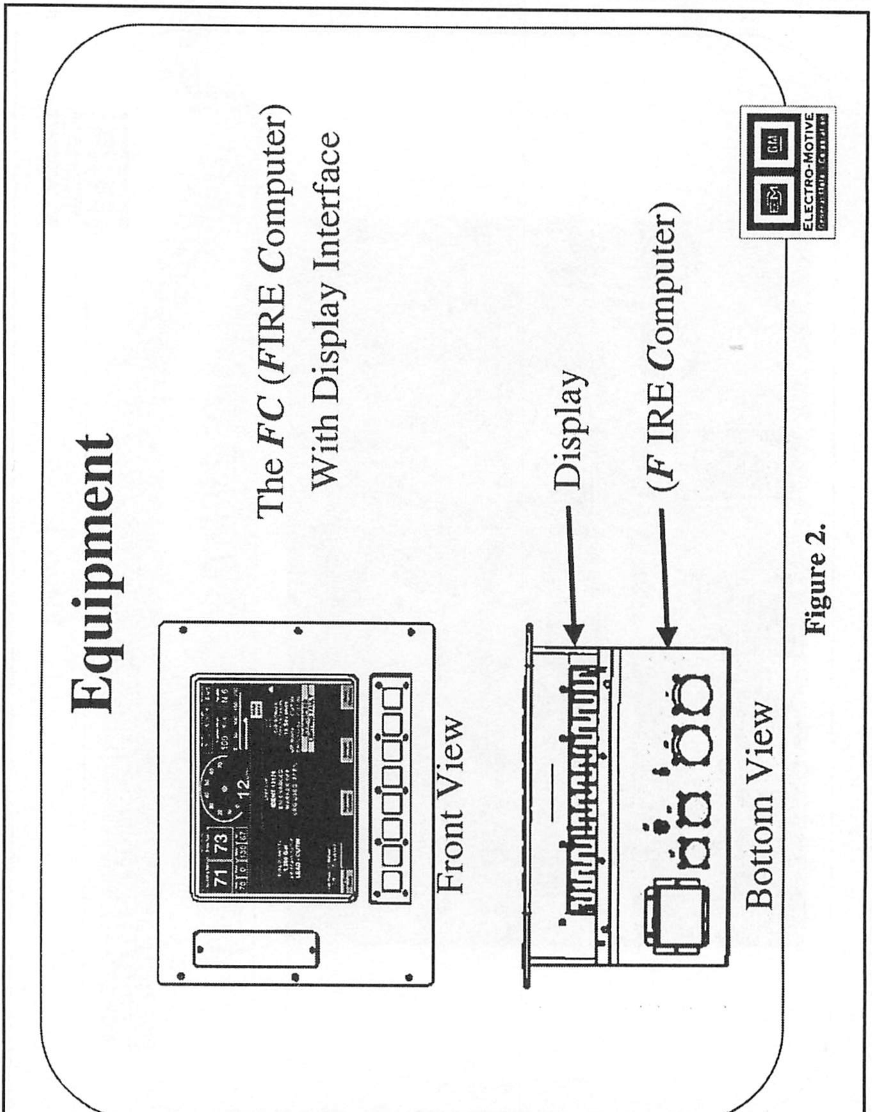

Equipment
The FC (FIRE Computer)
With Display Interface
Front View
Display
(F IRE Computer)
Bottom View
ELECTRO-MOTIVE

Figure 2.

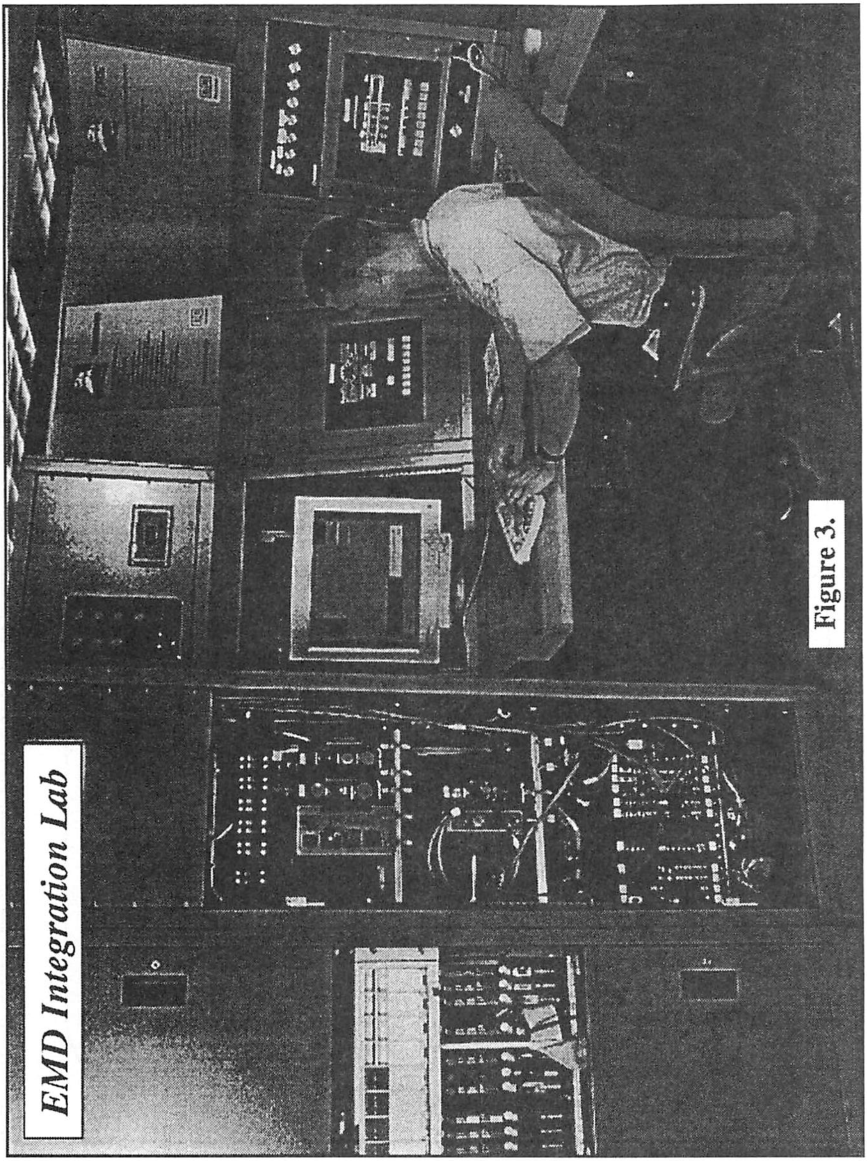


Figure 3.

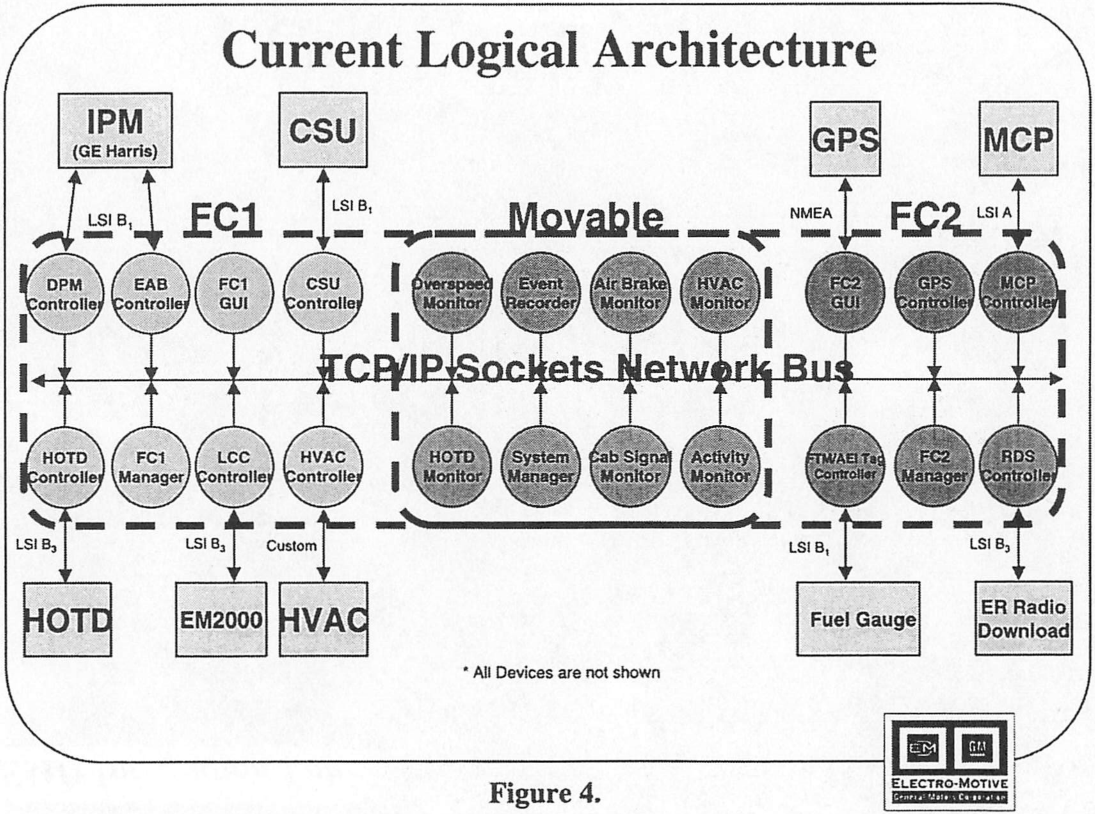

Current Logical Architecture
IPM
(GE Harris)
CSU
GPS
MCP
LSI B1
FC1
LSI B1
Movable
NMEA
FC2
LSI A
DPM Controller
EAB Controller
FC1 GUI
CSU Controller
Overspeed Monitor
Event Recorder
Air Brake Monitor
HVAC Monitor
FC2 GUI
GPS Controller
MCP Controller
TCP/IP Sockets Network Bus
HOTD Controller
FC1 Manager
LCC Controller
HVAC Controller
HOTD Monitor
System Manager
Cab Signal Monitor
Activity Monitor
FTM/AEI Tag Controller
FC2 Manager
RDS Controller
LSI B3
LSI B3
Custom
LSI B1
LSI B3
HOTD
EM2000
HVAC
Fuel Gauge
ER Radio Download
* All Devices are not shown
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Figure 4.

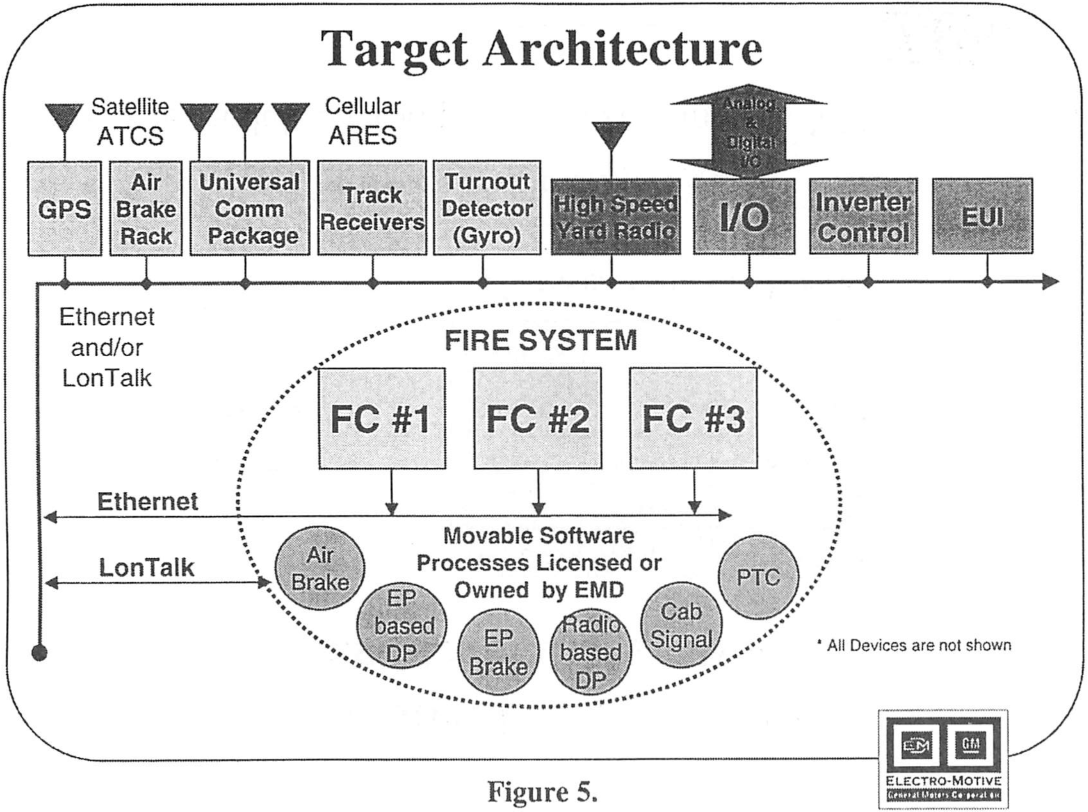
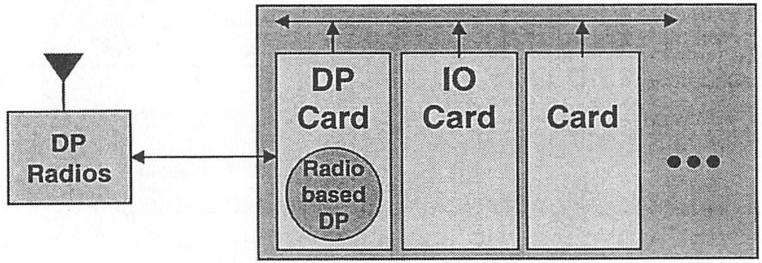

Target Architecture
Satellite
ATCS
Cellular
ARES
Analog & Digital I/O
GPS
Air Brake Rack
Universal Comm Package
Track Receivers
Turnout Detector (Gyro)
High Speed Yard Radio
I/O
Inverter Control
EUI
Ethernet and/or LonTalk
FIRE SYSTEM
FC #1
FC #2
FC #3
Ethernet
LonTalk
Movable Software Processes Licensed or Owned by EMD
Air Brake
EP based DP
EP Brake
Radio based DP
Cab Signal
PTC
* All Devices are not shown
ELECTRO-MOTIVE
General Motors Corporation

Figure 5.

Distributed Power Example
(Card-level Integration)



Chassis with VME Bus

- Specialized hardware and interfaces used
- LSI module repackaged into non-compliant VME card

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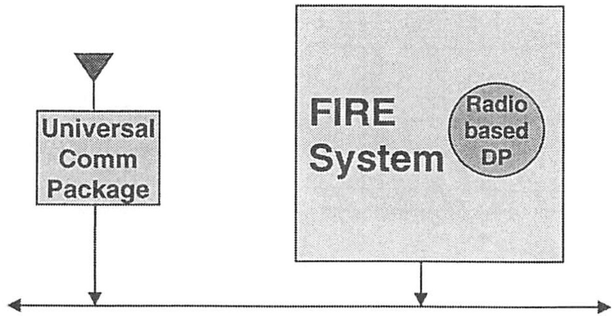
Figure 6.

Distributed Power Example (Software Integration)



- All hardware is LSI compliant
- Integration extends to the radio modules.
  - A single comm package handles distributed power and EOT.
- No additional hardware is required.

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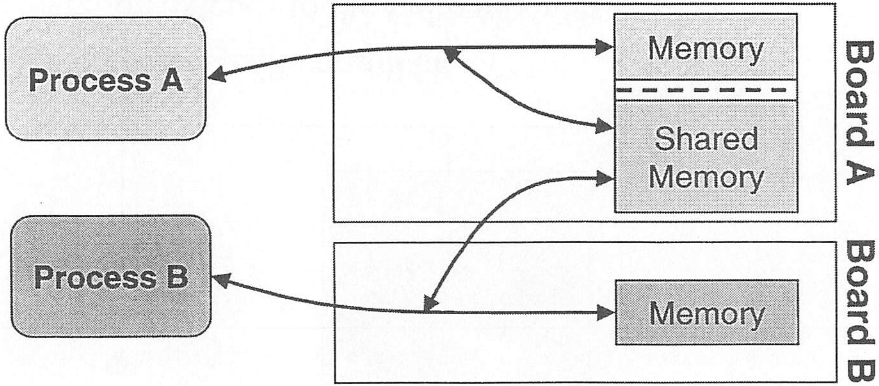
Figure 7.

Shared Memory Interface - Card Level Integration



Board B has direct access to memory on Board A.

Board B can corrupt the system.

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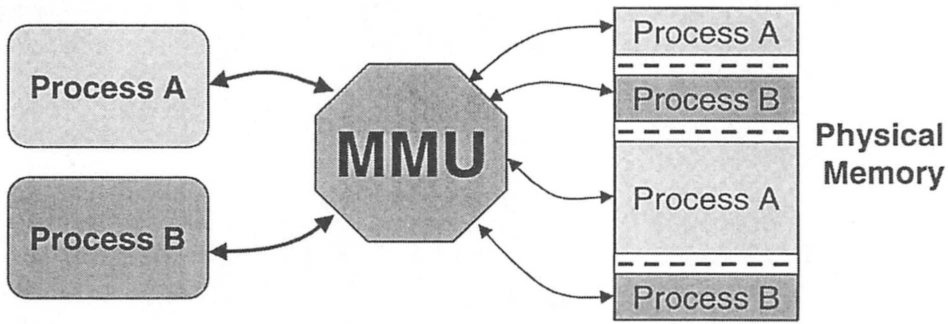
Figure 8.

Shared Memory Interface - Strong Multi-Tasking Software Integration



The MMU creates a firewall between processes.

Physical memory is protected from corruption.

Figure 9.

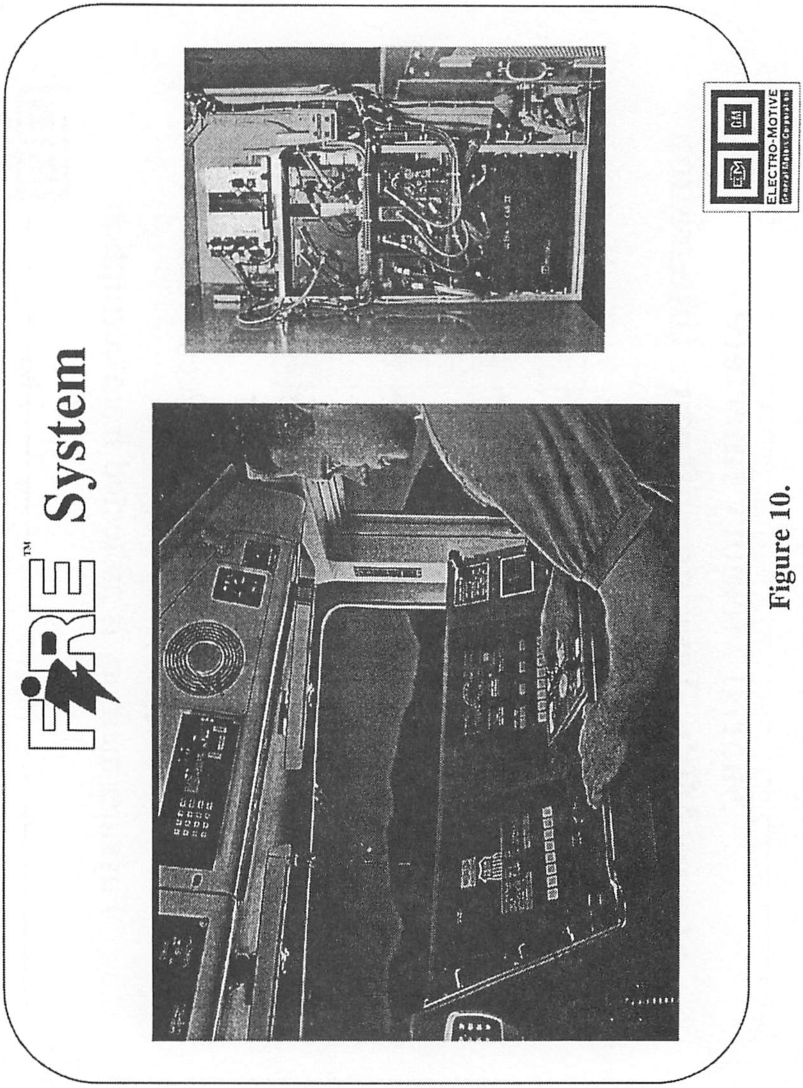


Figure 10.

II. PUT THE CHILL ON AIR CONDITIONING COSTS

By: Tim Black,
Manager Locomotive Scheduling,
Union Pacific RR

CSX Transportation has equipped a number of EMD locomotives with a unique air conditioning system. This system reduces initial installation costs and has potential for reducing maintenance costs long term.

The application consists of a single inverter located in the locomotive inertial air filter compartment and twin R/V air conditioning units installed on the rooftop. The inverter is a 74-Volt D C primary input / 120 Volt A C single phase 60 Hertz secondary output providing power for the air conditioning units. In addition, the locomotive rooftop is painted white. Refer to Figures 1 & 2 for a typical installation on a CSX GP39-2 locomotive.

The inverter uses air flow within the inertial air filter compartment for ventilation, and supplies power to a pair of 12,500 BTU low cost R/V air conditioning units. The rooftop is painted white to reduce the extra sheet metal temperature and the thermal load on the air-conditioning units.

Table 1: Cost comparison of air conditioning applications:

Standard Rooftop Unit		**Twin R/V Units**	
Air Conditioner	$8,400.00	Air Conditioner	$1,120.00
18 KW Aux Gen	$9,900.00	Inverter	$6,000.00
Labor	$1,000.00	Labor	$ 600.00
Total	$19,300.00	Total	$7,720.00

Table 2: Cost comparison of air conditioning maintenance:

Standard Rooftop Unit		**Twin R/V Units**	
92-day intervals			
Rinse Filter & Fins	$ 40.00	Rinse Filter & Fins	$ 40.00
Annual Intervals			
Unit Exchange	$1,300.00	Rinse Filter & Fins	$ 40.00
Total Maintenance Costs Per Year			
Rooftop Unit	$1,420.00	R/V Units	$ 160.00

Reliability of the inverter is being evaluated in service.

Additional installations have been made using a single R/V air conditioning unit and an inverter with reduced load demand. A new rooftop insulating material is used to reduce the thermal load on the R/V unit and the cab interior temperature.

This enables the use of a single air conditioning unit. Application cost for this configuration of equipment is reduced by $2,860.00 (Refer to Table 3 below).

Refer to Figures 3 through 6 for application of the insulating material. The application looks good when finished and does not come off easily. The product does not absorb water and is strong enough to drive on. It must be painted with non-skid material.

CSX conducted tests on cab interior and rooftop temperatures before and after installation of the new insulating material. On August 15, 1999, three locomotive roofs were cleaned, coated with 1.25" of foam, and painted with 7-30 mils of white mastic coating and mixed with non-skid. These units were the 8012 and the power unit roadslug combo 6902/2345 (GP40-2/Rdslug).

The two test units for comparison were:

8012 SD40-2 Built: 4-79 Sprayed with R-10 worth of foam and painted white.

2550 GP38-2 Built: 11-73 Standard blue paint and rust.

The units were tested within a five-minute period, and both units had been stationary with windows/doors closed for 1-hour minimum. Temperature readings are surface temperature using an infrared thermometer. The following temperatures were measured:

T amb - shaded portion of the #1 truck.
T blue - short-hood of cab that is painted blue, in front of the horn.
T white - the center of the roof on the foam-treated locomotive.
T cab - the electrical cabinet door, 4 feet off the deck on the locomotive centerline.
T ceiling - ceiling, measured at the center of the cab ceiling.

Table 3: Application cost, Twin vs Single Units:

Twin R/V Units		**Single R/V Unit**	
Air Conditioner	$1,120.00	Air Conditioner	$ 560.00
Inverter	$6,000.00	Inverter	$3,000.00
Labor	$ 600.00	Cab Fans	$ 700.00
		Labor	$ 600.00
Total	$ 7,720.00	Total	$4,860.00

Table 4: Test Result Comparison:

	Preliminary test	2nd test, 8012/2550 comparison	
	8012 (1600 hrs)	8012 (1645 hrs)	2550 (1640 hrs)
T amb	103°	98°	98°
T blue	155°	124°	124°
T white	127°	113°	
T cab	118°	117°	118°
T ceiling	122°*	116° #	124°

* - Temperature at ceiling cross member, inside cab were 150° F.
# - Temperatures at ceiling cross member, inside cab were 116°F.

Results:

1. By coating and painting, we have reduced the surface temperature on the cab roof; this delta T is most noticeable during high sun exposure.

2. In comparing the 8012 and the 2550, we see that:

   a. In the 8012, the cab ceiling temperature is reduced to less than cab ambient, which means that the roof surface temperature is not driving the cab interior temperature.

   b. In the 2550, the roof surface temperature and the interior ceiling temperature are the same, and are six degrees higher than cab ambient, which means that the roof surface temperatures is driving the cab interior temperatures.

   c. The 8012 rooftop was 11 degrees cooler than the the 2550 rooftop.

   d. Both cabs had about the same interior temp., indicating that a thermal soak results in the same interior temperatures.

Conclusions:

The most significant improvement is that the foam coating greatly reduces the interior ceiling temperature.

The LMOA New Technology Committee feels that the application of R/V air conditioners with the roof insulating material described has potential for reducing maintenance costs on Class 1 and short line railroads.

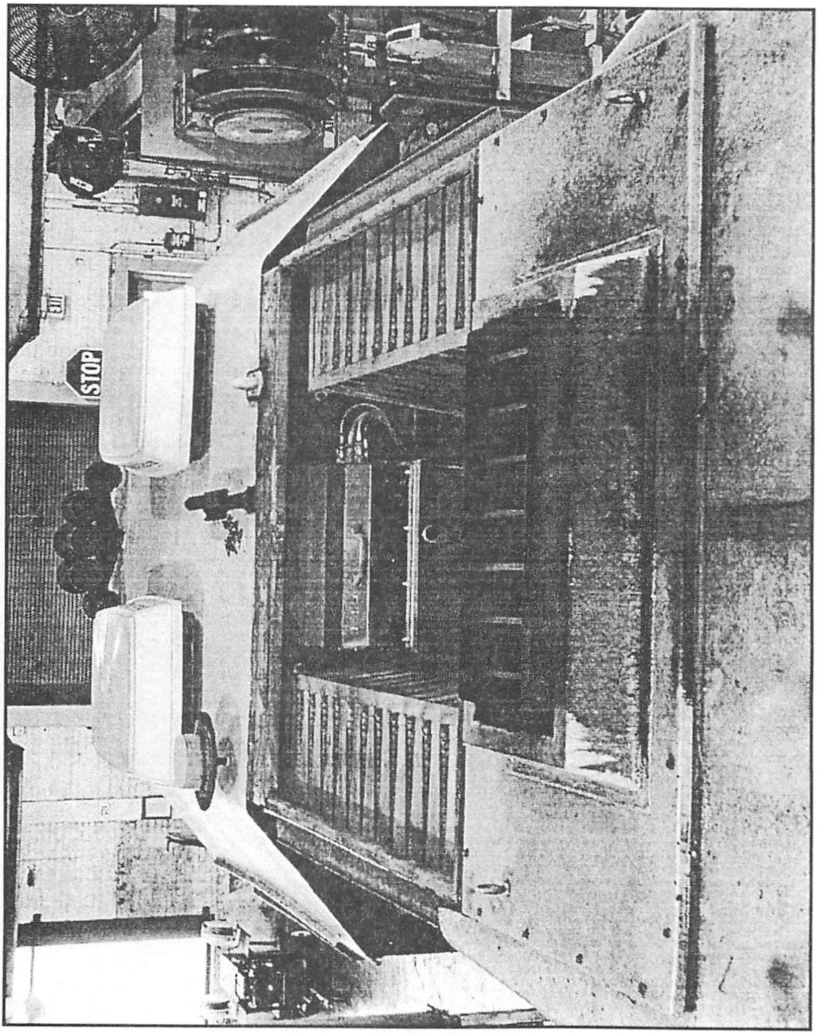


FIGURE 1 ROOFTOP VIEW OF INVERTER AND R/V UNITS

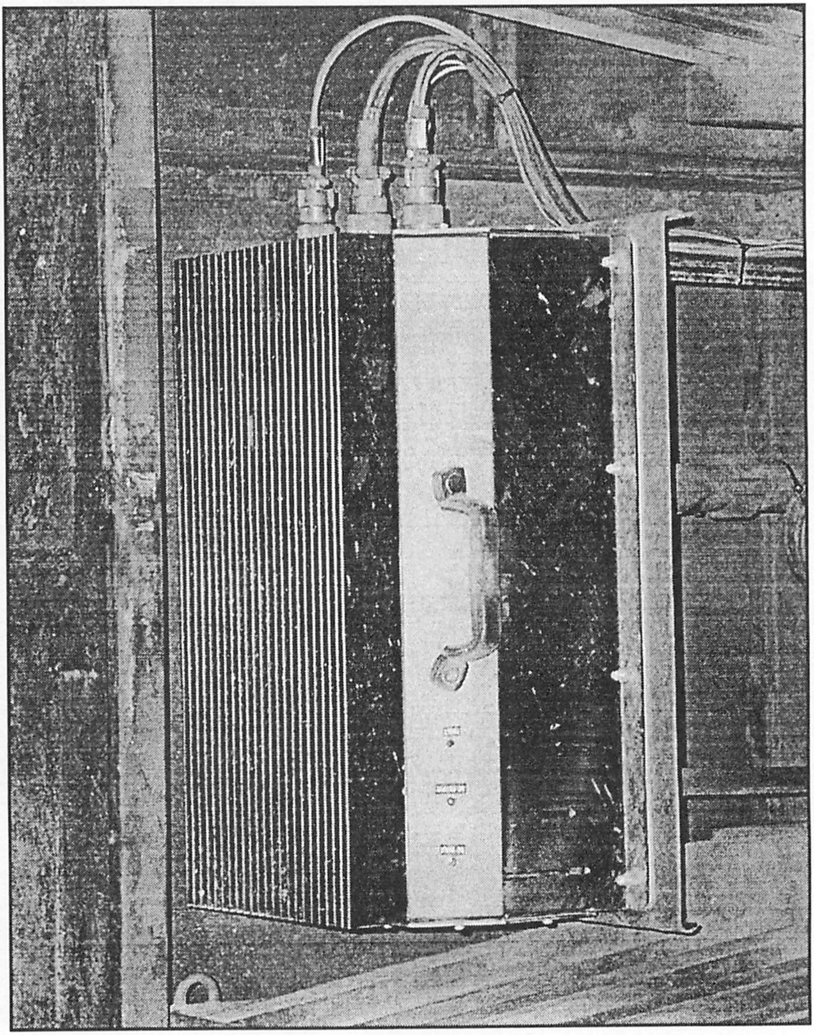
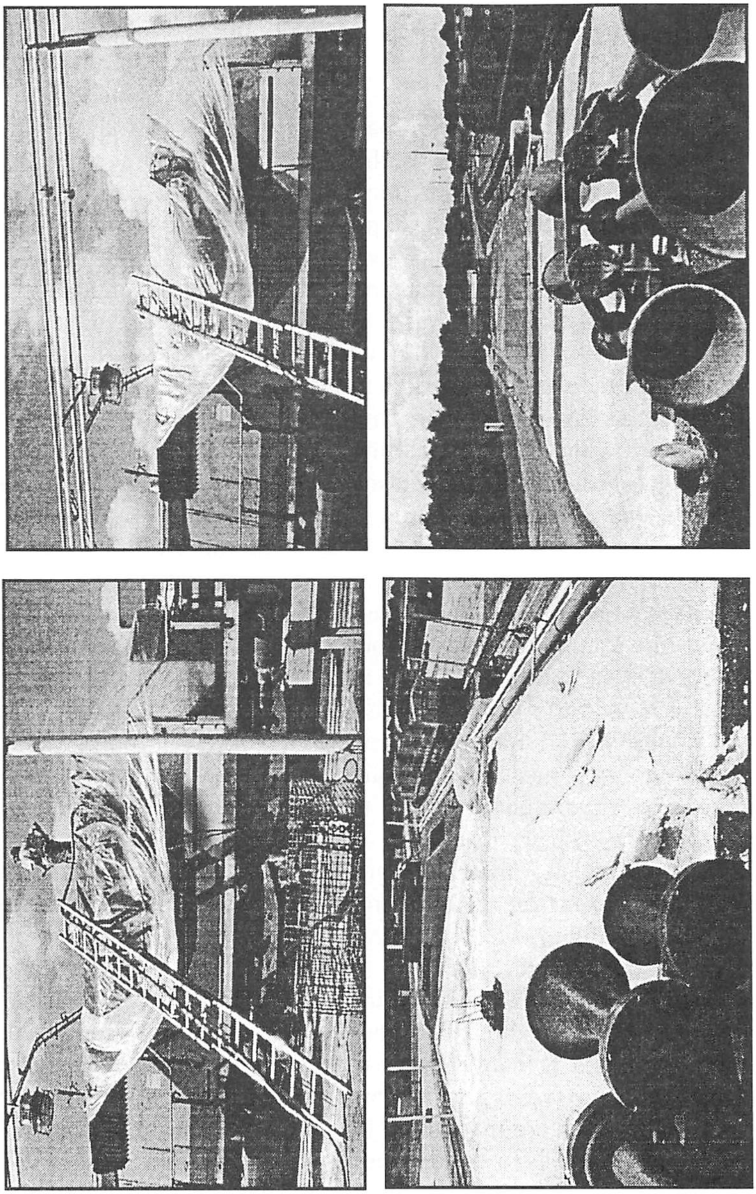


FIGURE 2 CLOSE-UP VIEW OF INVERTER

FIGURE 3 THROUGH 6 ROOFTOP INSULTATING MATERIAL



III. DO NOT GET "$TEAMED" OVER FUEL TANK REPAIR

By: Lawrence J. Biess and Donald L. Robey
CSX Transportation

Introduction

One area of locomotive repair that confronts all railroads is the occasional damaged fuel tank (Figs. 1 and 1a). To repair this type of damage the rail industry will commonly drain any remaining fuel from the tank and wash or steam the tank until the internal hydrocarbon levels are less than 10% of the lower explosive limit (LEL). Following a tank repair, the fuel tank is tested for leaks by filling it with water and performing a standing water test.

Although fuel tank damage is not a consistent problem, when it does occur, the locomotive is taken out of service. It often takes two to four days to route the locomotive to a facility that has oily waste handling facilities and steam generator equipment required to perform the repair. Once at an equipped facility, the fuel tank repair itself can take an additional day of steaming, welding, filling, testing, draining, etc... (Fig. 2).

Following a tank repair using steam and water, the locomotive can experience as many as three to four repetitive fuel-system related problems, which are manifested by an engine that fails to deliver rated horsepower and a costly out-of-service incident.

Current repair method - negative effects

The fuel oil tank on a locomotive has no internal coating. The material, mild steel, is usually prevented from rusting by the presence of fuel oil on a tightly adherent rust layer. The oil soaks into the internal surface and presents a barrier to oxygenated air and water.

When a fuel tank is drained of fuel and steamed, the oil coating that is present in the tank is "sweated" out of the tank's internal surfaces. Unless the fuel oil is removed from the tank in this manner, an LEL of less that 10% may not be achievable and will be exceeded during welding operations (hot work). LEL will be exceeded on a partially steamed tank because residual oils in the vicinity of the hot work are heated, vaporized, and burned. Often a craftsman will remark that a fuel tank will bang and pop, or otherwise "bark" during a weld repair. This popping or barking is caused by LEL exceeding 100% in the area of the repair with the coincidental high temperatures in way of the repair.

When the steamed tank is cooled prior to a repair, the steam vapor in the tank interior condenses and creates a mild vacuum that is filled by oxygenated air entering the fuel tank vent and fuel fill lines. At this point the tank has had its internal oil coating removed, and water and oxygen are introduced to the exposed metal. The result is a rust "bloom"

which occurs in less than 30 minutes on all the tank internals (Fig. 3). The rust is not scale, however, but a very fine surface oxide that is similar to talcum powder.

If the tank is older, with a tightly adherent rust layer, the expansion and contraction of the fuel tank during steaming and cooling disturbs the rust layer. The rust layer flakes off, exposing virgin material, which is subject to additional rusting. The adherent layer flakes off because it has a different thermal expansion characteristic than the base metal. These rust flakes or deposits fall to the bottom of the tank and eventually foul the limber holes at the bottom of each fuel tank baffle plate.

Following the repair, the fuel tank is completely filled with oxygenated water to test the repair area. After a satisfactory inspection, the water is drained. As the water is drained, another fresh exchange of oxygenated air enters the tank through the tank vent and fuel fills, promoting even more rust.

It is known that the surface rust and loosened deposits that are created during the fuel tank steaming are partially responsible for fuel filter obstruction and potential injector damage.

Following a "complete" draining, it is estimated that a fuel tank contains 100 to 200 gallons of residual water, if all of the baffle plate limber holes are open. If some or all of the baffle holes are completely or partially blocked from rust and scale deposits, the residual water volume can exceed 200 gallons.

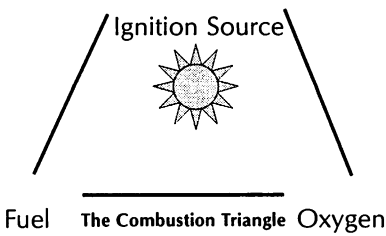
Finally, when a tank is steamed, repaired, passes a standing water test, and then drained of water, the fuel tank may STILL leak fuel oil at the repaired site. In other words, a repaired crack that will hold water may not hold fuel oil.

A New Approach

The biggest concern with any work being done on a locomotive is that of personnel safety. The challenge presented to CSX was to investigate and implement a fuel tank repair method that would be safe or safer than the current method. Another criterion was to eliminate fuel tank contamination caused by the introduction of steam, water, and air. The answers to this challenge were to be found in basic fire safety principles and the application of these principles as they have been historically used by the marine and petroleum industry.

The Fire Triangle

In order for a fire or explosion to occur, three ingredients must be present. These are fuel, oxygen, and a source of ignition.



The Combustion Triangle

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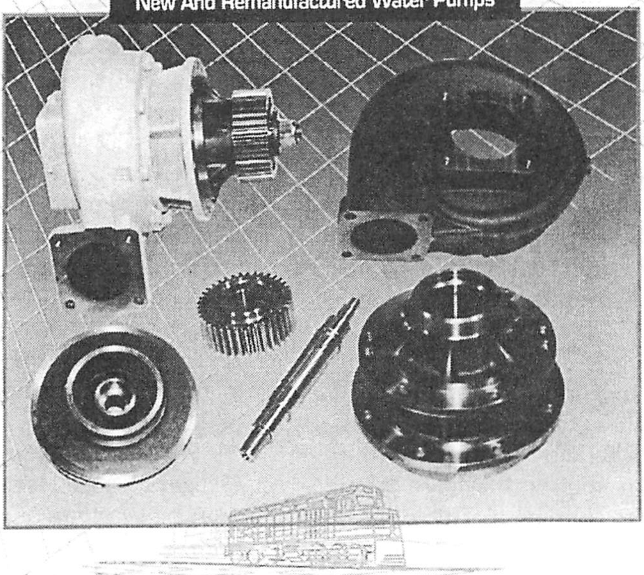

Triangle Engineered Products Company specializes in the manufacture of new and the remanufacture of locomotive water pumps.

All remanufactured pumps receive new gaskets, shaft nuts, seals, stationary bushings, shaft bearings, springs and hardware. All pumps feature computer balanced shaft assemblies. Brand new impellers, pump housings, gears, impeller housings, and shafts are available from stock to replace non remanufacturable components.

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Since the ignition source is an ever-present part of fuel tank repair, it cannot be eliminated.

Fuel elimination by way of tank steaming has been the industry's standard for railroads since railroads came into existence. Removing fuel and measuring the internal tank atmosphere to verify an internal LEL of less than 10% has been and is a safe, measurable way of assuring personnel safety during tank repairs.

Oxygen elimination, otherwise known within the marine and petroleum industries as "inertion," is the method that was examined, tested, and implemented for fuel tank repairs at CSX. Before a tank can be inerted, it is necessary to establish **method, limits, and controls.**

Inertion Method

Basically tank inertion is accomplished by displacing the oxygen in the tank with a non-flammable, non-combustible gas. As this gas is being purged into the tank, the gas exiting the tank at various sample points is tested until the oxygen level is reduced to less than an established limit. When this limit is reached, tank repair can begin. When inerted, the tank can be repaired regardless of the fuel level in the tank. During tank inertion and repair, pressure on the tank is maintained at 0 pounds per square inch gauge (PSIG), with minimum inert gas flow required to maintain the low oxygen limit. Following the inertion and repair, tank internal gas pressure is permitted to rise to an established limit to verify that the repair is satisfactory (low pressure test).

Inertion Limits

The following limits were identified as being necessary to ensure safety to personnel and equipment. They are the minimum safe oxygen levels for men, the maximum safe oxygen levels inside the fuel tank for hot work, and the maximum fuel tank pressure to prevent tank damage.

Oxygen

To derive oxygen limits, the NFPA and Occupational Safety and Health Administration (OSHA) limits were consulted. Two limits for oxygen were derived (Fig 4).

1. Oxygen levels in the area of the locomotive are not permitted to be less than 19.5%.

2. Oxygen levels inside the tank must be less than or equal to 6% prior to any hot work.

Refer to Table 1 for **O**xygen levels (Percentage of O_2).

Tank Pressure Limit:

To derive a safe internal tank pressure limit, the OEM drawings were consulted and current test pressure using standing water was calculated. An internal tank pressure limit not to exceed 2PSIG was derived** (Fig. 5).

Refer to the following Table 2 for tank pressure, pounds/square inch, gauge (PSIG).

Table 1: Oxygen Levels (Percentage of O_2):

Parameter, Oxygen	Oxygen Level, 1%
Normal Atmospheric Oxygen Levels	20.5% - 21.5%
Minimum Safe Level for Workers, NFPA/OSHA	19.55
Minimum Level Required for Combustion	16%
Maximum Level for Hot Work, NFPA Limit	Less Than 8%
Maximum Level for Hot Work, CSXT Limit	Less Than or Equal to 6%

Table 2: Tank Pressure, pounds/square inch, gauge (PSIG):

GE Fuel Tank Hydrostatic Test Pressure	9.0+/-1.0 PSIG
EMD Fuel Tank Hydrostatic Test Pressure	5.0+/- 1.0 PSIG
Standing Water Test, Pressure on Tank Bottom	1.73 PSIG*

* Pressure based on a tank that is 48″ deep, filled to overflowing with water.
** Pressure limit selected is a conservative whole number rounding of the operational pressure of 1.73 PSIG.

Controls

During tank inertion and testing, controls are required to address the following primary concerns:

1. Provide safe working conditions for personnel. (Do not hurt anyone.)

1. Prevent damage to the fuel tank. (Do not break anything.)

Personnel Safety Controls

The primary safety concerns for personnel during a tank inertion are fire safety and the minimum oxygen limit as established by the NFPA and OSHA. To address these concerns, with adequate controls, a procedure was developed which requires the use of calibrated instrumentations to measure the tank's internal oxygen levels. If either of the established limits is exceeded, the procedure contains instructions for re-establishing safe conditions. Since CSX has an established confined work-space program that includes calibrated gas-monitoring equipment, this equipment is also used during the fuel tank inertion and repair.

Another consideration for personnel safety is the selection of an inert gas. Several gases, including carbon dioxide and argon, could be used to inert a tank, but nitrogen (N2) was chosen. The reasons being:

1. Nitrogen is non-toxic. Breathing air contains about 79% nitrogen.

2. Nitrogen is slightly lighter than air. With an atomic number of 7

(N_2=28 grams/mole) it is slightly lighter than oxygen, which has an atomic number of 8 (O_2=32 grams/mole). This physical characteristic means that nitrogen will not pool in low-lying areas like argon or carbon dioxide, but will instead dissipate evenly and rise throughout a space.

3. Nitrogen is a "dry" gas that does not freeze or ice as it is vented to atmosphere.

4. Nitrogen is inexpensive and easily obtainable.

Tank Protection Controls

The primary fuel tank concern is the possibility of over-pressurizing the fuel tank during the test-phase of the tank repair procedure. Tank over-pressurization is primarily prevented by the implementation of CSX written procedure and operator action. The test procedure emphasizes verbatim compliance and is written to permit slow and deliberate pressure increases during tank testing (Fig. 6). The presence of two people is required during pressure testing. The CSX designed test equipment is assembled using components that prevent over-pressurizing the tank, including redundant pressure gauges and relief valves. The test procedure identifies two methods of over-pressure protection:

1. The primary means of over-pressure protection is manual overpressure protection (operator action). The operator will vent the tank and isolate the pressure source if either test gauge exceeds 2 PSIG, or if either gauge fails to respond.

2. The secondary means of over-pressure protection is relief valve operation in response to an over-pressure condition. The relief valve settings are verified at specific intervals and are operationally tested prior to each test.

Benefits of Nitrogen Inertion

Nitrogen inertion can be used in 90-95% of all fuel tank repair scenarios. If the tank is so damaged that it needs to be removed from the locomotive or the endplates or side plates are ripped open, nitrogen inertion may not be possible. In these extreme cases, steaming or water washing the tank internals may be required.

Repair rigs are used to inert, purge and test a fuel tank (Figs. 7-10). All CSX fuel tanks are pressure tested with nitrogen gas, regardless of whether or not the tank was steamed or inerted. Therefore, water contamination and the usual problem of removing the residual water after a tank test is eliminated. Since the entire tank is being tested to a set pressure using nitrogen gas, the tank is inspected for leaking fuel (below fuel line) and soap solution is used to detect gas leaks above the fuel line. By using gas and testing to a pressure slightly higher than operational pressure, conservative test results are obtained.

If a leak is detected during pressurization, the tank pressure is vented and internal oxygen levels are verified, enabling immediate repair of the tank. Back to back repairs can occur as often as is necessary to complete a repair.

Average fuel tank repair time (make tank safe, repair, and test) has been reduced from 18-36 clock hours to less than 2 hours. Since the repairs seldom require steaming, the repairs can be performed wherever a test rig and trained personnel are stationed. By adopting the inertion method, CSX has avoided the need to outfit outlying areas with steam generating equipment and oily water recovery facilities.

When a tank is inerted, the tank may be repaired regardless of the fuel level. If a welder is comfortable welding a damaged area below the level of fuel, he/she may safely do so. If not, the tank level can be quickly reduced by pumping fuel to another locomotive fuel tank or stationary fuel tank. Craftsmen at CSX have been trained on a variety of repair techniques and have become quite comfortable repairing leaks below and above the fuel level.

Summary

Tank repairs using nitrogen inertion are safe, simple and quick. Past problems associated with water and rust contamination of the fuel system are avoided using this new technique.

FIGURE 1 MAJOR FUEL TANK REPAIR

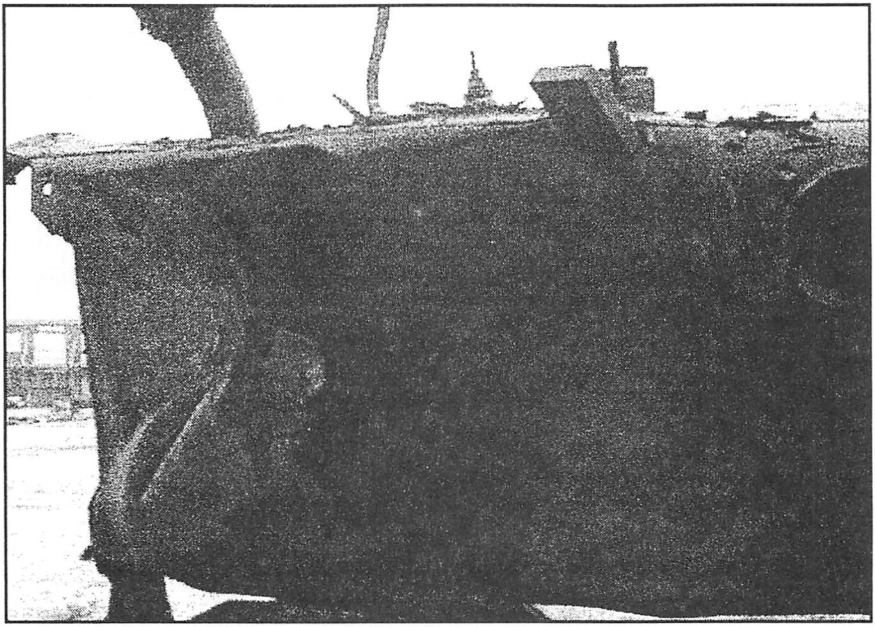


FIGURE 1A MINOR FUEL TANK REPAIR

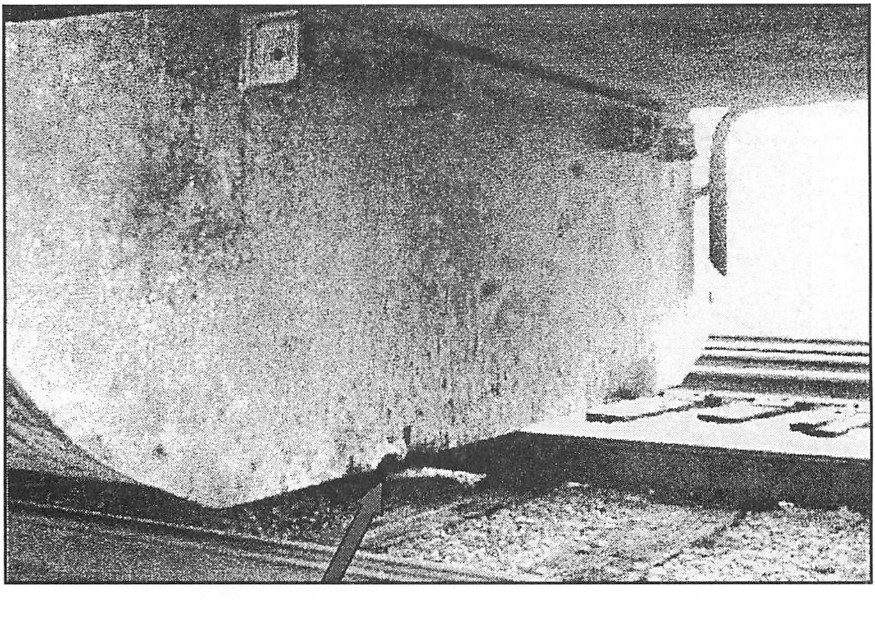
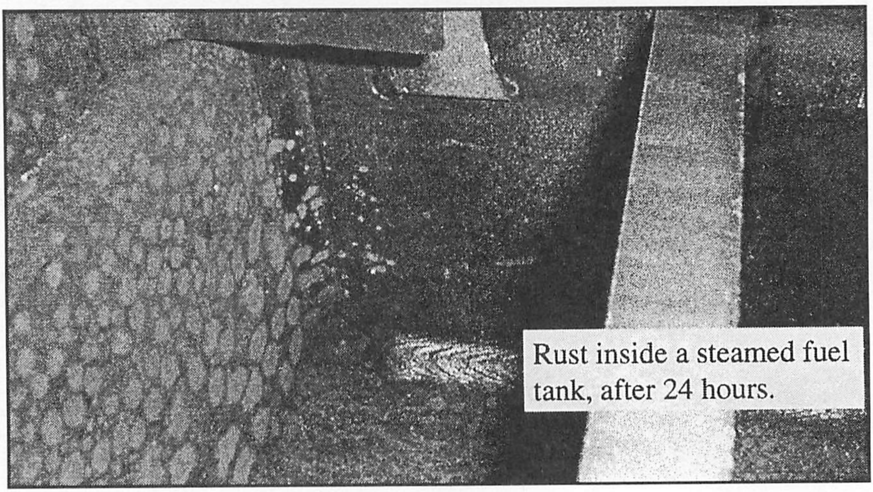


FIGURE 2 COST ANALYSIS OF A STEAM TANK PROCESS

Action:	Steam Repair	Cost	Actual Cost
Route to special shop steam	required, 2-3 days min.	Lease Loco ($800/day, average)	$1,600
Drain fuel	Hook-up and disconnect draining apparatus, 3-4 man-hours	$25/hr	$75
Fuel oil removal/reprocessing (removal fee sur-charge)	3000 gals (requirement at some shops)	$.10/gallon	$300
Process waste from tank steaming	200-300 gallons,	$.25/gallon	$63
Repair tank	Same in either process	N/A	N/A
Process water following test	3,000 gallons (average)	N/A	$1,350
Detention time:			$1100
Drain take	3 hrs. (min.)	33 hrs	
Steam tank	18 hrs. (min.)	($800/day)	
Tank repair	same in either process		
Test take	12 hrs. (min.)		
Lift one end to drain water	3 hrs. (min)		
Man-hours for each task:			$200
Drain take	No mn-hrs required	8 man-hours @	
Steam tank	2 mn-hrs	$25.00/hr	
Tank repair	same in either process		
Test take	2 mn-hrs		
Lift one end to drain water	4 mn-hrs		
Perform further repair (first attempt to repair fails water test)	Requires draining and refill each time an attempt is made	low probablity of occurs (no cost added)	$0
Certify tank	Required, 5 minutes	N/A	
Purge tank	N/A	N/A	
Nitrogen gas	N/A	N/A	
Cost Break Down	- Detention time Cost		$2,700
	- All other Cost		$1,988
Total cost		N/A	$4,688

FIGURE 3



Rust inside a steamed fuel tank, after 24 hours.

FIGURE 4 RELATIVE OXYGEN LEVELS

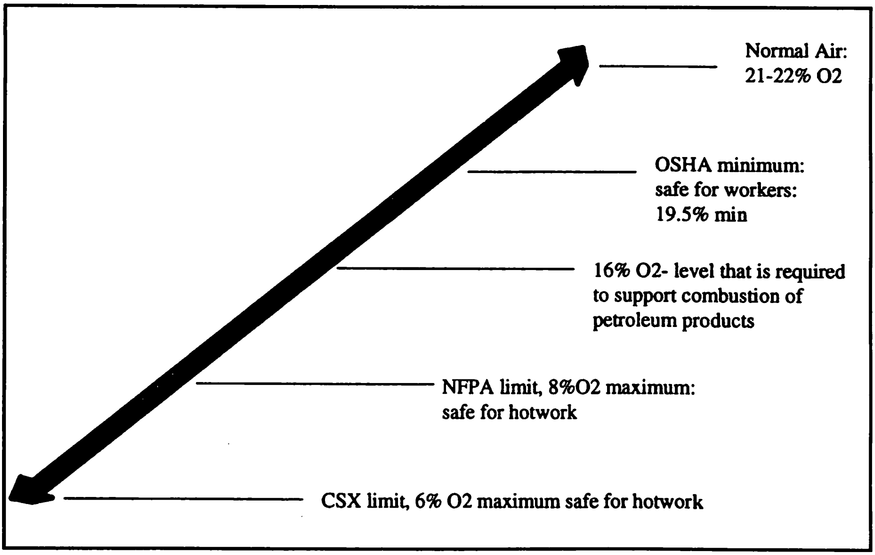


FIGURE 5 RELATIVE PRESSURE LEVELS

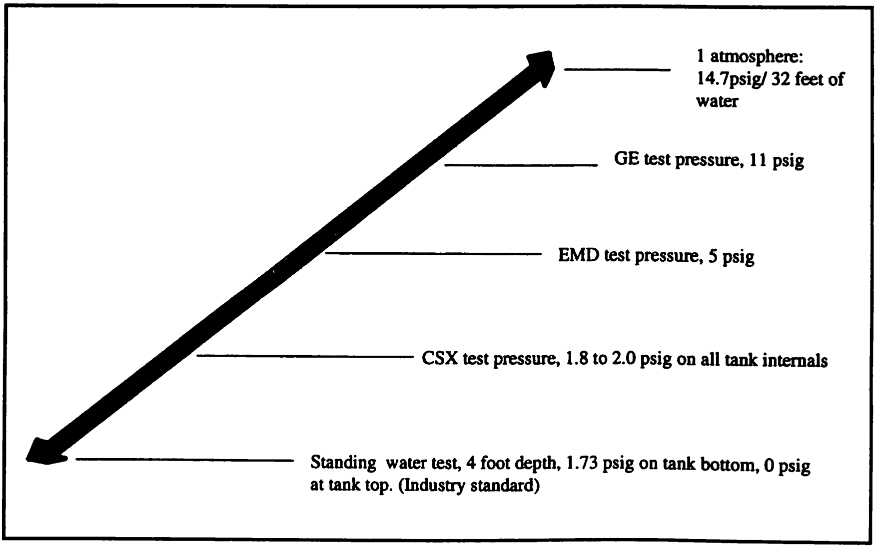


FIGURE 6 METHOD, LIMITS AND CONTROL PROCEDURE

CSX TRANSPORTATION

Locomotive Fuel Tank Repair

SMR X-2600-03 Revision B

8/15/99

PURPOSE: To provide safe job instructions for performing fuel tank repairs.

UNITS: All units

LOCATION: All CSX facilities that have been properly trained on the use of this procedure.

MATERIAL: As delineated.

TOOLING: As delineated.

INSTRUCTIONS: **Observe all applicable safety rules and regulations.**

Table 3: Protect Valve Lineup VL3

Valve	Required Position	Position	Initial Positioner, Initials	Verifier, Initials
Header Valve H1	Closed			
Header Valve H2	Closed			
Header Valve H3	Closed			
Header Valve H4	Closed			
Master Valve H5	Closed			
High Pressure Regulator R1	Backed out			
V1	Closed			
V2	Closed			
Low Pressure Regulator R2	Pre-Set IAW Reference B.4			
V3	Closed			
V4	Closed			
V5	Closed			
V6	Open			
V7	Closed			
MV1	Closed			
MV2	Closed			
PV1	Closed			

Signature, Initial Positioner:______________________

Date:______________ Pay Number:______________

Signature, Verifier:______________________

Date:______________ Pay Number:______________

FIGURE 7 NITROGEN TEST RIG (3 PART APPARATUS)

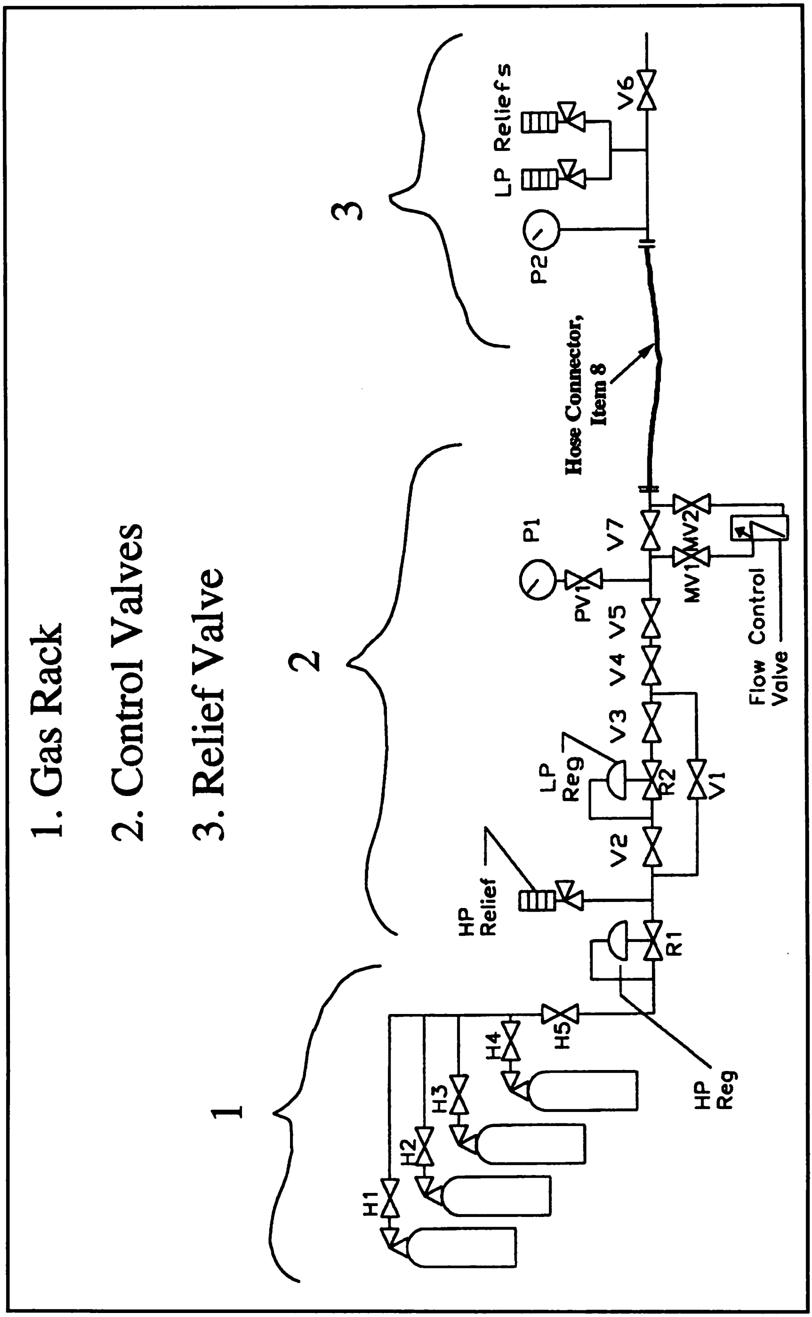


FIGURE 8 NITROGEN RACK

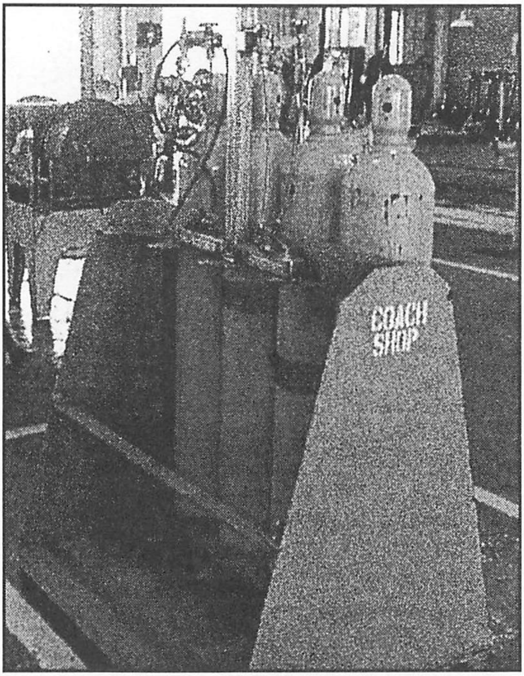


FIGURE 9 CONTROL VALVES

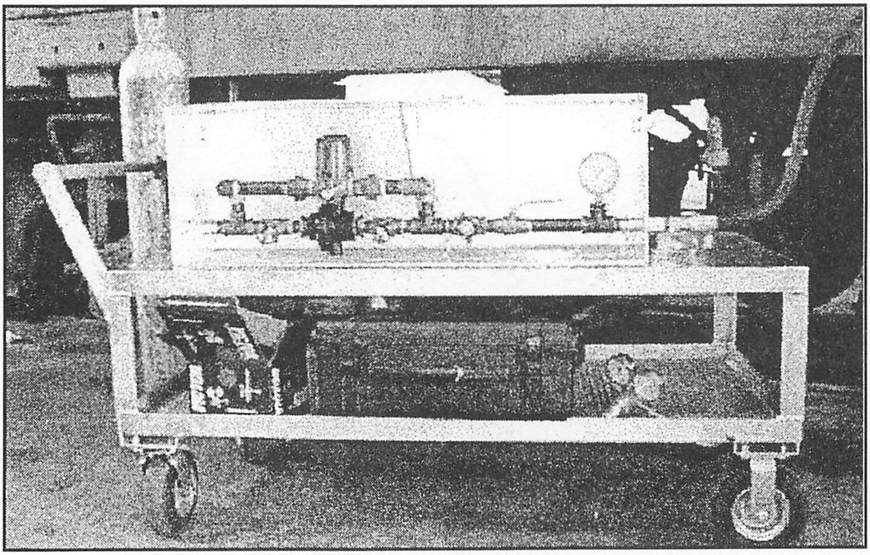


FIGURE 10 RELIEF VALVE

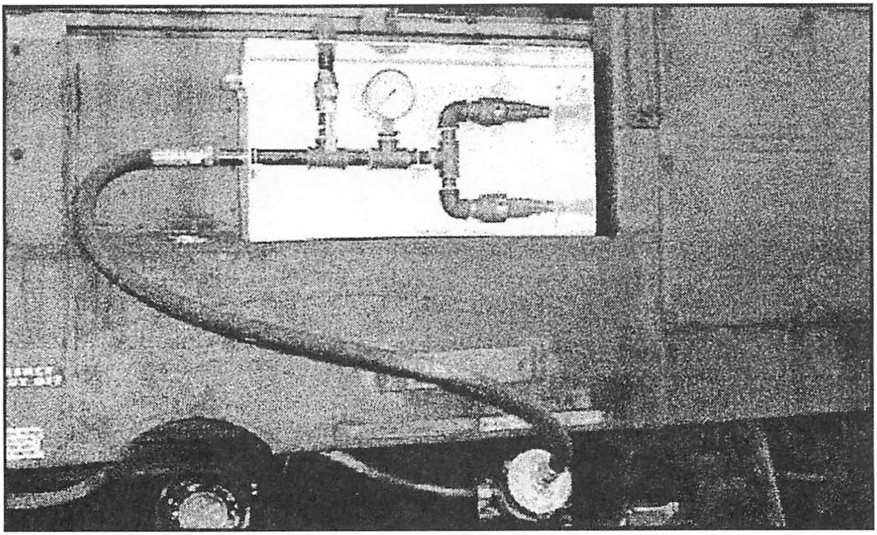
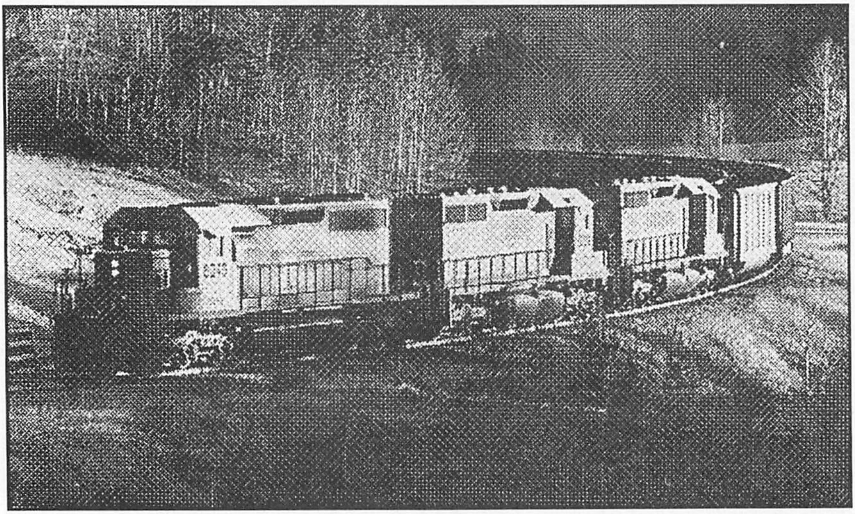
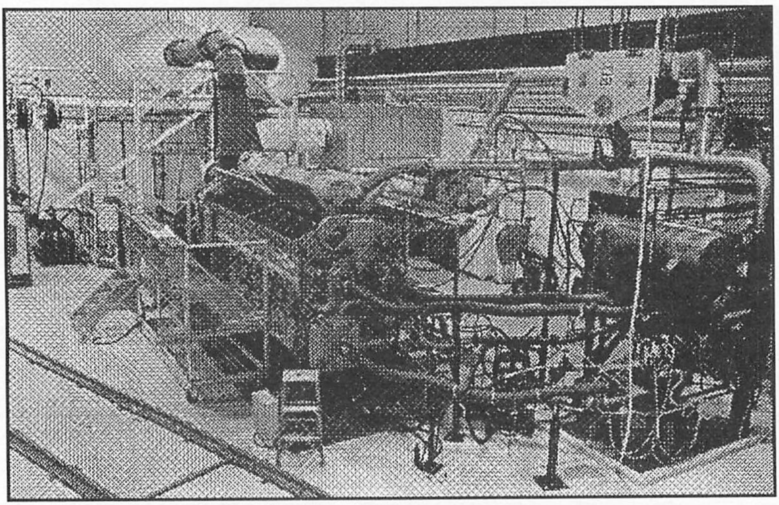


FIGURE 11 COST ANALYSIS OF A NITROGEN INERTION PROCESS

Action:	Nitrogen Repair	Cost	Actual Cost
Route to special shop steam	not required	Lease Loco ($800/day, average)	$0
Drain fuel	not required	$25/hr	$0
Fuel oil removal/reprocessing (removal fee sur-charge)	not required	$.10/gallon	$0
Process waste from tank steaming	not required	$.25/gallon	$0
Repair tank (detention time & man-hours)	Same in either process	N/A	N/A
Process water following test	not required	N/A	$0
Detention time: Drain take Steam tank Test take Lift one end to drain water	 not required not required 10 minutes not required	essentially zero ($800/day)	$0
Man-hours for each task: Drain take Steam tank Test take Lift one end to drain water	 No mn-hrs required not required 10 minutes not required	1/4 man-hours @ $25.00/hr	$6
Perform further repair (first attempt to repair fails water test)	Requires draining and refill each time an attempt is made	low probablity of occurs (no cost added)	$0
Certify tank	Required, 5 minutes	N/A	
Purge tank	N/A	N/A	
Nitrogen gas	$20/tank	2 tanks (avg. comsumption)	$46
Cost Break Down	- Detention time Cost - All other Cost		$0 $46
Total cost			$46



IV. CLEARING THE AIR ON EMISSIONS



IV. INDUSTRY RESPONSES TO EMISSION REGULATIONS

By: Alain Mercier,
ALSTOM Transport

1. Understanding the Future

Railroad Perspectives

The introduction of the EPA regulations is one of the most significant events in the last twenty years to affect both railroads and the locomotive industry as a whole. This change has not only pushed the development of more efficient engines in new locomotives, but it will also result in an increased cost of ownership of the almost 20,000 mainline style locomotive in North America.

The cost of managing EPA compliance is now one of the greatest concerns facing each railroad. Fleet downsizing, as a result of post-merger productivity increases and new acquisitions will lower the total industry cost burden. Outside of fleet rationalization however, approaches to control EPA conversion costs include:

I. Setting long-term fleet strategy based on models that are expected to have the lowest costs of conversion (phase out of 20 cylinder 645 engines, early generation GE's);

II. Accelerated programs to overhaul/acquire locomotives before the scheduled date of application of the regulation;

III. Where outsourcing of maintenance is planned, to transfer the responsibility of compliance to the supplier as part of the agreement (e.g. BNSF, CSX have included these requirements in recent maintenance and lease transactions); and

IV. Maximize credits under the banking, credits and trading provisions to defer retrofits on existing fleets.

Most railroads have publicly stated that they are prepared to invest in modifications to meet EPA Tier 0; however there are varying degrees of interest in the types of changes and benefits they are willing to pay for. Some railroads have proposed meeting EPA requirements at the lowest modification cost even if efficiency deteriorates (e.g. fuel). On the other hand, some railroads have expressed a desire to invest more in retrofits in order to generate operational savings.

Supplier Perspectives

EMD/GE

Under the EPA rules, the OEM's have opted different strategies to qualify their existing products under the new norms:

✔ General Motors (EMD) has opted to release early in 2000 a Tier 0 package for existing locomotives containing the 710 engine.

✔ General Electric Transportation (GE) has opted for later release of its Tier 0 kit to meet the introduction phase for existing locomotives in 2001.

Separate papers are being presented specifically on the EMD and GE solutions; therefore this paper will concentrate on railroad and aftermarket solutions regarding compliance.

After-Market

Outside of EMD and GE, the supply industry has been very active in the development of solutions for the EMD with expectations to issue kits for the GE locomotives in 2001. There is a good base of technical literature on theoretical solutions with some test results published over the years. After-market suppliers are preparing EMD 645 kits for market release in the first half of 2001. In the case of GE's units, there is limited development due to a small after-market supply base. As well, more extensive changes are required for the FDL engine to attain Tier 0.

The major hurdle for suppliers has been the lack of testing capability in-house to develop proprietary technology. To date, only Southwest Research can provide the necessary independent testing facilities for complete locomotives and has experience in emissions testing for large size engines. In Canada, ESDC has partial testing capability (excluding particulate matter). As the launch of the certification program by the EPA has taken more time than expected, some suppliers will delay certification testing until later this year. As a result, the ability to market a tested product is not expected before year-end 2000.

Changes in Regulations - Canada and Mexico

The Railway Association of Canada entered into a voluntary program with Environment Canada in 1995 to limit the total tonnage of NOx released in the atmosphere to 115kilo-tons subject to a 1.5% increase in traffic growth per year. 1997 results have already surpassed this limit due to average traffic growth of 4.3%.

The Canadian government has yet to establish a formal ruling governing locomotives. Papers commissioned by Transport Canada proposed that the harmonization of rules with the EPA might be desirable as interchange and reduced trade barriers are desirable. The political realities are, however that it is a matter of provincial jurisdiction and therefore a national policy may take some time before materializing.

Compounding this jurisdictional issue, the Canadian government signed the Kyoto Accord to reduce greenhouse gases and may include specific norms in regard to carbon-derived emissions. As such, Environment and Transport Canada are reviewing the role of establishing rules for locomotive

emissions in this matter. These departments are currently commissioning their own studies in order to recommend a final policy sometime in 2001.

There is no specific regulatory rule governing emissions of locomotives in Mexico. Both supplier and railroad personnel anticipate a move to EPA standards over time and only in a post-election period beyond 2000.

Cross-Boarder Operation of Fleets

The EPA regulations (Sec. J.9) states that locomotives that are non-conforming and which are deemed to be foreign-owned (Canada and Mexico) are excluded from the regulations if their operation is incidental within the U.S. This policy is expected to promote use of an EPA compliant fleet for international traffic (modern compliant locomotives) with non-EPA compliant fleets relegated to Canadian/Mexican operation - until, of course, regulations are harmonized.

2. Survey of Kits Under Development - Tier 0 Compliance

Strategy A - Engine Timing Retarding

In order to minimize short-term costs related to modifications to major locomotive systems, a minimal approach to EPA compliance will be to adjust engine timing.

In an EPA-commissioned study by Acurex Environmental Corporation in 1997, evidence was presented demonstrating the reduction in NOx levels as a result of retarding engine timing for most classes of locomotives. The table below is an extract of some of the locomotives tested (note: the EPA is 9.5 grams:

Locomotive Model	Locomotive	NOx Baseline Mean (g/bhp-hr)	NOx Retarted Timing	Reduction (%)
SD40 -2	645E3	11.1	8.3	25%
SD40 -2	645E3B	12.2	9.2	25%
SD60	710G3	10.3	7.7	25%
C40-8	7FDL	12.4	9.7	22%
C44-9	7FDLN6 EFI	11.3	8.2	27%

This technique, while effectively producing acceptable results for some classes of EMD and GE engines, has also demonstrated in published results that fuel costs can increase by up to 1-3% depending on test conditions and engine types.

Strategy B - Improved Cooling of Charge Air

A second strategy that is well understood for both engine designs is to lower charge air through a more efficient 4-pass aftercooler. This technique is applicable to both two and four-stoke designs. Where significant reductions in NOx is required, a split cooling circuit with direct routing of cooled water to the aftercooler further lowers the charge air temperature necessary to reduce NOx formation. This cooling principle is used to offset initial high combustion temperature associated with turbocharged engines.

There is some development to produce a 6-pass aftercooler in conjunction with a split-cooling circuit. A 6-pass aftercooler in itself is claimed to be more efficient in cooling charge air over the 4-pass. Temperature reduction to affect NOx however, is dependent on the water temperature from the radiator bank circuit. With a separate cooling circuit, the charge air temperature can be reduced below the engine cooling circuit temperature of 170 degrees F normally found in an EMD SD40 for example. This strategy is a proven method to address NOx formation without negative effects on fuel consumption.

Strategy C - Injection/Combustion

To control fuel consumption, the development of a more efficient injection/combustion chamber is a third strategy to offer better control over emissions and lower operating costs. Several firms with injector experience are currently designing and testing both improved mechanical designs and new electronic fuel injection. Their objective is not only to offset the fuel penalty associated with retarding engine timing, but also to provide saving to railroads.

Most fuel friendly injectors are characterized by "zero-sac" tips, which are documented in studies to reduce excess fuel leakage into the combustion chamber. Optimization of fuel spray pattern has also been claimed to be a potential solution.

Strategy D - Re-Engine

As a final strategy, several engine suppliers have expressed a desire to re-engine existing locomotives (under 3,000 HP) given their off-shore experience in this area. At this point, low cost re-engining and proven creditability in the locomotive market will be the key factors for these suppliers. Given that most low emission engines are of high speed design (1,800 rpm versus 900 rpm), fuel saving may not offset costly replacement of the alternator/auxiliaries and the more frequent overhaul cycles. Modern replacement engines are all reported to offer 10-25% fuel savings depending on the engine it is replacing while providing Tier 1 emission characteristics.

Both Caterpillar and Cummings have EPA-compliant high-speed diesels for the low horsepower markets.

One supplier is in the preliminary phase to demonstrate a locomotive with a British-built MAN medium speed engine using the existing AR10 alternator and systems in an EMD model locomotive. Tier-1 emission levels, fuel savings exceeding 20%, a 180-day maintenance regimen and a 60,000-hour mean time between major overhaul are the specification aspects of this planned product.

The above strategies, although effective, will require a new more important review by operating railroads either in terms of accepting future fuel savings over one-time conversion costs or increased configuration costs from new or replaced designs.

Development Readiness

A sampling of suppliers who are either developing and/or testing products are:

Hatch & Kirk Inc. is pursuing a Tier Zero solution that will meet EPA requirements for the model year of 2001. Hatch & Kirk's goal is to achieve Tier Zero compliance while providing improved fuel efficiency. Tests are currently underway to validate their proposed kit.

Energy Conversions Inc. has developed a multi-pass aftercooler with a split cooling circuit coupled with a cylinder bank control mechanism which will act to limit the number of pistons firing during idle. As well, they are proposing a modified piston crown with a more effective injector. This product package is said to be tested for both EMD 645 and 710 engines and is planned to be adapted to GE products.

Other suppliers (e.g. Wabtec, ALSTOM) are in the process of validating solutions and are expected to release certified conversion kits initially for EMD products in 2001.

As mentioned above, the ability to test new products in a live environment is limiting the development of an after-market kit. Most firms are using single cylinder modified test engines and have limited time on full engine test cells; therefore development is a slow process. Wabtec is creating further testing capacity, Energy Conversions has partial testing capability and ALSTOM is currently modifying its recently constructed test cell facility.

Given the lack of readily available testing facilities to develop and prove these types of products, it is expected that most of these technologies will not be brought to market before the year-end 2000.

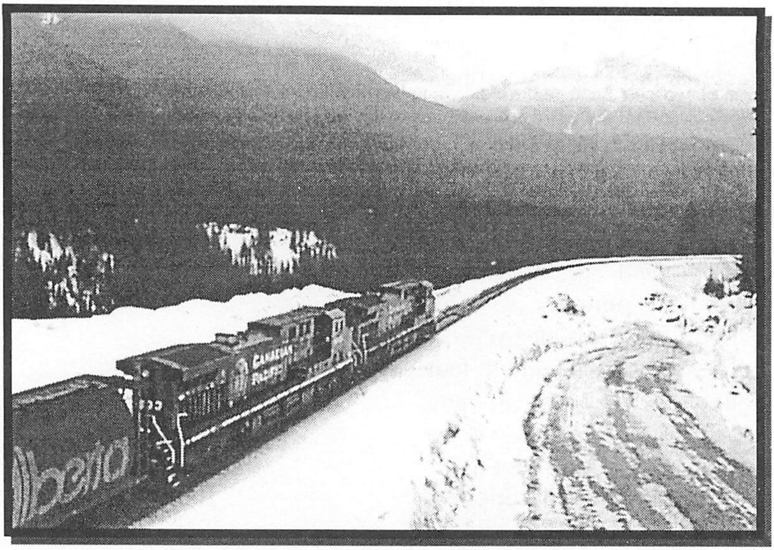
Durability

The EPA will require manufactures of products certified under this program to have demonstrated reasonable emissions control over the identified life period - either the life of the engine overhaul cycle (750,000 miles) or within a maintenance period to be maintained during this life-cycle. It can be reasonably assumed that the reliability inherent in any supplier's existing product will be equal to products developed for EPA consideration if suppliers remain within the known design changes. Adequate testing facilities and extended live trials by suppliers, which are necessary to meet both EPA and customer requirements, remain the fundamental prerequisites.

In the case of re-engining, most engine manufacturers have documented life-cycle cost and performance history which will be used to assess the durability aspects of the rules.

3. The Certification Process

Except for professional consultation, the EPA has not released the certification templates or the process requirements / interpretations at the time of drafting this paper.



IMPROVED ADHESION THROUGH THE USE OF INDIVIDUAL AXLE INVERTERS

Ajith Kumar, Admir Mesalic and Adam Oser - General Electric Co.

[Note: this paper was part of the New Developments Committee presentation at the 1999 convention, but was not able to meet the yearbook publication deadline.]

Introduction

GE Transportation Systems (GETS) is privileged to share news of a development partnership with Canadian Pacific (CP) Railway. During the last three winters GETS has had a valuable opportunity to work with CP in some of the most demanding railroading environments. The combination of a Canadian winter, heavy trains and the grade through the Rocky Mountains makes for some of the most difficult wheel to rail adhesion conditions in North America. The open relationship between GETS and CP has led to some breakthroughs in the use of individual axle inverters to deliver significant advancements in adhesion.

Background

Beginning in 1994 GETS introduced the AC4400 heavy haul locomotive into revenue service. Through Sept. 1999 GETS has delivered over 1300 ACs into some of the most demanding rail environments in the world. Besides adhesion, individual axle control provides some unique system advantages. The individual axle inverter allows the use of very high efficiency, low slip motors. This low slip design provides less internal losses due to motor slip, which translates directly into more fuel-efficient movement of freight. Individual axle control also permits large variations in the individual wheel size. This enables the mechanical department more flexibility with combo replacement and wheel truing. Individual axle control also supports increased mission completion. The propulsion system is automatically reconfigured to continue operating in the event of a motor or a inverter failure. The circuitry for the failed inverter/motor combination is automatically isolated and the unit will continue to operate at full rated horsepower. In the unlikely event of two failures, the AC4400 system will continue to deliver 4000 traction horsepower through the remaining four motors. These and other aspects of the individual axle control allow for unmatched propulsion mission completion. Additionally, the unmatched ability to accurately control each wheel speed, creep, and torque with the individual axle control provides world class adhesion on varying rail conditions.

Adhesion

Electrical propulsion system capabilities are reliable and predictable - they don't vary day to day in normal operation. However, the adhesion available at the rail to resist traction force is a statistically varying phenomenon that changes from rail segment to rail segment. The ability of the propulsion system and wheelslip control system to capitalize on the available adhesion differs from one locomotive design to another.

AC technology breakthrough

Higher adhesion utilization requires ability to transfer tractive effort from one axle to another to maximize total tractive effort at any given time. Single axle control has two advantages in this regard. First, since the control of each axle is independent of the others this system can easily drive each axle to the optimum creep and torque command regardless of the track conditions or wheel diameter differences. Second, for a given size traction motor it is possible to have higher capability since the electrical losses in the lower slip motor are less.

Another advantage of single axle control is that the power electronics devices can be smaller. Fault damage is reduced without the need for electrical crowbars. This design lends itself to smaller, ready-track serviceable, replaceable units (RU's). Another benefit is that it can quickly take advantage of improvements in semiconductor technology. For example, when AC locomotives were introduced, GTO's (gate turn off devices) were used as the inverter power electronic devices to drive the traction motors. New high power electronic switches called IGBTs (insulated gate bipolar transistors) are now available. Since GETS uses individual axle control, the device ratings required are smaller and can take advantage of this and future emerging technologies sooner with faster time-to-market including validation testing.

The GTO technology has matured to the limit of its capability; the IGBT technology makes possible a quantum leap in reliability, parts reduction, and maintainability. Use of this newest technology has resulted in elimination of 144 power/snubber components, over 5000 electrical components, and 400 electrical connections. IGBTs also simplified gate driver design, allowing a reduction of over 3000 watts in snubber losses, and provided the addition of features like short circuit protection and ride-through capability. All of this and a reduction in weight of phase module RU's by 12 lbs., with a potential to reduce size. These propulsion system benefits all translate to over 20% reliability improvement and maintenance advantages to GETS customers with the potential for further reliability enhancement as the IGBT technology matures.

Using Six Sigma Tools for Measurements

A tremendous body of technical literature has been written in the field of locomotive adhesion. In landmark presentations such as Logston 1980, adhesion was described as a statistically varying phenomenon. Measurements were taken over the course of months and even years using methods that required dedicated trackage or long delays in rail traffic. The methodology of this experimentation seems to have advanced A/B testing as the favored industry test method. While this method is certainly preferred to simply pulling tonnage up a grade on one run with one configuration versus another run with another configuration, it still has some serious limitations. These limitations are discussed and an improved adhesion measurement method has been developed to overcome these limitations.

A/B testing is intended to compare two different locomotives or configurations for adhesion performance; one loco or configuration is labeled "A" and the other "B" for convenience. A section of track, usually a siding, is oiled making the rail slick, thus inducing adhesion-limited. The locomotive then pulls a consist with said consist in dynamic braking to simulate the resistance of a train behind the locomotive. The maximum tractive effort achieved is then plotted versus run number. Alternate runs are performed with the A and B configurations; and as the oil is cleaned off by the wheels under power, the maximum tractive effort per run goes up until the locomotive's capabilities are reached. Finally, the data points for all the A runs are connected and plotted against all the data points for the B runs and a graphical comparison is made to discern performance differences. Figure 1 shows an example of a typical A/B test result.

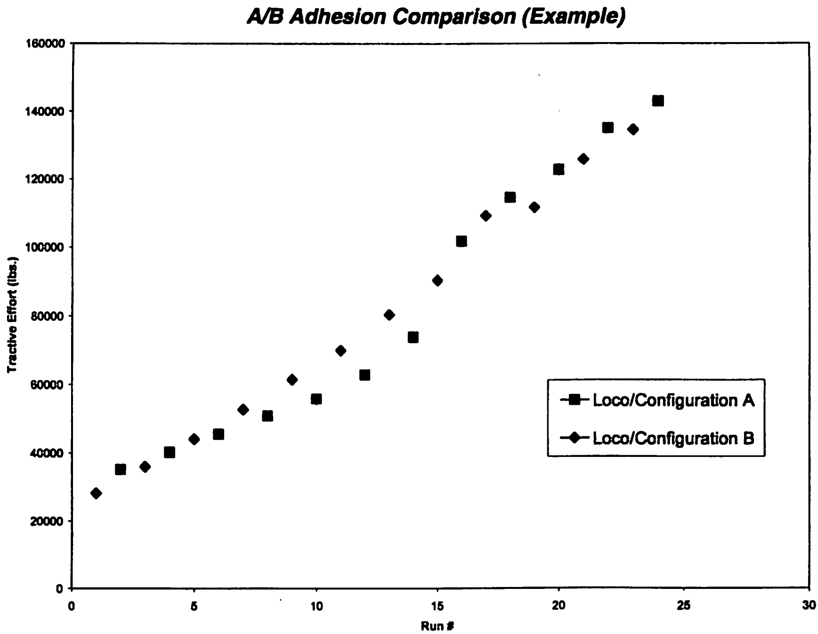


FIG. 1 Above Example of A/B Test Results

As you can see from this example of actual over-the-road test results, it is difficult to tell if A is better than B. This test method also presents additional concerns. The test is conducted on oiled rail without sand. This condition does not exist under normal operation and the locomotive will react differently to this condition versus the same condition with sand or, more relevantly, to wet, snow-covered or dry rail with sand.

Another issue with this test method is that the inertia of a consist of locomotives is much lower than of a real train. It is difficult for operators to regulate consist speed exactly. When large speed variations take place, the locomotive will perform very differently. This is because the control system has rate limits in place that reject speed signals that are changing too fast to be a inputs from an actual train.

Finally, the rail that is repeatedly traversed in an A/B test changes from run to run. In the world of real, several hours may pass between trains. If we consider a wet day, the rail is oxidizing (rusting) all that time between trains. Again, wet/rust/sanded rail is very different from oiled rail without sand. What we ideally want is a way to test locomotive/configuration A versus B on the mainline, real time, at speed, with minimal delay, with sand, with curves and with all of mother nature at work.

Six Sigma statistical techniques

have led to the development of the "Common Rail Test" (CRT). The CRT is a scientific, statistics-based test process that yields useable results in real time. It allows the comparison of two different locomotive configurations or, when combined with design of experiment methods, multiple configurations at the same time, on the mainline, at speed, with minimal delay, with sand, with curves and with all the rest of the actual railroading environment. Specific details of how the test is actually conducted and how the results are interpreted will be shared with all GETS customers upon request.

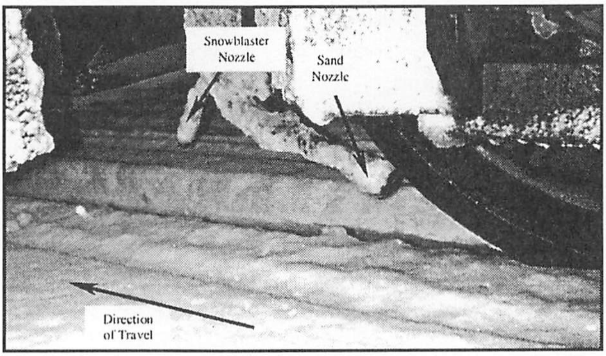
While CRT is a significant improvement over A/B testing, another advancement was recently made that is at least as significant. It is calles "Automatic Rail Characterization" (ARC) software and it is a powerful tool enabling the measurement of the actual current rail condition. ARC is engineering test software that is not intended for revenue service.

The details of how ARC works are proprietary and will not be discussed here. ARC allows unprecedented levels of adhesion performance quantification. The combination of ARC and CRT gives more useful information than was ever possible to obtain previously, and will most certainly lead to increased understanding of adhesion phenomena.

Advancements in Locomotive Adhesion

The GE and CP adhesion development partnership resulted in several major advancements: "Torque Maximizer" wheelslip control software, the "Snowblaster" compressed-air rail cleaning system (see Figure 2) winterized sand nozzles and a reduction in sand application during yard handling. These performance enhancements were developed with Six Sigma methods and computer models and as a result preformed as expected on the very first field trial.

FIG. 2 Below First Production Run of the "Snowblaster" Compressed-Air Rail Cleaning System



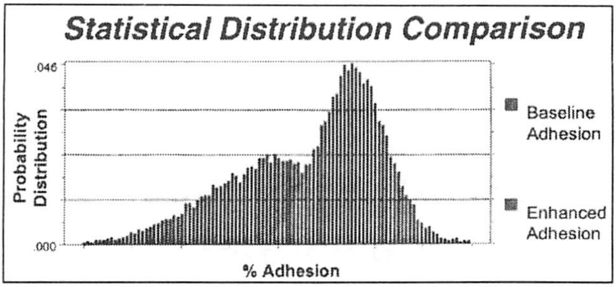


Fig. 3 Improved dispatch adhesion illustration, all weather conditions combined

Controlling Variations and "Raising the Bar"

Most any railroader will tell you that he or she needs to dispatch trains with the "bad days" in mind. The statistical variation seen in available adhesion tends to force dispatch tonnage levels lower to ensure a high probability of completing the missions. It is not relevant to talk in terms of 40+ percent adhesion if that is only possible when the moon, sun and stars align. What matters is the "actual adhesion" that can be obtained reliably as this becomes the dispatch adhesion level that dictates train size in heavy haul applications.

A graphical representation of what these adhesion enhancements do for the day-to-day actual adhesion is shown in Figure 3. The enhancements served to move the average adhesion level upward for all weather conditions. More importantly, they also served to reduce the variation in performance to allow better asset utilization with increased confidence. These enhancements clearly "raise the bar" for dispatch adhesion.

Result of GE and CP Partnership

The adhesion development partnership with Canadian Pacific Railway has resulted in consistently higher dispatch adhesion levels with a reduction in the number of adhesion-related stalls. Several new technologies and advancements emerged from this work and several patents are now pending. These advancements are available on GE locomotives as of this writing. Please contact GE personnel for specifics or for more information on availability.

Acknowledgements

This work would not have been possible without the terrific support from Ed Dodge, Richard Parent, John Farrer, Dave Grant, the train crews and many others within Canadian Pacific. Special thanks to the dedicated efforts of the core GE adhesion team responsible for the product designs and test methods: Bret Worden, Ajith Kumar, Ed Balch, Suresh Reddy, Jack Cooper and Admir Mesalic and to the important contributions from others in GETS and the GE Corporate R&D center.

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

WEDNESDAY, SEPTEMBER 20, 2000
8:45 A.M.

JOHN BRAWLEY, MANAGMENT
Director-Material Management
Amtrak
Beech Grove, IN

Vice Chairman
JOHN MINNIE
Manager - Materials
BNSF Rwy
W. Burlington, IA

COMMITTEE MEMBERS

R. Brandt	Director-Materials	VMV Enterprises	Paducah, KY
A. Chapman	Senior Mgr. of Materials	CSX Transportation	Waycross, GA
R. Delevan	Mgr.-Trans. Products	Natl. Elect. Carbon	Wilkes Barre, PA
R. Florczyk	Mgr.-Loco. Parts Sales	GE Transportation	Erie, PA
B. Girard	Sr. Materials Supply Spec.	CP Rail	Calgary, AB
B. Graham	Material Manager	Montana Rail Link	Livingston, MT
J. Hartwell	V.P. Sales	Progress Rail Svcs.	Green Cove Springs, FL
B. Harvilla	Sales Mgr.	Standard Car Loco.	Strongsville, OH
D. Rhyne	Sr. Materials Analyst	Electro Motive Div.	La Grange, IL

Note: Guest Speakers: Mike Coyler-GE Transportation and Robert Dudley - SAP
Jim McCauley of CSX will be joining the committee.

PERSONAL HISTORY

John Brawley

John Brawley is the Director of Materials Management at the Amtrak Beech Grove, Indiana Maintenance Facility with over 23 years of experience in the rail industry.

He began his career with Amtrak in 1977 in the mechanical department at the New York Maintenance Facility (Sunnyside Yards).

He has 3 children and 2 grandchildren.

I. GE GLOBAL eXchange SERVICES

Prepared by
Steve Crowley and
Mike Colyer, GETS

Introduction

It's estimated that by 2004 business-to-business e-commerce will be anywhere between $2.7 trillion and $6.4 trillion, with 45% to 75% of this figure flowing through marketplaces and exchanges (Source: AMR Forrester).

So What Is An Exchange?

At GE Global Exchange Services (GXS), it's defined as a highly focused, secure Internet site that aggregates buyers, sellers and experts for commerce, content and community - just like the market squares of old. And because of ever changing technology and globalization, one-to-one transactions are evolving into many-to-many transactions. Many exchanges have already taken shape - specifically in the metals, plastics and chemical industries.

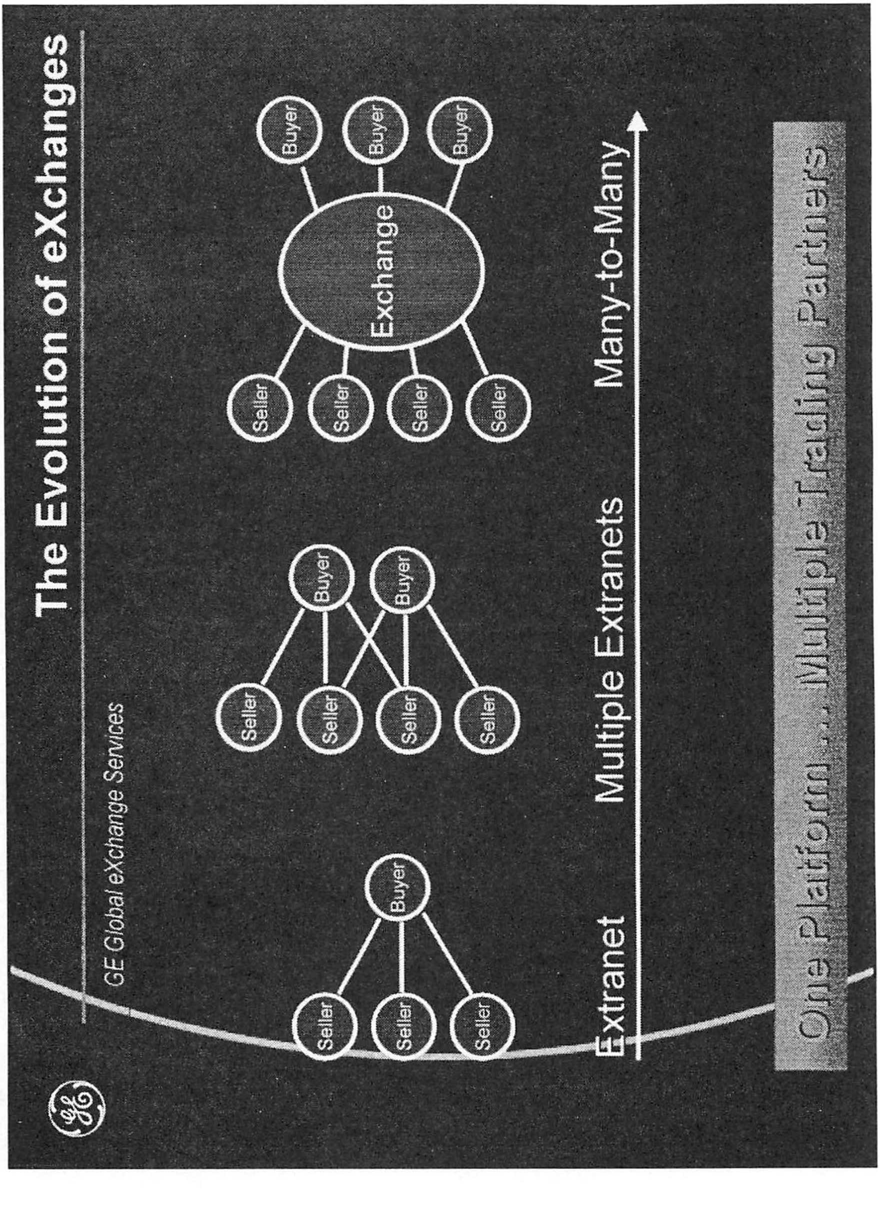
So What? Where's The Benefit?

The benefits of an online exchange are wide and varied, depending on the industry or commodities that are involved. By sharing better information, streamlining processes and achieving a global reach, a more efficient market will develop. It's estimated that marketplaces will mean a 20% to 35% increase in indirect material price productivity, a 50% reduction in material inventory, and a 15% to 30% saving in sourcing. Qualitative benefits include great negotiation and buying power, lower transactional costs, elimination of excess inventory and scrap, real-time access to opportunities and wider reach to suppliers and customers.

What Do I Get?

As the leader in bringing intelligence to supply chains, GXS has experience in working with 10's of thousands of trading partners using a variety of tools and exchanging many different business documents. By leveraging this experience, GXS sees some key applications that will lead to the benefits outlined above. They include asset and excess inventory disposition, supply chain processes (proposals, quotes, auctions), demand forecasting and invoicing, indirect material sourcing (aggregation, catalogs, reverse auctions) and community building and expertise across vertical industries and horizontal needs.

With GXS, any company can buy or sell any good or service using any purchasing technique with any other company using GE Global eXchange Services.


The Evolution of eXchanges
GE Global eXchange Services
Seller
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Exchange
Buyer
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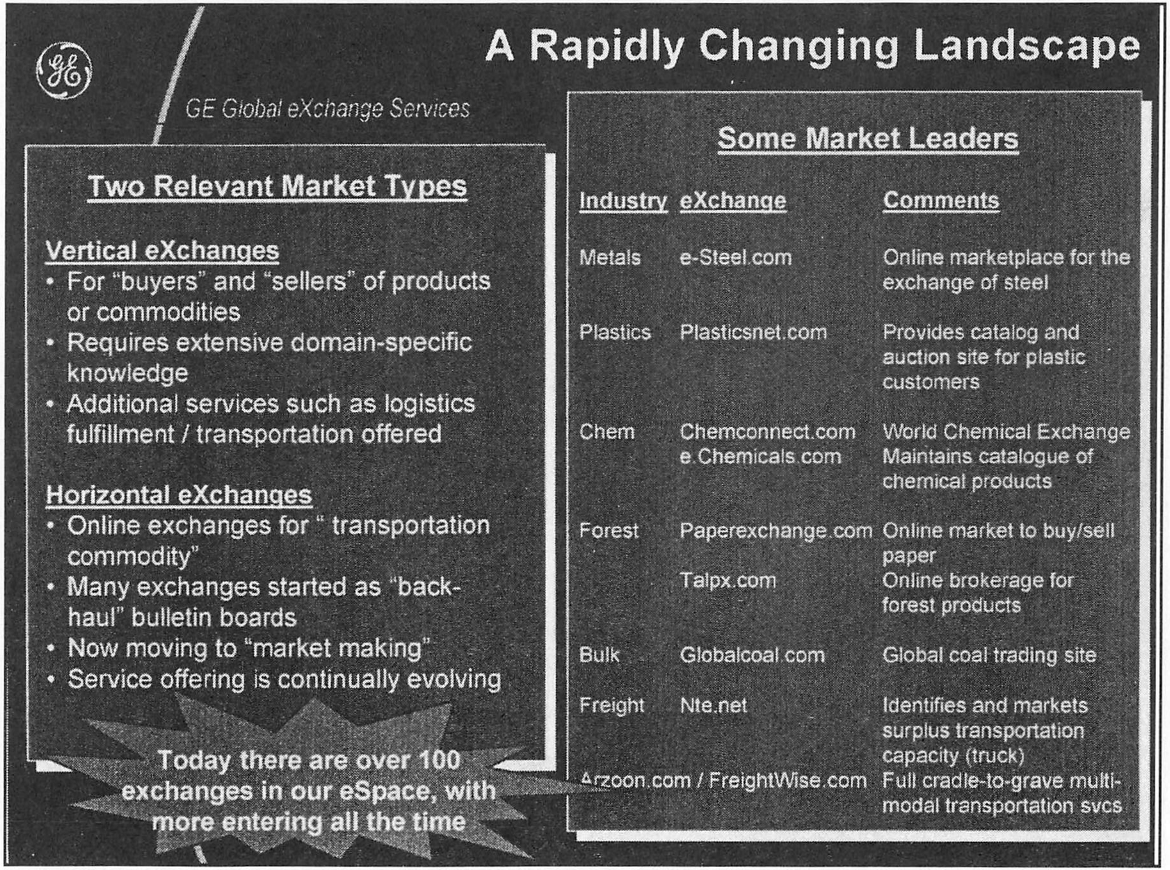
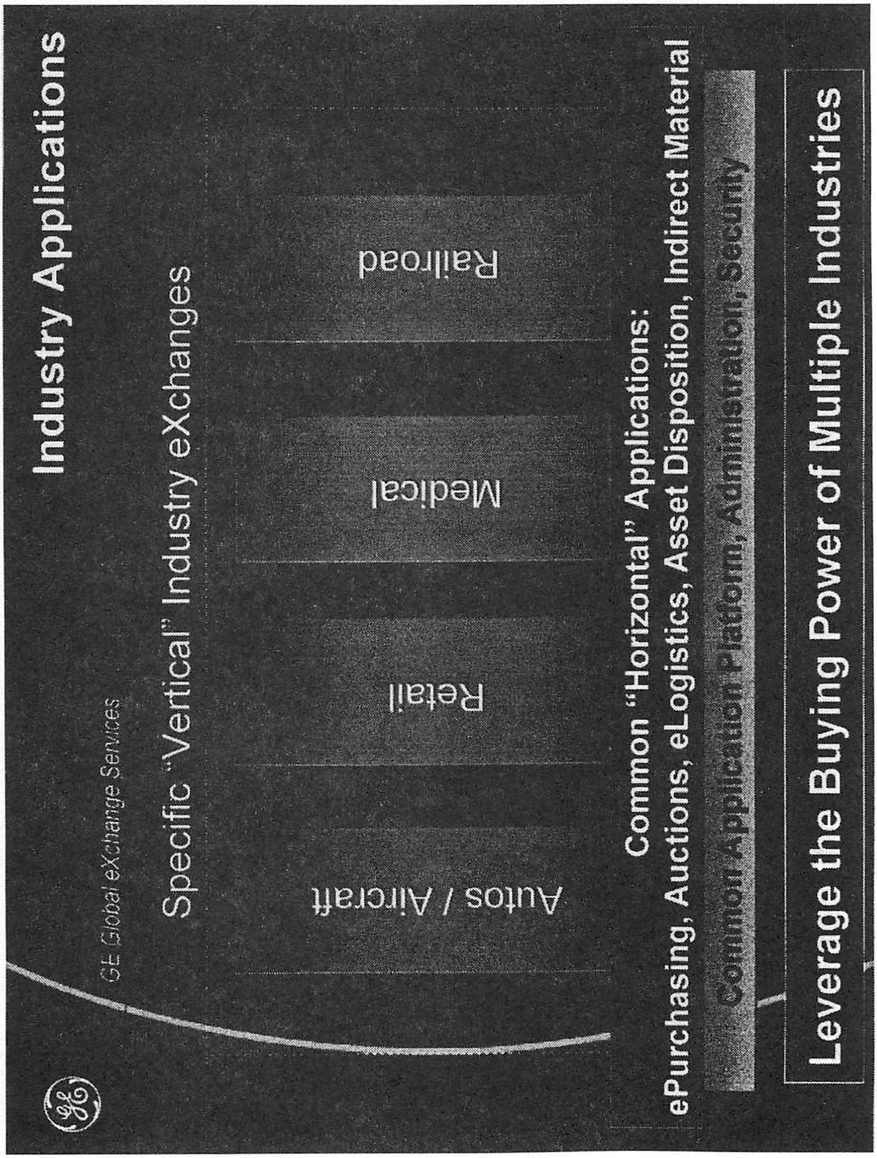
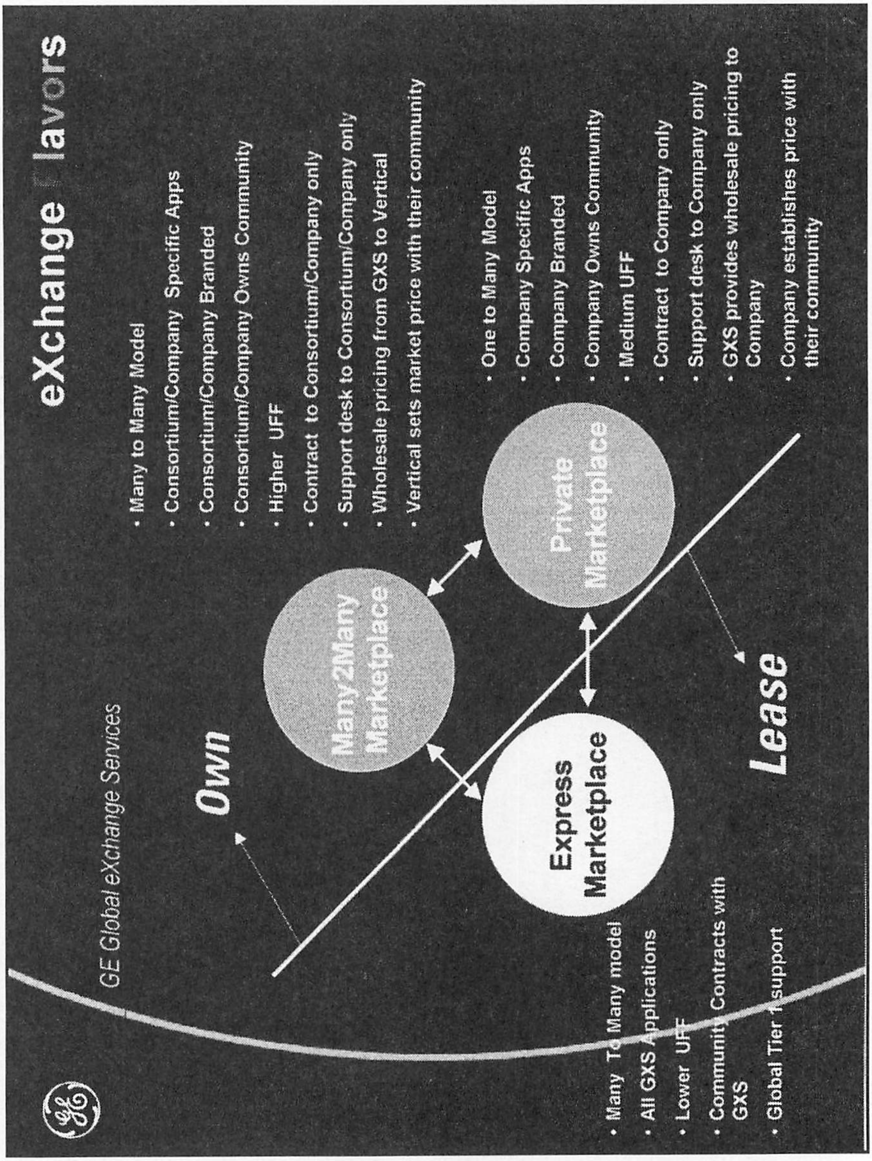
Extranet
Multiple Extranets
Many-to-Many
One Platform ... Multiple Trading Partners


A Rapidly Changing Landscape
GE Global eXchange Services
Two Relevant Market Types
Vertical eXchanges
• For "buyers" and "sellers" of products or commodities
• Requires extensive domain-specific knowledge
• Additional services such as logistics fulfillment / transportation offered
Horizontal eXchanges
• Online exchanges for " transportation commodity"
• Many exchanges started as "back-haul" bulletin boards
• Now moving to "market making"
• Service offering is continually evolving
Today there are over 100 exchanges in our eSpace, with more entering all the time
Some Market Leaders
Industry eXchange Comments
Metals e-Steel.com Online marketplace for the exchange of steel
Plastics Plasticsnet.com Provides catalog and auction site for plastic customers
Chem Chemconnect.com World Chemical Exchange
e.Chemicals.com Maintains catalogue of chemical products
Forest Paperexchange.com Online market to buy/sell paper
Talpx.com Online brokerage for forest products
Bulk Globalcoal.com Global coal trading site
Freight Nte.net Identifies and markets surplus transportation capacity (truck)
Arzoon.com / FreightWise.com Full cradle-to-grave multi-modal transportation svcs


Industry Applications
GE Global eXchange Services
Specific "Vertical" Industry eXchanges
Autos / Aircraft
Retail
Medical
Railroad
Common "Horizontal" Applications:
ePurchasing, Auctions, eLogistics, Asset Disposition, Indirect Material
Common Application Platform, Administration, Security
Leverage the Buying Power of Multiple Industries


eXchange Flavors
GE Global eXchange Services
Own
Lease
Many2Many Marketplace
Private Marketplace
Express Marketplace
• Many to Many Model
• Consortium/Company Specific Apps
• Consortium/Company Branded
• Consortium/Company Owns Community
• Higher UFF
• Contract to Consortium/Company only
• Support desk to Consortium/Company only
• Wholesale pricing from GXS to Vertical
• Vertical sets market price with their community
• One to Many Model
• Company Specific Apps
• Company Branded
• Company Owns Community
• Medium UFF
• Contract to Company only
• Support desk to Company only
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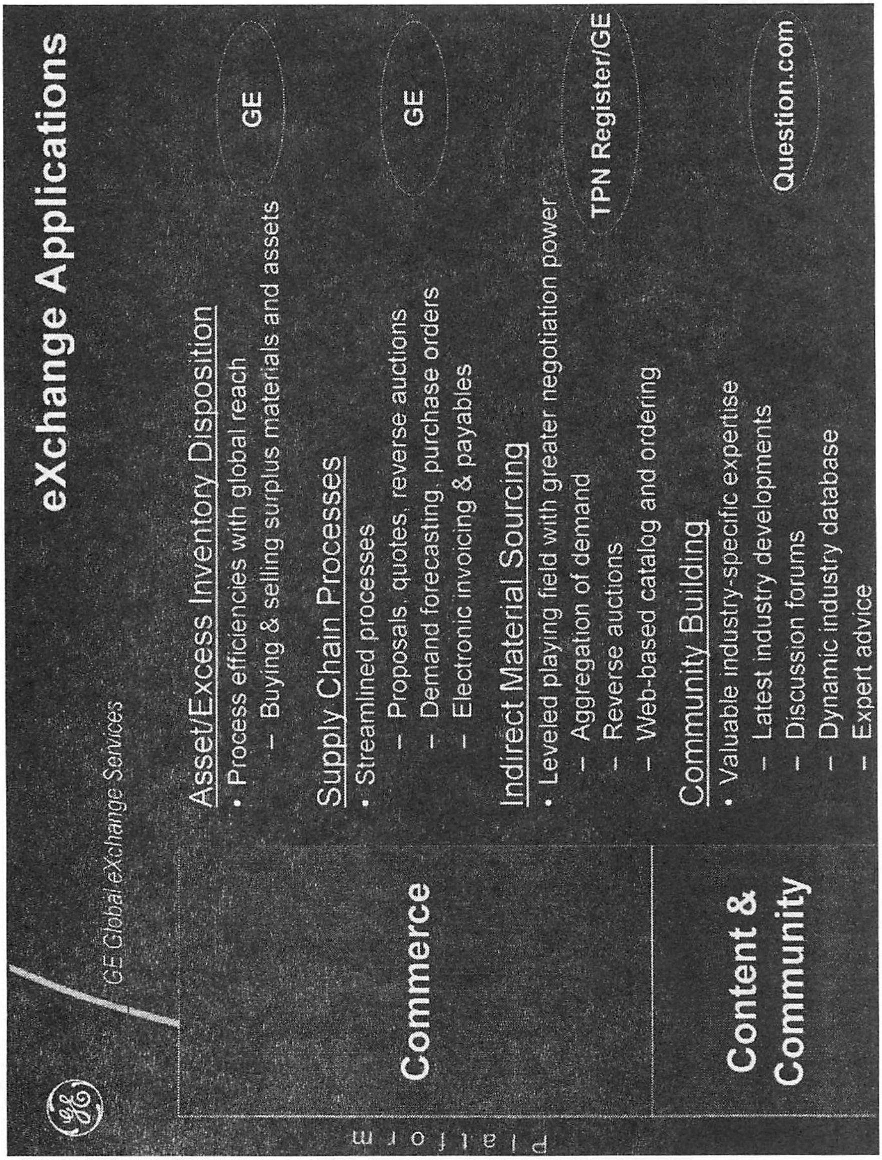
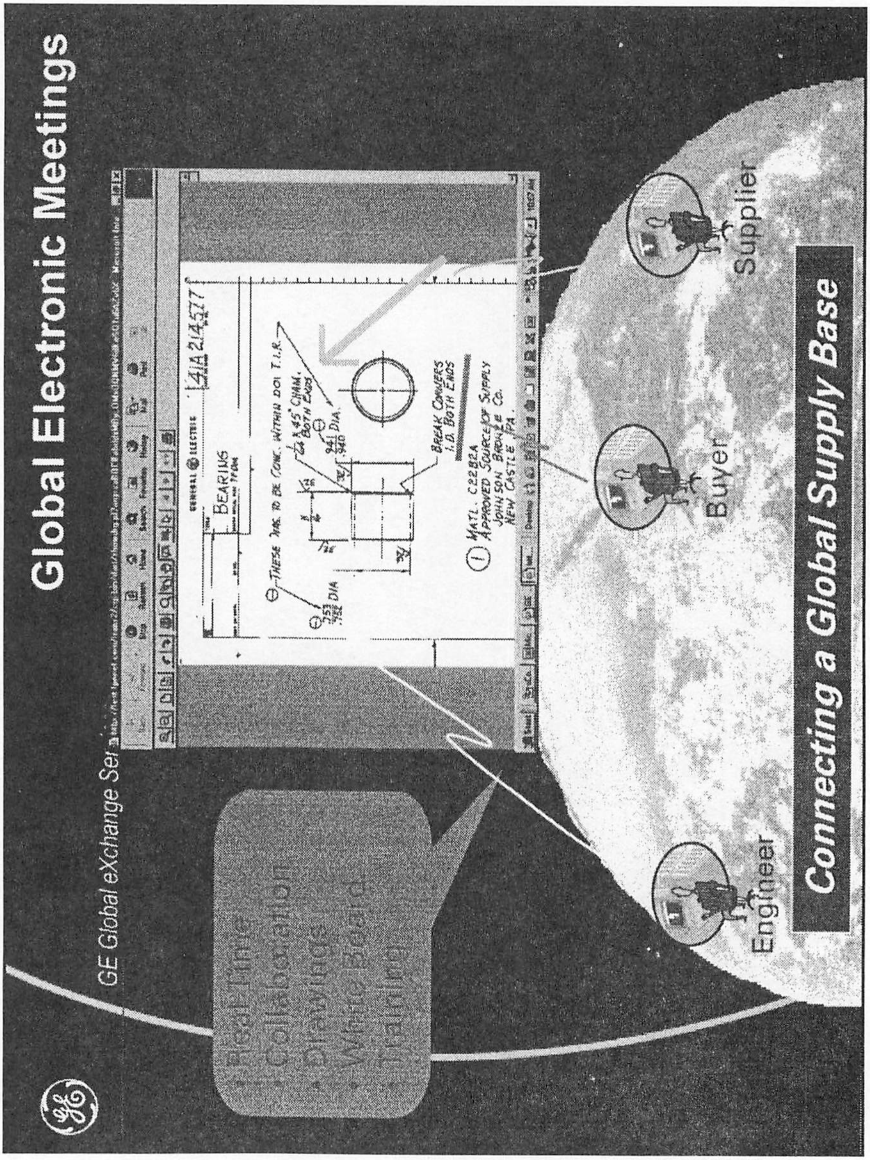
• Company establishes price with their community
• Many To Many model
• All GXS Applications
• Lower UFF
• Community Contracts with GXS
• Global Tier 1 support


GE Global eXchange Services
eXchange Applications
Platform
Commerce
Asset/Excess Inventory Disposition
• Process efficiencies with global reach
– Buying & selling surplus materials and assets
GE
Supply Chain Processes
• Streamlined processes
– Proposals, quotes, reverse auctions
– Demand forecasting, purchase orders
– Electronic invoicing & payables
GE
Indirect Material Sourcing
• Leveled playing field with greater negotiation power
– Aggregation of demand
– Reverse auctions
– Web-based catalog and ordering
TPN Register/GE
Content & Community
Community Building
• Valuable industry-specific expertise
– Latest industry developments
– Discussion forums
– Dynamic industry database
– Expert advice
Question.com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Collaboration
Drawings
White Board
Training
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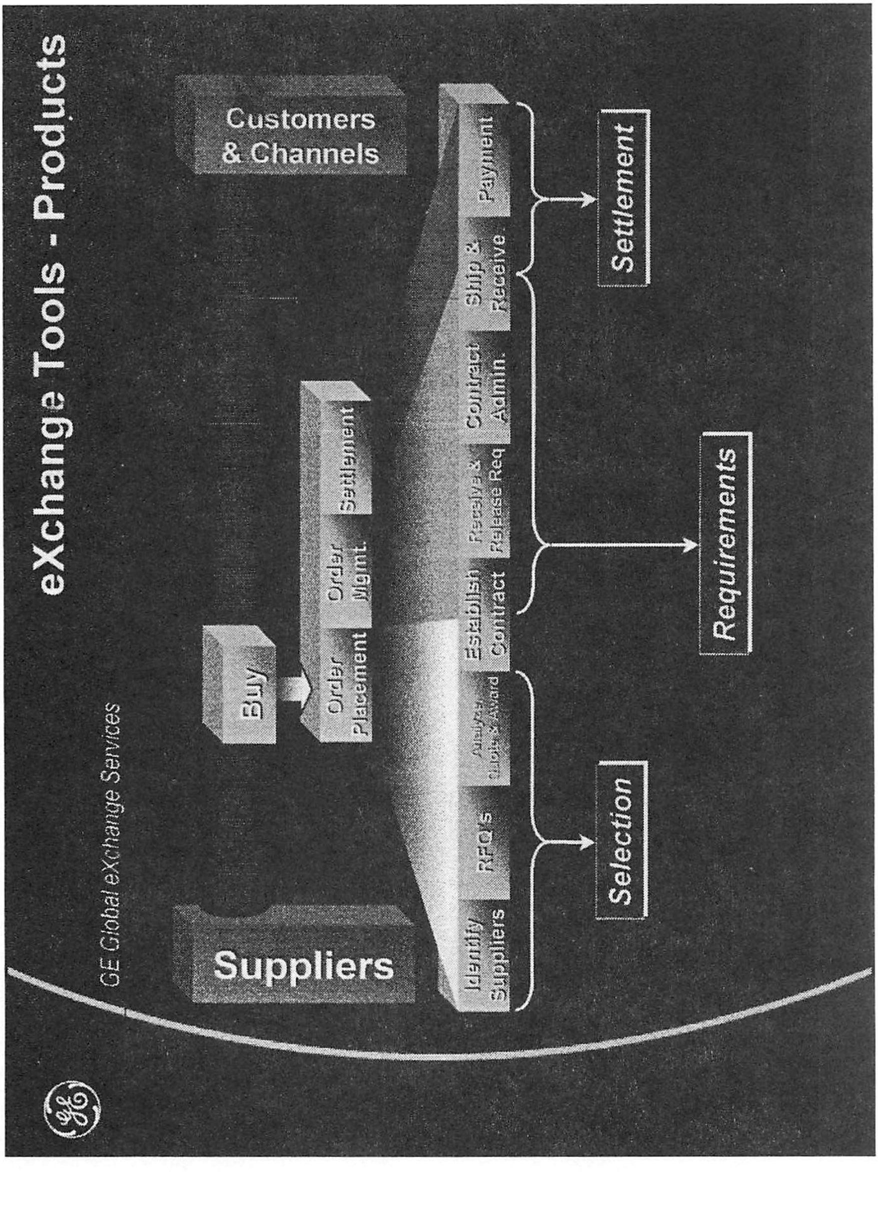
Engineer
Buyer
Supplier
Connecting a Global Supply Base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Customers & Channels
Buy
Order Placement
Order Mgmt
Settlement
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Analyze Bids & Award
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Contract Admin.
Ship & Receive
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Requirements
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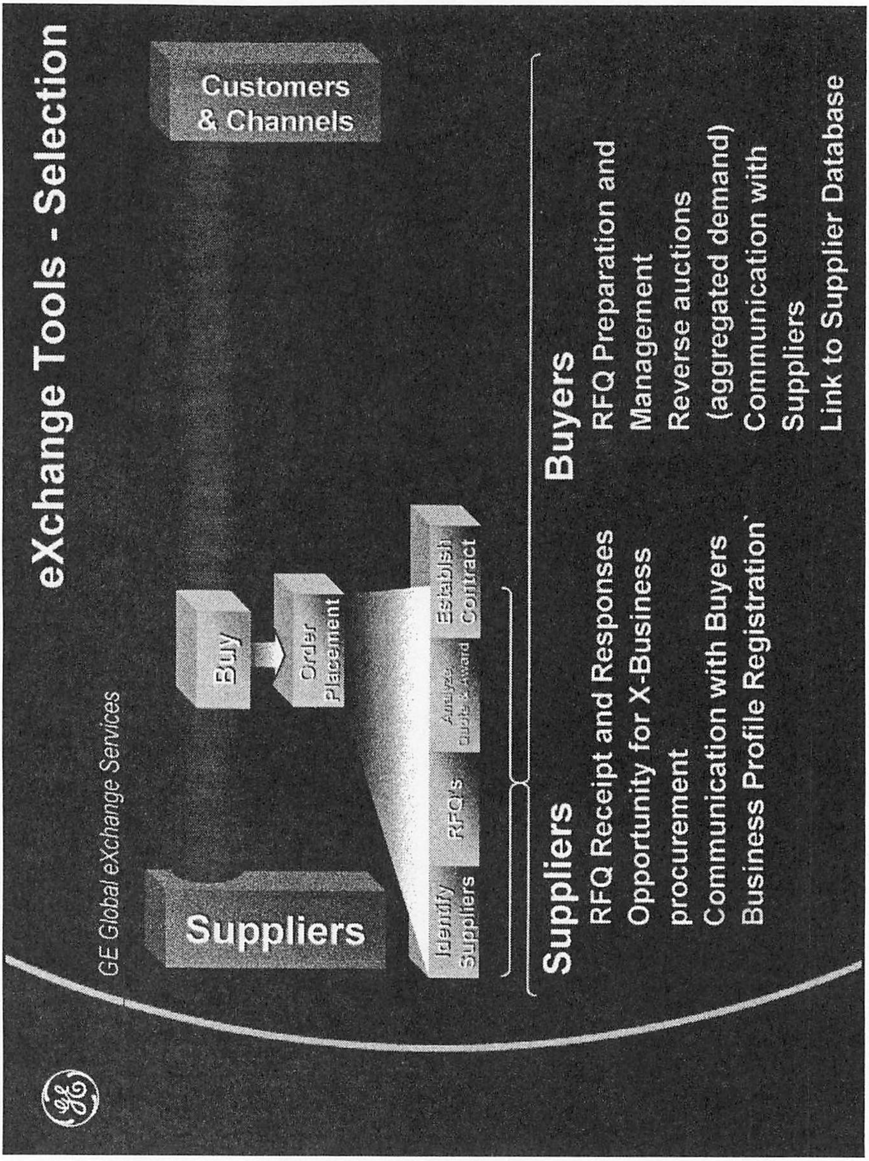
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Suppliers
Customers & Channels
Buy
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Identify Suppliers
RFQ's
Analyze Quote & Award
Establish Contract
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RFQ Receipt and Responses
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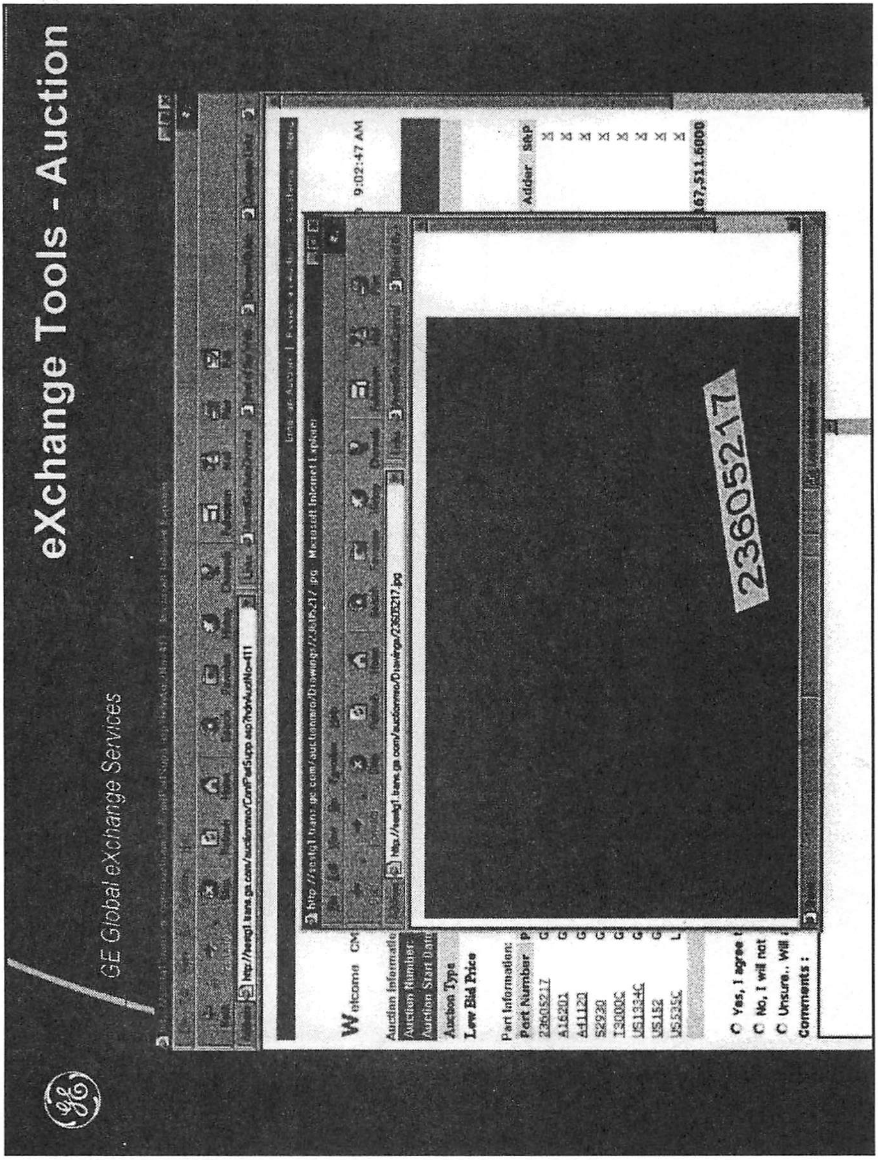
Buyers
RFQ Preparation and Management
Reverse auctions (aggregated demand)
Communication with Suppliers
Link to Supplier Database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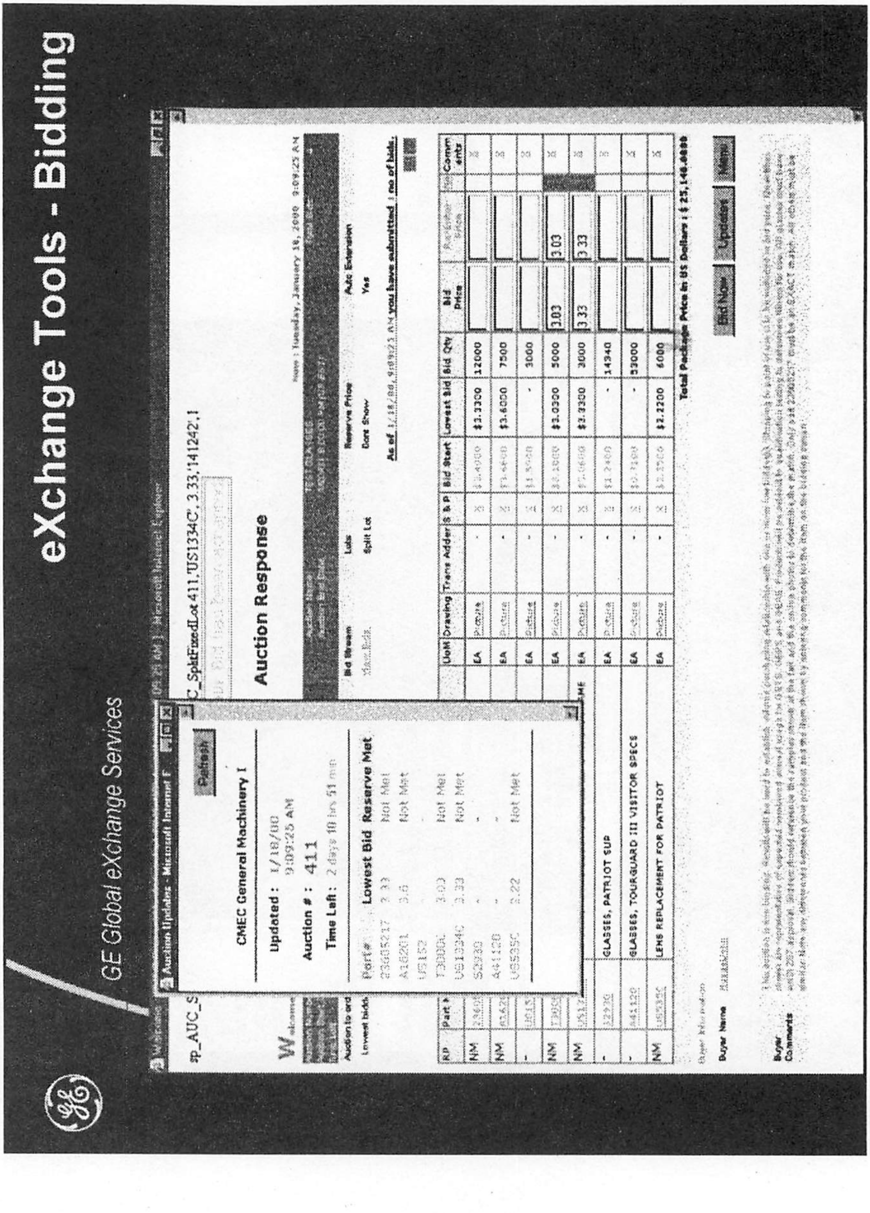
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GE Global eXchange Services
Auction Response
CMEC General Machinery I
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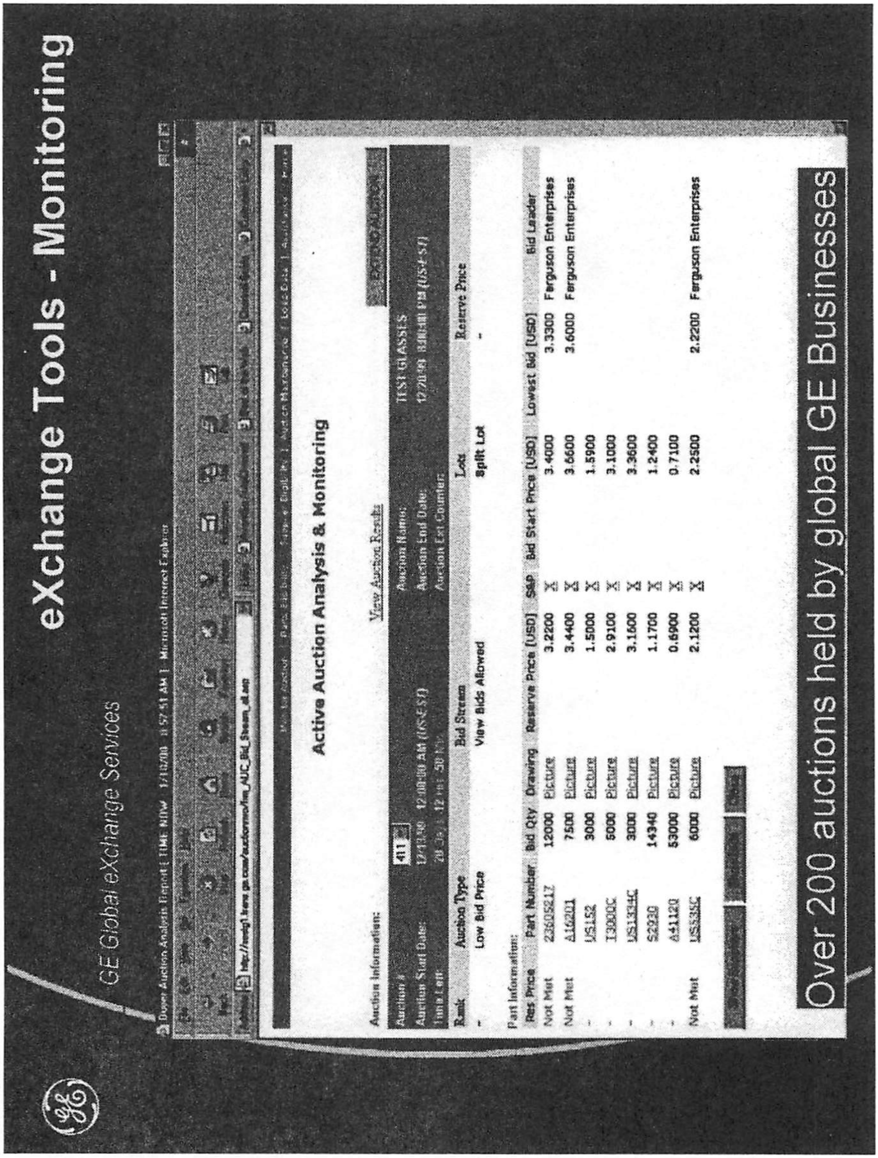
Auction # : 411
Time Left : 2 days 10 hrs 51 min
Part # Lowest Bid Reserve Met
Refresh
Total Package Price in US Dollars : $ 25,148.0000
Bid Now
Updates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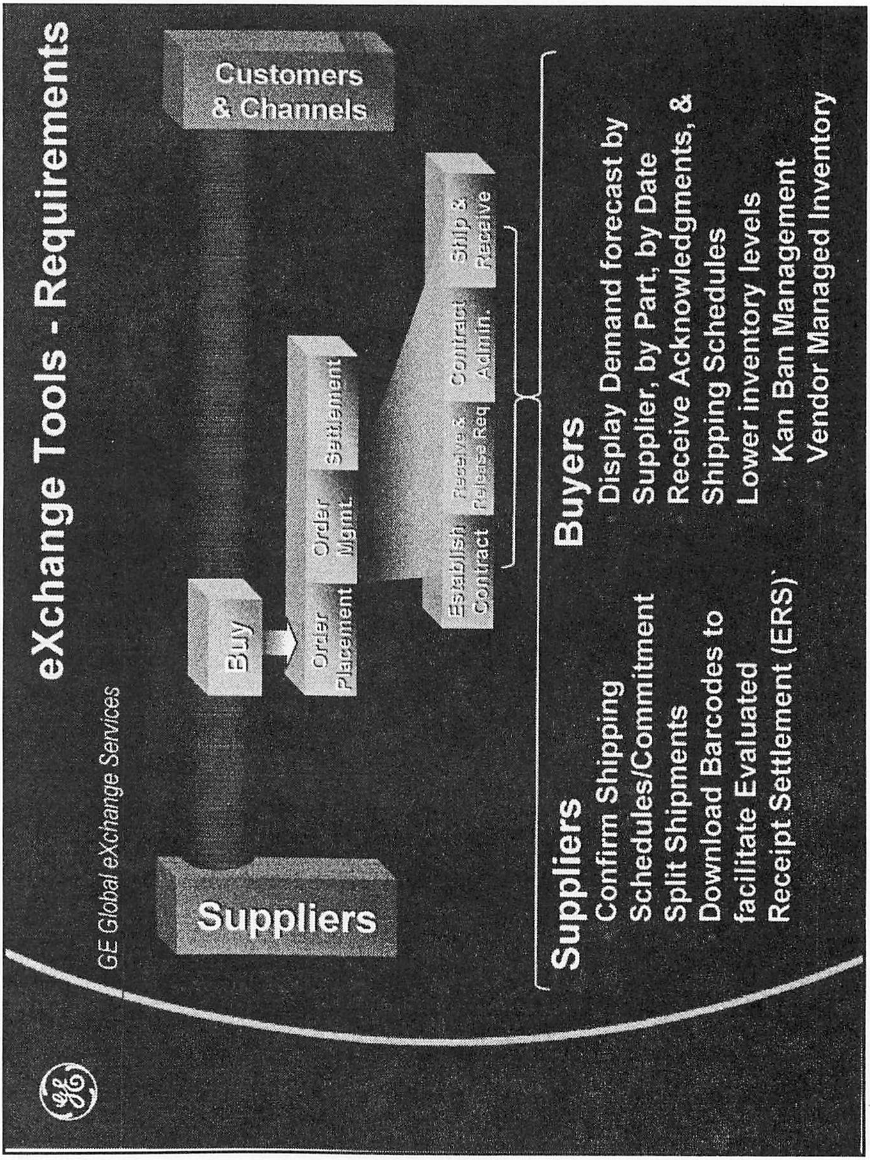
eXchange Tools - Requirements
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Suppliers
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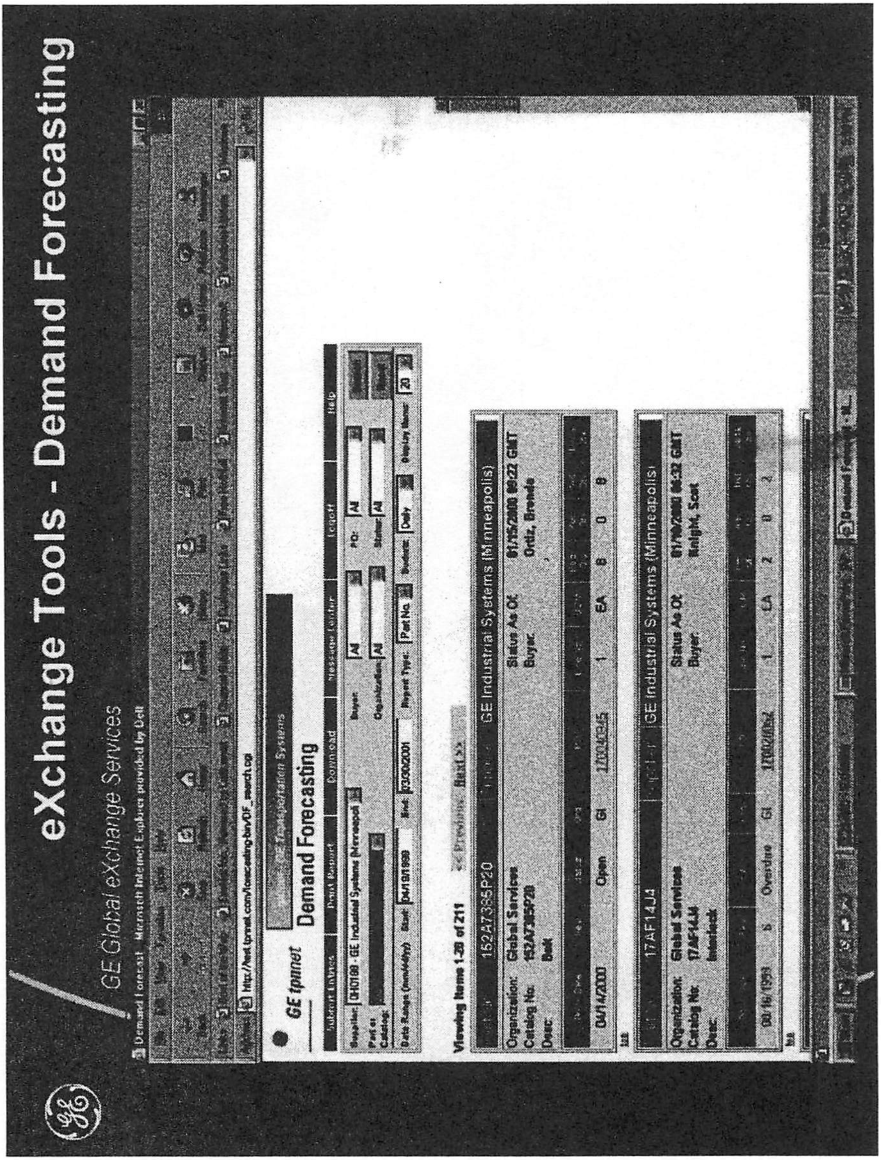
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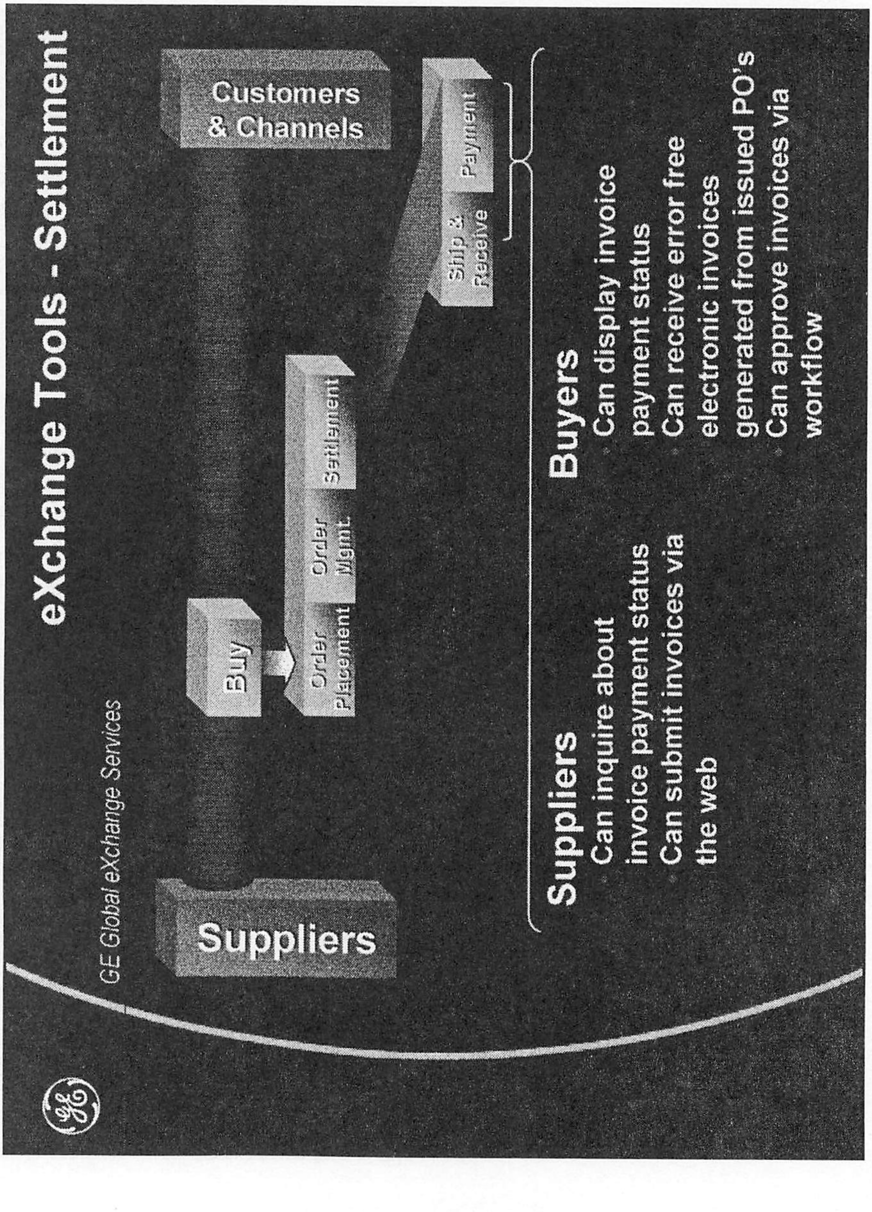
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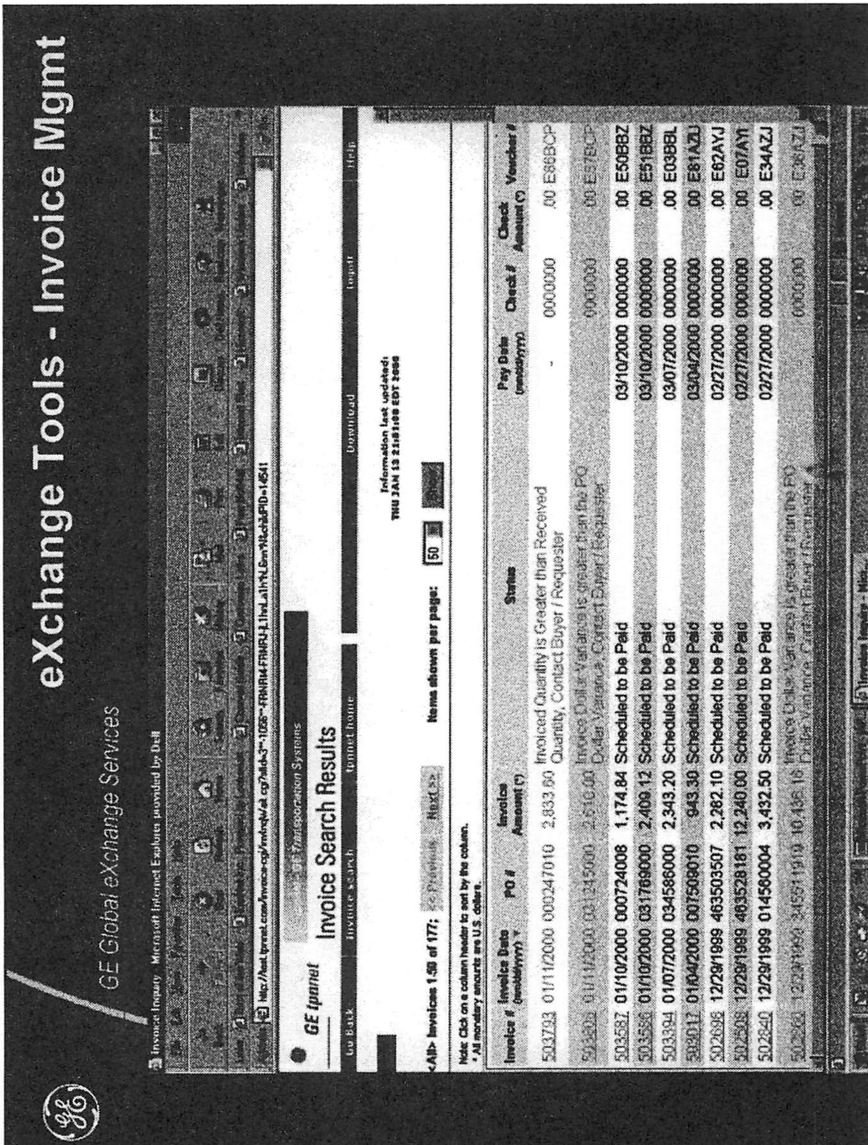
Payment
Suppliers
Can inquire about invoice payment status
Can submit invoices via the web
Buyers
Can display invoice payment status
Can receive error free electronic invoices generated from issued PO's
Can approve invoices via workflow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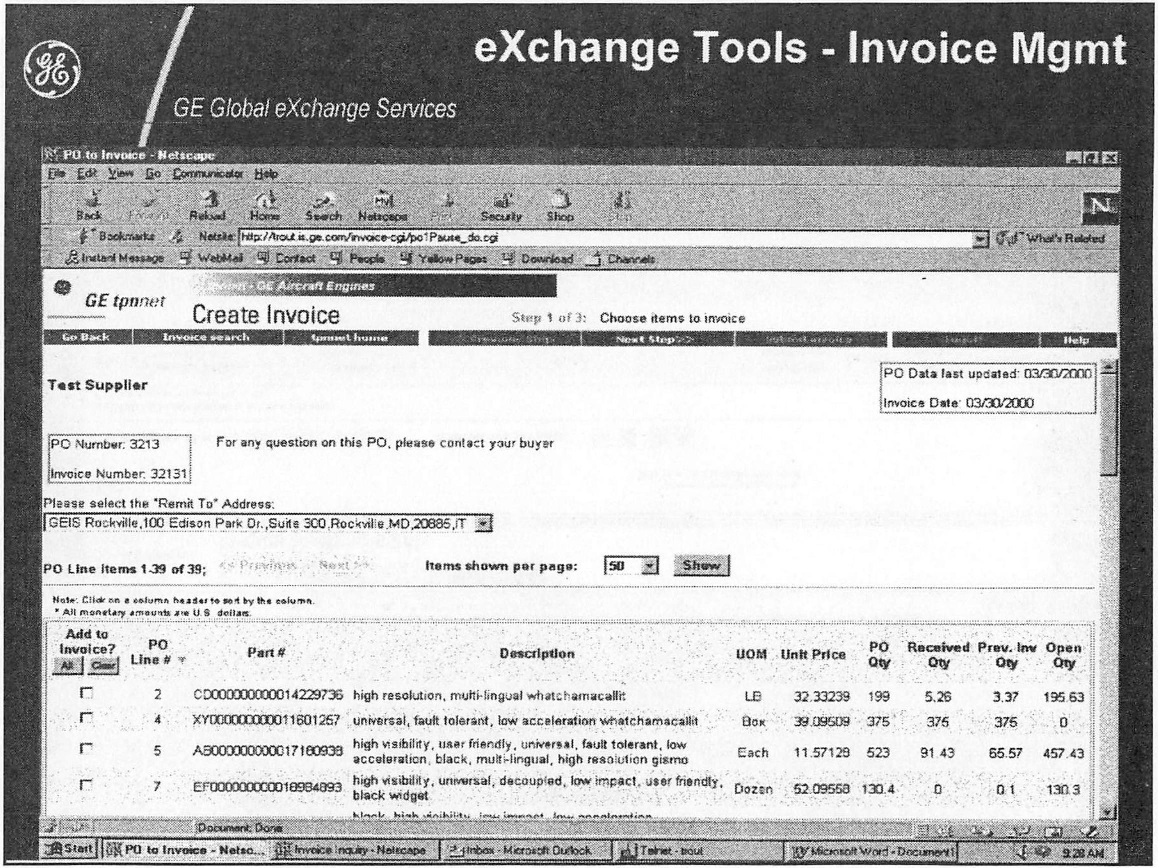
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PO Data last updated: 03/30/2000
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PO Number: 3213
Invoice Number: 32131
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PO Line items 1-39 of 39;
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50
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* All monetary amounts are U.S. dollars.
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2 CD00000000014229736 high resolution, multi-lingual whatchamacallit LB 32.33239 199 5.26 3.37 195.63
4 XY00000000011601257 universal, fault tolerant, low acceleration whatchamacallit Box 39.09509 375 375 375 0
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Microsoft Word - Document1
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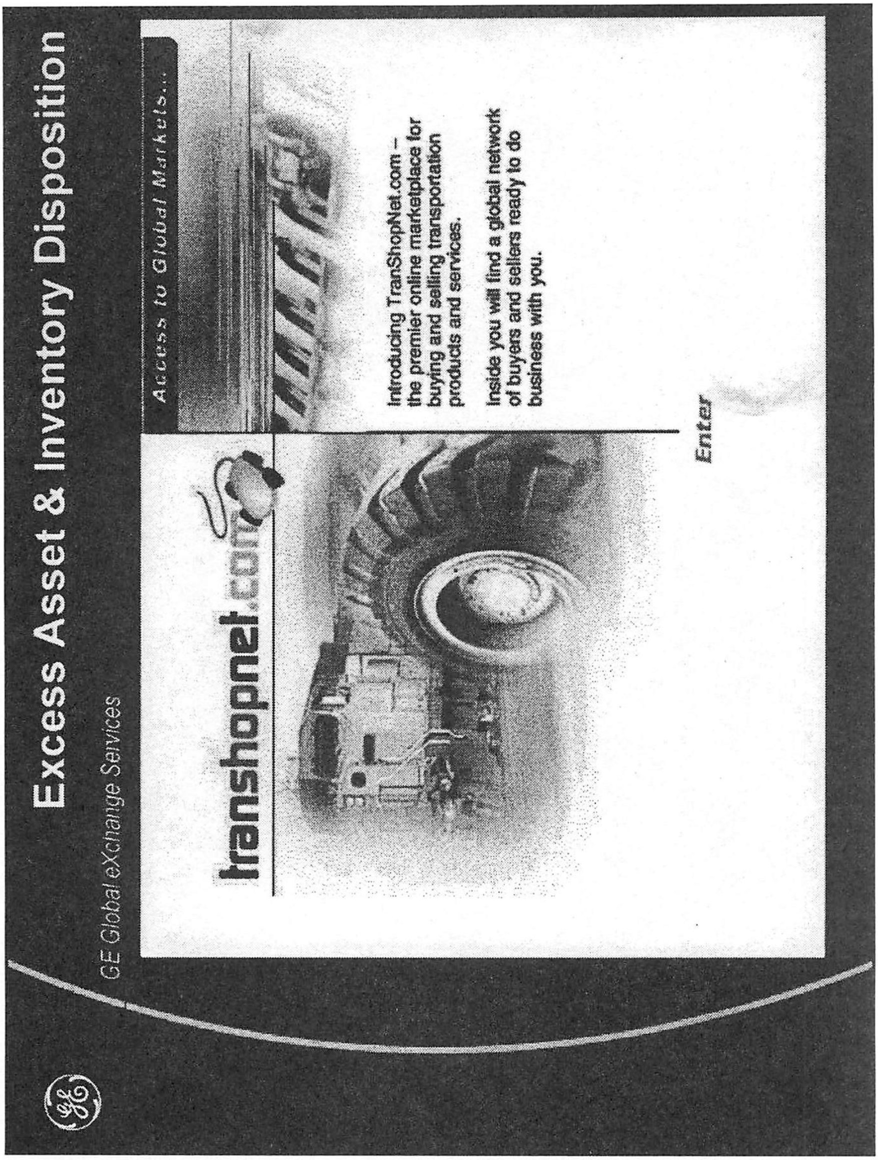
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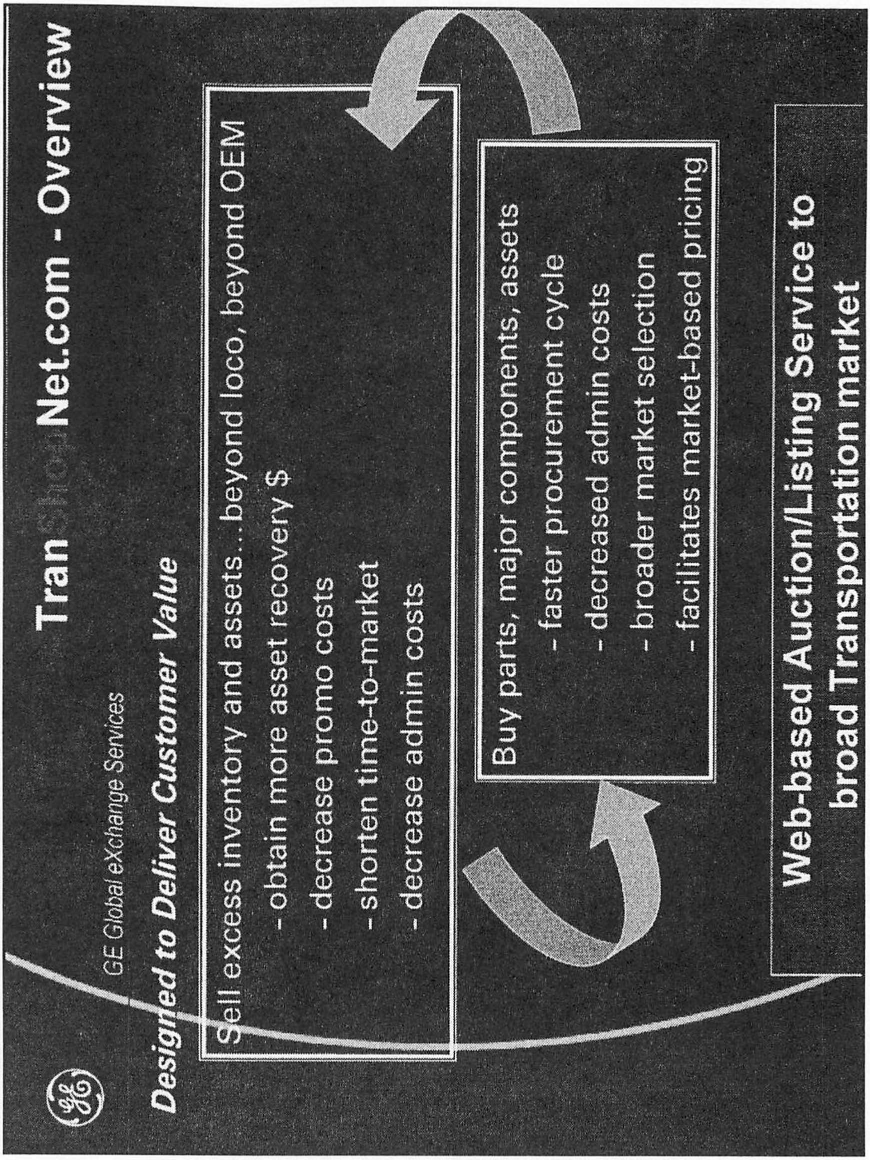
TranShopNet.com - Overview
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- decrease promo costs
- shorten time-to-market
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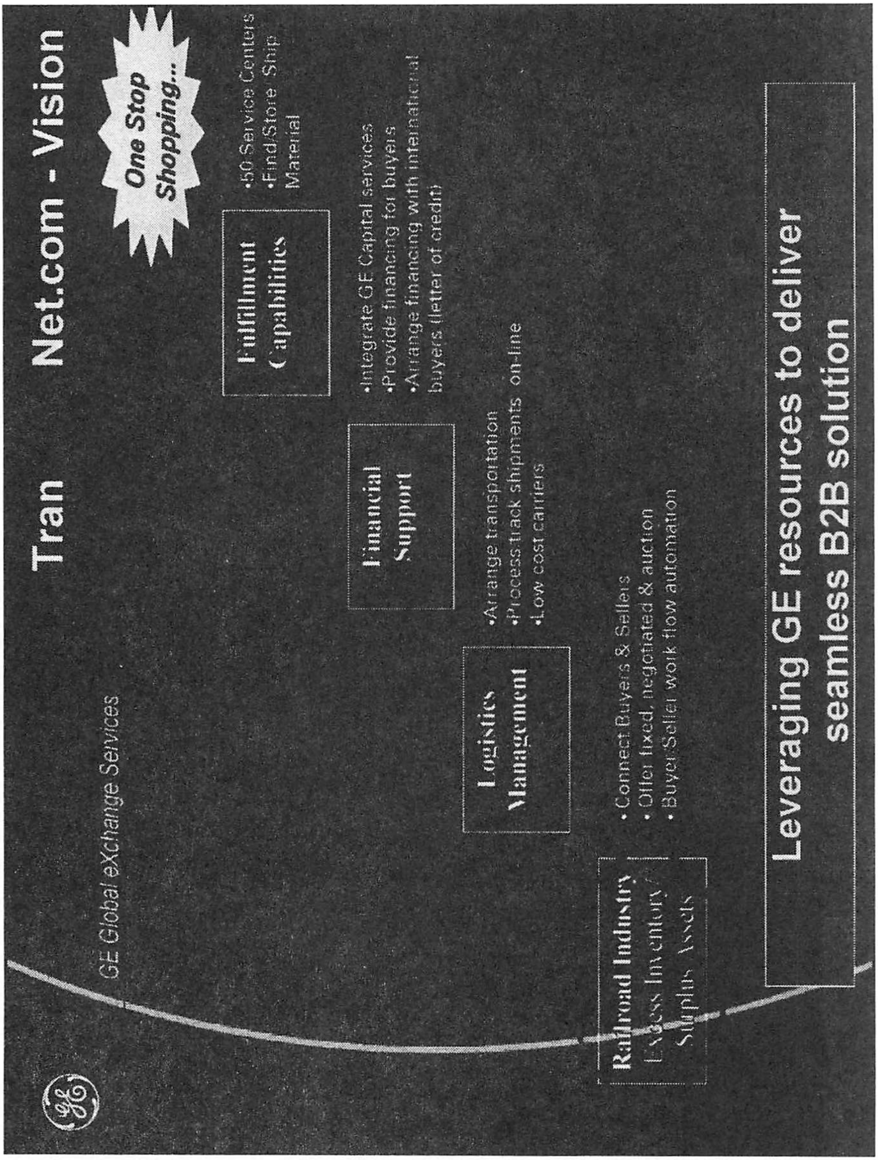
Buy parts, major components, assets
- faster procurement cycle
- decreased admin costs
- broader market selection
- facilitates market-based pricing
Web-based Auction/Listing Service to broad Transportation market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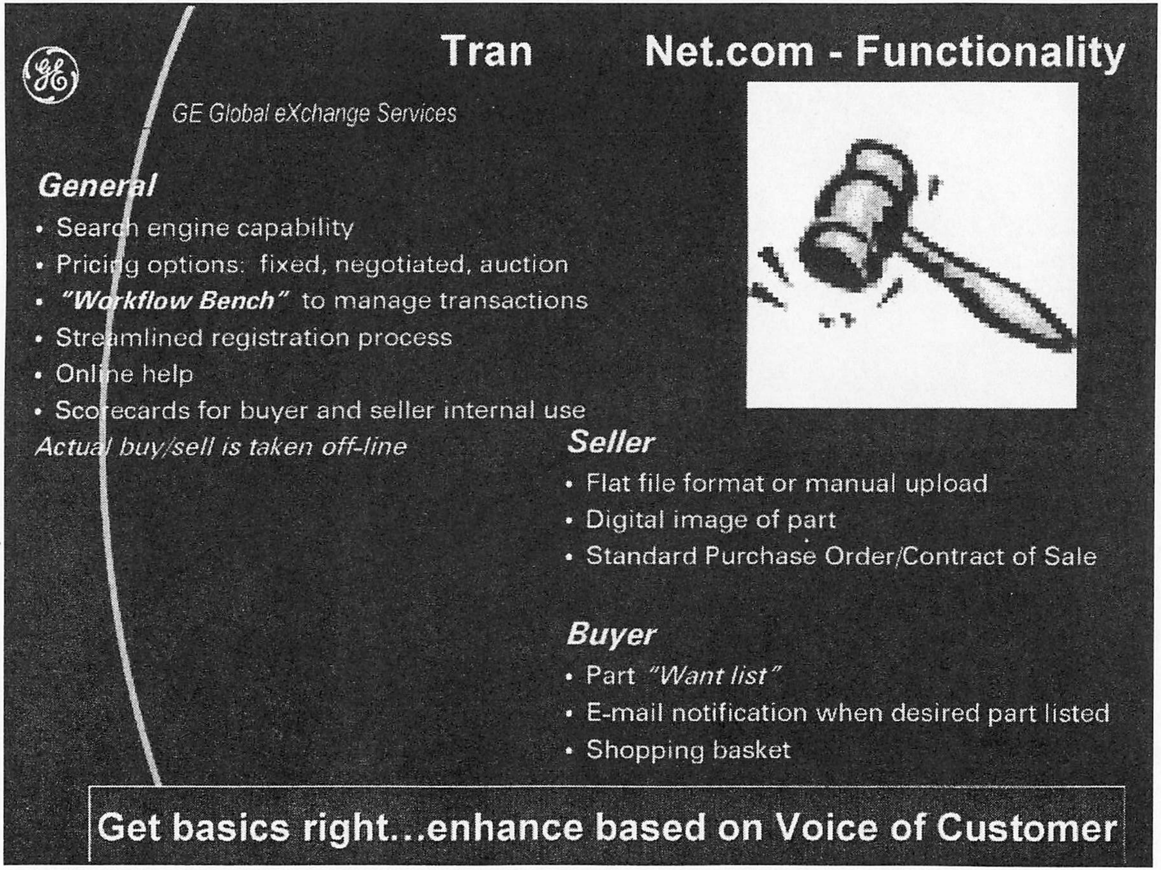
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Actual buy/sell is taken off-line
Seller
• Flat file format or manual upload
• Digital image of part
• Standard Purchase Order/Contract of Sale
Buyer
• Part "Want list"
• E-mail notification when desired part listed
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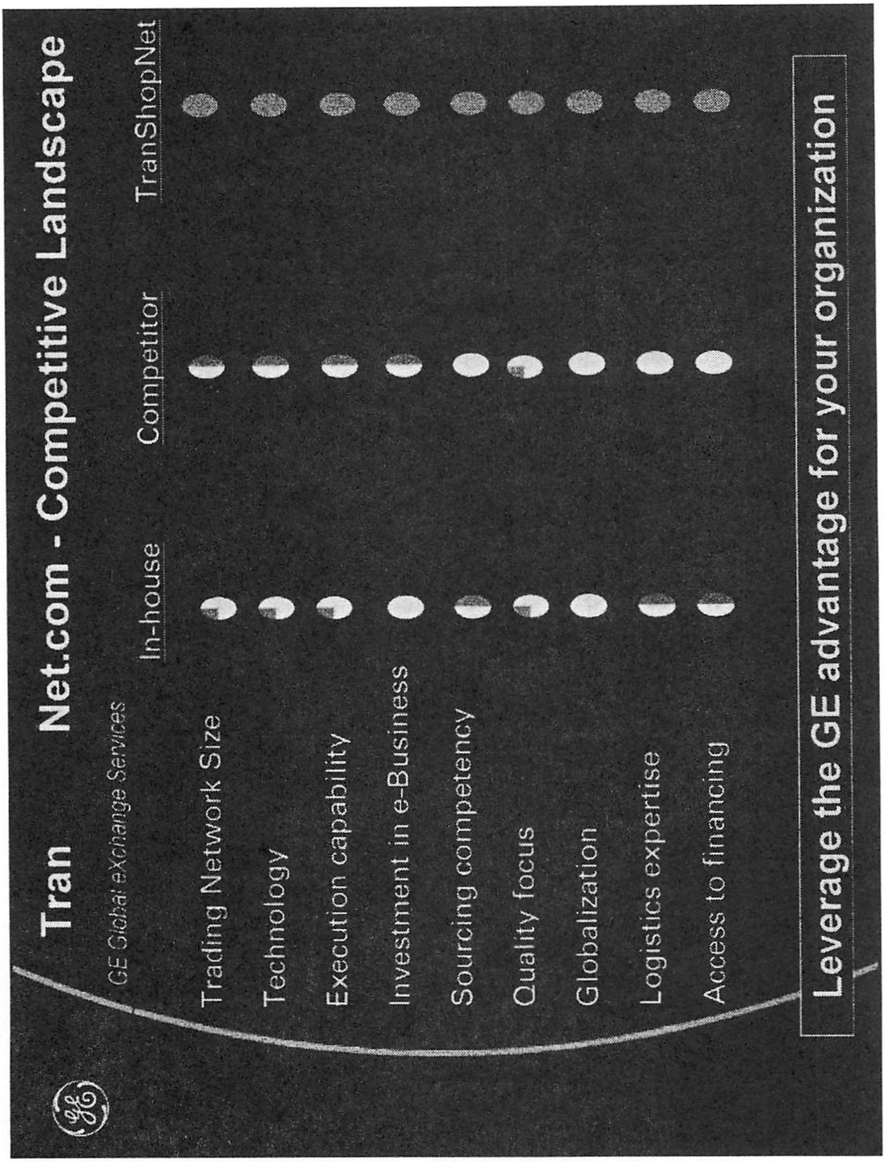
Get basics right...enhance based on Voice of Customer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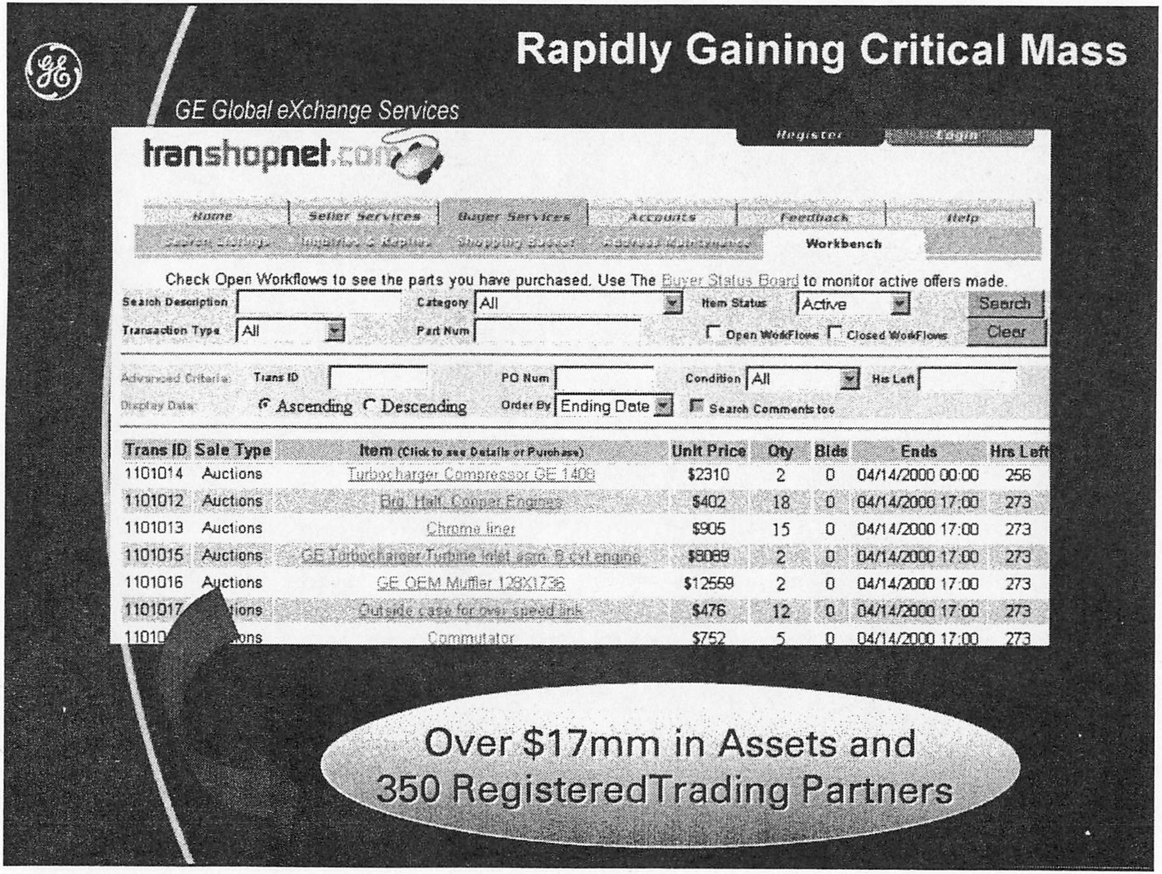
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Category All
Item Status Active
Search
Transaction Type All
Part Num
Open WorkFlows
Closed WorkFlows
Clear
Trans ID
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Trans ID | Sale Type | Item (Click to see Details or Purchase) | Unit Price | Qty | Bids | Ends | Hrs Left
1101014 Auctions Turbocharger Compressor GE 1408 $2310 2 0 04/14/2000 00:00 256
1101012 Auctions Brg. Half, Cooper Engines $402 18 0 04/14/2000 17:00 273
1101013 Auctions Chrome liner $905 15 0 04/14/2000 17:00 273
1101015 Auctions GE Turbocharger Turbine inlet asm. 8 cyl engine $8089 2 0 04/14/2000 17:00 273
1101016 Auctions GE OEM Muffler 128X1736 $12559 2 0 04/14/2000 17:00 273
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Commutator $752 5 0 04/14/2000 17:00 273
Over $17mm in Assets and
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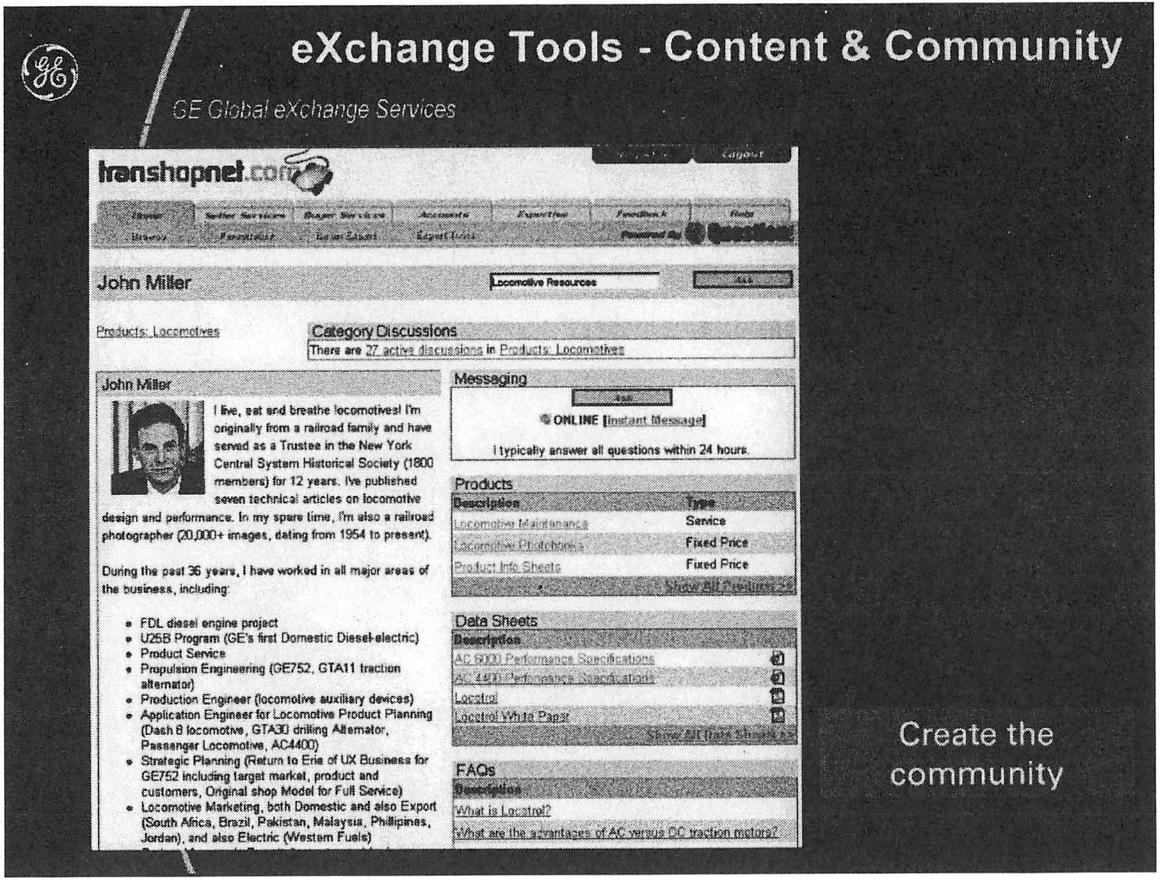
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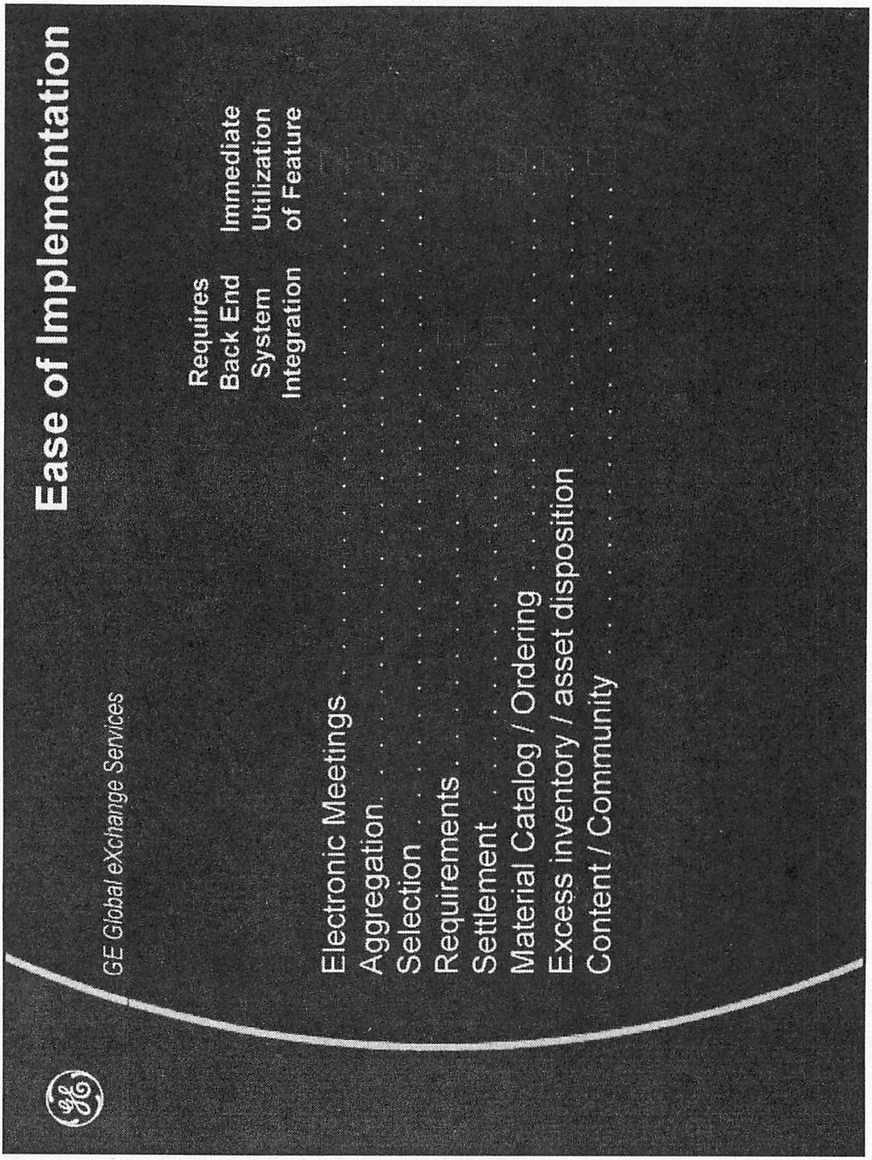
John Miller
I live, eat and breathe locomotives! I'm originally from a railroad family and have served as a Trustee in the New York Central System Historical Society (1800 members) for 12 years. I've published seven technical articles on locomotive design and performance. In my spare time, I'm also a railroad photographer (20,000+ images, dating from 1954 to present).
During the past 36 years, I have worked in all major areas of the business, including:
FDL diesel engine project
U25B Program (GE's first Domestic Diesel-electric)
Product Service
Propulsion Engineering (GE752, GTA11 traction alternator)
Production Engineer (locomotive auxiliary devices)
Application Engineer for Locomotive Product Planning (Dash 8 locomotive, GTA30 drilling Alternator, Passenger Locomotive, AC4400)
Strategic Planning (Return to Erie of UX Business for GE752 including target market, product and customers, Original shop Model for Full Service)
Locomotive Marketing, both Domestic and also Export (South Africa, Brazil, Pakistan, Malaysia, Phillipines, Jordan), and also Electric (Western Fuels)
Messaging
ONLINE [Instant Message]
I typically answer all questions within 24 hours.
Products
Description
Type
Service
Fixed Price
Product Info Sheets
Fixed Price
Data Sheets
Description
AC 6000 Performance Specifications
Locotrol
Locotrol White Paper
FAQs
Description
What is Locotrol?
What are the advantages of AC versus DC traction motors?
Create the community


Ease of Implementation
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Requires Back End System Integration
Immediate Utilization of Feature
Electronic Meetings
Aggregation
Selection
Requirements
Settlement
Material Catalog / Ordering
Excess inventory / asset disposition
Content / Community

II. my.SAP.COM

Prepared by
Robert Dudley - SAP

As the market leader of inter-enterprise software solutions, SAP is leveraging its strength in industry-focused business software and the world's largest enterprise software customer base to deliver mySAP.com. MySAP.com provides an open, collaborative business environment of personalized solutions on demand. This enables companies of all sizes and industries to fully engage their employees , customers and partners to capitalize upon the new Internet economy. MySAP.com allows people to harness the power of the Internet to work smarter, better and faster by optimizing supply chains, managing strategic relationships, reducing time to market, sharing virtual information, and increasing productivity and shareholder value.

This paper will provide an overview of mySAP.com and the benefits it can bring to the locomotive industry. It will answer the following questions:

a) MySap Workplace - using Internet technology and mini-applications via a customized portal for each employee.

b) MySAP Marketplace by SAPMarkets - an array of e-business buying and selling capabilities, including business-to-business procurement, dynamic pricing, RFP/RFQ, and the architecture to build any type of open or closed marketplace.

c) MySAP Customer Relationship Management - attracting new customers, generating sales leads, and creating effective customer service centers to retain customers.

d) MySAP Supply Chain Management - the application of supply chain processes collaborates with partners, while managing the supply chain back-office operations.

e) MySAP Product Lifecycle Management - leveraging the Internet for collaborative design, engineering, and product data management.

f) MySAP Business Intelligence and Data Warehousing - providing the information in a format supporting decision-making and strategic enterprise management.

g) MySAP Mobile Computing - wireless communications via the Internet to mySAP.com applications and business processes.

h) MySAP Application Hosting - a new organization delivering a full range of e-business applications through SAP's hosting model vial the Internet.

I) MySAP Roles and E-Business Scenarios - the redefinition of streamlined business processes as performed by the people who do the work, with collaborative business scenarios as templates by industry.

How Can mySAP.com Help Companies Come Closer To Their Suppliers And Customers?

As part of the mySAP.com solution, SAP provided web-enabled collaborative business scenarios that enable business partners to integrate their processes via the Internet. These scenarios include, but are not limited to, collaborative engineering, supply chain integration, business to business procurement, and customer relationship management.

What Are Internet Marketplaces And How Do They Affect How Companies Do Business?

Internet Marketplaces provide the infrastructure and technology to enable cross-business collaboration.

SAP is the leading provider of inter-enterprise software solutions that integrate the processes within and among enterprises and business communities. It enables companies of all sizes and industries to fully engage their employees, customers and partners to capitalize upon the new Internet economy.

MySAP.com reflects the SAP commitment to e-business - a significant step beyond e-commerce - as companies seek to extend their investment in technology to adapt to the modern Internet business landscape, in which each customer's needs must be met immediately. Delivering such optimal service requires an integrated, open marketplace on the Internet, with companies leveraging suppliers, partners and customers. SAP is in a unique position to help businesses gain competitive advantages in the Internet economy. The flexible mySAP.com offering can be implemented to fully integrate an organization's operational business processes, from finance, human resources and manufacturing to sales and distribution, while enabling it to reach out to its customers and business partners along the supply and value chain.

With globalization, expansion, diversification, mergers and acquisitions, and the opportunities of the Internet, the requirements for a coordinated view and management of information have assumed greater importance than ever. The proven and reliable SAP ™ Internet platform offers complete and seamless integration of back-office and front-office information, providing users with a complete view of the data integral to their job roles, whether it is for an accurate image of an individual customer or the financial standing of a key account.

A MODIFIED MU CABLE AND CONTROL UNIT FOR SAVING FUEL ON DIESEL LOCOMOTIVES

By Michael Howard (Pr. Eng.), Gerhard Lesch, Andrew Boy, Spoornet, South Africa

1. Executive Summary

A diesel fuel saving system called SLIMKABEL has been developed. The system consists of a control unit and up to 5 modified MU (multiple unit) cables. SLIMKABEL is a retrofit or "plug and play" system, which enables the railway operator to use it on existing locomotive fleets without expensive modifications to locomotives.

The driver in the leading locomotive cab uses the control unit to make or break train lines at the selected modified MU cable. This enables the train driver to switch any number of trailing locomotives into standby mode or back to the status of the leading locomotive(s). Notching up of the trailing locomotives is always done in a controlled manner to the same notch as the leading locomotive(s).

The objective of developing SLIMKABEL is to save on diesel fuel. Diesel fuel is saved in this way because as few locomotives as possible operate for as long as possible under maximum power output (higher duty cycle) - an operating condition that has been well proven to be fuel efficient.

SLIMKABEL has been shown to save 5 to 10% on diesel fuel during on-track tests conducted by Spoornet. Initial results from operational usage confirm these savings. Tests have also shown that SLIMKABEL has no detrimental effects on locomotives.

2. Introduction

This paper reports on the development of a modified MU cable and control unit called SLIMKABEL. The benefit of using this system instead of the standard MU cable is in fuel savings. The paper describes some of the background theory to the development of the unique system. Some of the main beneficial features of SLIMKABEL are highlighted. The tests performed to establish the amount of fuel savings are described and discussed, as well as tests performed to determine whether SLIMKABEL has any detrimental side effects on locomotives. The current status and future of SLIMKABEL in South Africa and internationally is briefly considered; however the scope of this paper is limited to technical aspects of SLIMKABEL and thus no economical or business influences on SLIMKABEL's future are analyzed.

3. Theoretical Background

SLIMKABEL is based on the principle that the higher the duty cycle of a diesel locomotive, the more fuel efficient it will be. SLIMKABEL enables train drivers to switch trailing locomotives in and out of standby mode and hence

operate their locomotives under full load in notch 8 at speeds higher than minimum balancing speed and lower than maximum economical speed, which results in diesel fuel savings. The standby mode is actually motoring notch 1, but this mode can be set to any notch. Spoornet sets Notch 1 as the standby mode in order to keep trailing locomotive 'engines' at acceptable operating temperatures and to keep current on traction motor brushes, thus reducing flash-overs and commutator wear.

The following example illustrates the fuel saving principle:

The manufacturer's rating of a particular diesel locomotive (a South African Class 37-000) is as follows:

- In accelerator notch 3 it delivers 54.5kN of tractive effort at 30km/h, with a fuel consumption of 135kg/h. By simple multiplication it can be seen that four of these locomotives operating in notch 3 deliver 218kN with a fuel consumption of 540kg/h.

- In accelerator notch 8 this locomotive delivers 218kN of tractive effort at 30km/h, with a fuel consumption of 440kg/h.

The above example illustrates that operating one locomotive in notch 8 achieves the same tractive effort as four locomotives in notch 3, but consumes 18.5% less fuel. This is the basic characteristic that SLIMKABEL exploits.

The philosophy of train design is that trains are compiled at departure with enough locomotives to haul the load over the steepest, or ruling, gradient on the route, or trajectory. Assume, as in the above example, for a specific load and trajectory this turns out to be 4 Class 37-000's. The 4 Class 37-000's haul the train load over the ruling gradient in notch 8 and so are operating at maximum fuel efficiency. However, the trajectory is not composed only of ruling gradients. Assuming 20% of the total length of the trajectory in this example consists of the ruling gradient, over the other 80% of the distance the 4 Class 37-000's operate in less than notch 8 and hence at less than optimal fuel efficiency. To increase fuel efficiency, SLIMKABEL allows the driver to use all four locomotives only where necessary, and switch into standby mode those that are not required, thus ensuring that the locomotives in use are operated in as high a notch as possible, and hence at optimal fuel efficiency.

In response to power demand changes made by the driver through the controls, the leading locomotive in a normal multiple unit consist of locomotives sends a sustained 4-bit binary signal on the four train MU lines (lines 3, 12, 7, 15) to the trailing locomotives.

SLIMKABEL operates by means of signals received from the SLIMKABEL control unit in the leading locomotive cab through the MU lines to bring trailing locomotives into full power or place them in standby mode. The SLIMKABEL MU cable whose address corresponds to the signal sent from the control unit makes or breaks these 4 train lines to control whether the locomotives to the rear of the selected SLIMKABEL MU cable are in standby mode or in the same notch as the locomotives in front. After a SLIMKABEL MU cable has received its address signal for three consecutive synchronization periods, it breaks MU lines 3, 12, 7 and 15 immediately. It keeps those MU lines broken until it has lost its address for three consecutive synchronization periods, in which case it immediately makes lines 7 and 15 and, after 7 seconds, lines 3 and 12.

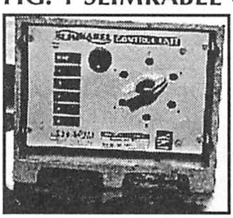
SLIMKABEL can also be used for coupling different locomotives together in a consist. This has been successfully achieved on the iron ore export line in South Africa where SLIMKABEL connects diesel locomotives to Class 9E electrical locomotives thus, allowing the driver of the leading electric locomotive to switch trailing diesel locomotives in and out as required.

SLIMKABEL helps to design trains more optimally. This is because, generally, the tractive effort required to haul a load is not exactly divisible by the tractive effort of one locomotive, which means that after performing a load calculation one often finds, for example, 2.4 locomotives are required. Three locomotives must then be used for this train. With SLIMKABEL the actual required tractive effort can be achieved by mixing different locomotives. Thus the third locomotive required in the consist would be a less powerful class and most likely a cheaper locomotive in terms of hiring and running costs as well. Any incompatibility of locomotives in terms of differing balancing speeds can also be overcome by SLIMKABEL control.

4. Main Features

- SLIMKABEL consists of modified MU cables between each diesel locomotive in a multiple unit consist and a control unit in the leading locomotive's cab. The control unit interfaces with the system through the open MU socket in the front of the leading locomotive via a long cable, requiring no modification on the locomotive. With a minor modification to the locomotive it can also interface, via a short cable, with the master controller in the leading cab. Figures 1, 2 and 3 illustrate the SLIMKABEL components.

FIG. 1 SLIMKABEL Control Unit

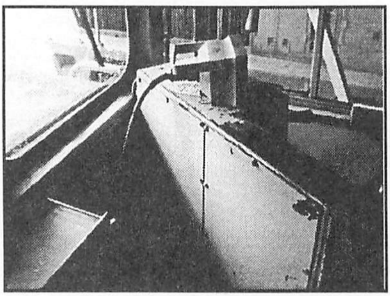


(Front panel)

- SLIMKABEL is a retrofit ("plug and play") addition to the consist of locomotives. Thus no complex modifications are required on existing locomotive fleets. Train personnel are able to simply plug the system into the MU sockets requiring no tools or extra training. The train driver performs the setup procedure by simply pressing a setup button on the control unit before departure. This takes less than 60 seconds and SLIMKABEL also performs a self-diagnostic test during this time.

- SLIMKABEL never adds anything to the control signals from the leading locomotive, but acts purely by making and breaking train lines in a controlled manner, so that the locomotives are never in danger of being damaged by invalid switching sequences. Thus SLIMKABEL cannot result in locomotives remaining in power mode after the driver has cut the power.

FIG. 2 Control Unit & short cable connection



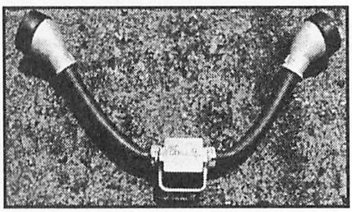
- The switching of the train lines is accomplished by electro-mechanical relays to ensure the voltage drop over the contacts is as low as possible.

- The train driver always has full dynamic brake available on all the trailing locomotives no matter what the SLIMKABEL status is (unless full dynamic brake is not available for some reason independent of SLIMKABEL).

- The relay contacts are connected in the normally closed position to ensure that the train lines will be continuous in the case of a failure. Thus, in the case of failure the SLIMKABEL MU cables operate as standard MU cables.

- Any number of up to 5 SLIMKABEL MU cables are able to work in one multiple unit consist controlled by on SLIMKABEL control unit. The complete system on the train can consist of any SLIMKABEL MU cables. The cables are not position sensitive as they are allocated addresses during the system setup.

FIG. 3 SLIMKABEL MU Cable



- No SLIMKABEL components will fail due to any operational failure of the locomotives, except in the case of catastrophic failures such as fire, derailment or electrical short circuits which did not trip the electrical protection circuits on the locomotives.

- SLIMKABEL is immune to interference from the interior and exterior of the locomotives, nor does it create any untoward interference.

- The components are extremely robust and are able to withstand extreme railway conditions of:

  - Industrial dust
  - Fuel and lubrication oils
  - Industrial solvents for cleaning purposes
  - Rain and sea spray
  - Ambient temperatures of -15°C to 50°C in shade and direct sunshine
  - Altitudes of sea level to 2500 meters above sea level
  - Rough handling - free fall from a height of 3 meters onto a concrete floor.

- The components have been designed to be as lightweight and comfortable to carry as possible.

- The components have been designed to be easily maintainable, ergonomically acceptable, low in capital expenditure requirements, reliable, with minimal installation cost, easy for train drivers and technical personnel to understand and use and with minimal logistical support required.

5. Project History

In the South African railway environment, as elsewhere, there is enormous pressure to drive operating costs down. The annual diesel fuel bill of approximately R400 million was one area of possible savings for Spoornet. A project was thus launched to study the potential savings in diesel fuel achievable by operating diesel locomotives at higher duty cycles, and to develop a cost affective technology innovation that would exploit this potential on the existing locomotive fleet. SLIMKABEL is the innovative solution that resulted.

SLIMKABEL was initially tested on two Spoornet railway lines to determine the amount of fuel savings. These initial tests showed a savings of 5-10%. A SLIMKABEL pilot project was then deployed in the operational environment of the Northern Province of South Africa. However, due to a lack of accurate data recording and management within the environment of a railway company in the process of major restructuring, savings were not openly visible. During this period, some technical improvements to SLIMKABEL were made and train driver training issues were addressed. Because of the lack of clear diesel savings being visible from the Northern Province, Spoornet management decided to re-test SLIMKABEL to confirm savings before considering further deployment to the rest of the railway. The results of these final tests are discussed in Section 6.

Subsequent to these tests, and based on the positive results, Spoornet deployed an initial production batch of SLIMKABEL into operation. Savings were observable at specific depots where monitoring was accurate and these figures confirmed that 5-10% saving on the diesel fuel bill is achieved due to SLIMKABEL usage. However, soon after this deployment, a perception arose amongst some operating staff that SLIMKABEL was responsible for an increase in traction motor failures on locomotives. Due to the seriousness of this concern, tests were immediately performed to check, in detail, whether SLIMKABEL could be causing any detrimental effect on locomotives. The results of these tests are discussed in Section 7.

Reassured by the positive results of the tests described in Section 6 and 7, Spoornet management is currently assessing the global fuel savings that can be expected from further SLIMKABEL deployment and future locomotive fleet sizes, so as to decide on the scope of further deployment of the product. Global, or overall national, fuel savings are dependent on the ratio of multiple header trains to single headers and on the topography of Spoornet's railway lines.

6. Fuel Saving Tests

The purpose of the final and most comprehensive series of fuel savings tests conducted was to confirm previous tests that showed fuel savings of 5-10%.

6.1 Test Method

The primary objective of the test methodology was to maintain as much consistency as possible during test runs with SLIMKABEL and without, with respect the following factors:

- The sane (constant) load was hauled for all tests.
- The same locomotives, in the same order, were used.
- The train was driven by the same driver throughout, with the objectives of keeping train-handling techniques identical throughout.
- The same technical test personnel recorded and analyzed all the test data.
- Comparative runs were performed at the same time of the day and under approximately the same weather conditions.
- The same data acquisition instrumentation was used.

Table 1 lists the instrumentation used.

TABLE 1 Instrumentation used during the tests.

Channel	Description of Instrumentation	Position on the Locomotive	Purpose
1	Mecer T1100 Notebook, Banner, Red-Eye, SCM9B Module and software.	Lead locomotive cab, No. 1 end B-Side lead wheel.	Ascertain distance traveled.
2	Mecer T1100 Notebook, transducer, SCM9B Module and software.	Lead locomotive cab, No. 1 end lead locomotive brake pipe.	Monitor all brake applications of the locomotive consist.
3	Mecer T1100 Notebook, SLIMKABEL Control Unit, SCM9B Module and software.	Lead locomotive cab, No. 1 end lead locomotive MU – coupling.	To monitor the notch profile of the locomotive consist in order to calculate the fuel consumption.
4	Mecer T1100 Notebook, SLIMKABEL Control Unit, SCM9B Module and software.	Lead locomotive cab, No. 1 end lead locomotive MU – coupling.	To monitor SLIMKABEL addresses and switching as performed by the Train Driver.
5	PSION–Organizer with L-18 programme software, operated manually.	Cab of the lead locomotive.	To note km points, stations, operating conditions.
6	SLIMKABEL MU Cables.	Between each locomotive in the consist.	To switch locomotives in, and out, as required.
7	CONTROL UNIT.	In the cab of the lead locomotive.	To allow the Train Driver to perform SLIMKABEL switching as required.

The complete test series comprised the following test runs on diverse trajectories between South Africa towns:

- Tzaneen to Hoedspruit - Without SLIMKABEL
- Hoedspruit to Tzaneen - Without SLIMKABEL
- Tzaneen to Hoedspruit - With SLIMKABEL
- Hoedspruit to Tzaneen - With SLIMKABEL
- Pietersburg to Messina - With SLIMKABEL
- Messina to Pietersburg - With SLIMKABEL
- Pietersburg to Messina - Without SLIMKABEL
- Messina to Pietersburg - Without SLIMKABEL

The constant load hauled on all test runs was 2553 tons for 40 wagons (160 axles). A consist of four Class 34 diesel locomotives was used at all times. The test trains were all vacuum braked. The runs performed without the aid of SLIMKABEL technology were, at all times, optimum runs with great emphasis being placed on the application of energy saving train handling techniques.

6.2 Results

Table 2 shows a summary of the fuel consumptions recorded and depicts the fuel savings as a percentage.

6.3 Discussion

The fuel consumption values depicted were calculated by constantly recording the notch status of all the locomotives in the locomotives in the multiple unit consist. The *fuel consumption* ascribed per notch is obtained from measurements recorded by Spooret's diesel traction department. It was found from all practical tests performed that the amount of fuel savings achieved is dependent on train-handling techniques employed, the applicable track section and the load in respect to the tractive effort employed. The saving when traveling between Pietersburg and Messina is negligible due to the predominantly down gradients in this direction. However, the saving in the opposite direction is in excess of 10%, thus an average savings of around 5% is achieved when considering travel in both directions on this trajectory.

7. Acceptance Tests

Some time after the introduction of the first batch of SLIMKABEL

Table 2: Fuel consumption's recorded and savings obtained during tests.

Number	Section	Fuel Consumed (Litres)	% Fuel saving with *SLIMKABEL*
1	Tzaneen – Hoedspruit (Without SLIMKABEL)	1938.46	8.69%
2	Tzaneen – Hoedspruit (With SLIMKABEL)	1770.0	
3	Hoedspruit – Tzaneen (Without SLIMKABEL)	2464.02	5.73%
4	Hoedspruit – Tzaneen (With SLIMKABEL)	2322.72	
5	Pietersburg – Messina (Without SLIMKABEL)	3263.51	0.8%
6	Pietersburg – Messina (With SLIMKABEL)	3237.40	
7	Messina – Pietersburg (Without SLIMKABEL)	5582.13	10.79%
8	Messina – Pietersburg (With SLIMKABEL)	4979.76	

into operation, a perception arose that SLIMKABEL was responsible for an increase in traction motor failures on locomotives. In order to investigate whether this was true or not, tests were conducted on track.

7.1 Method

The test consisted of four diesel locomotives, two of which were known to be "reliable" locomotives with a clean track record as far as traction motor failures are concerned and two locomotives identified by the local diesel maintenance depot as "troublesome".

Accurate measurement shunts to monitor the armature currents, as well as voltage transducers to monitor the motor voltages were installed on the traction motors in order to determine if any abnormal voltages or currents were experienced by the traction motors during use of SLIMKABEL.

The notch of each locomotive was determined through the use of an interface circuit installed in the cab of each locomotive. This circuit interfaced with the train line signals available from the electronic control circuits on each locomotive.

The oil pressure on the locomotives was recorded in order to provide information for the assessment of the effect of the SLIMKABEL on the operation of the diesel engine. Oil pressure transducers were installed at two positions on the engine, one directly after the lubricating oil pump and one at the input to the governor.

Maximum load for the consist of locomotives was hauled in order to ensure that this test consist would reflect the most demanding operating conditions presently experienced in-service, especially as far as traction motor failures are concerned.

7.2 Results

The tests showed that the SLIMKABEL does nothing abnormal to the motors of any of the locomotives and the motors work within their continuous rating.

At no stage was an abnormal oil pressure recorded. Low lubrication trip only occurred due to locomotive stalls through incorrect governor settings, independent of SLIMKABEL.

7.3 Discussion

The tests results showed that the SLIMKABEL does not cause traction motor failures or force locomotives to act outside of their ratings. However, because SLIMKABEL induces higher duty cycles on locomotives, it is feasible that it will bring to light any existing deviations of the locomotives from specification.

Independently of the test results, a survey of repairs to traction motors at various depots, before and after the introduction of SLIMKABEL was done by the Traction Department of Spoornet. No evidence could be found of increased traction motor failures.

It can thus be concluded that the perception that SLIMKABEL was responsible for an increase in traction failures on locomotives, was false.

8. The Future of SLIMKABEL

Based on the fuel savings tests, and the fact that SLIMKABEL has been exhaustively tested to ensure it causes no detrimental affects, Spoornet management is currently investigating full national deployment in South Africa. The scope of this project depends on:

- Final global fuel saving protections
- Final product reliability audits by Spoornet
- Projections of quantities of diesel locomotives in the future Spoornet.

For SLIMKABEL to live up to its potential, the critical success factors of train driver and technical personnel training and effective monitoring and management of SLIMKABEL and the savings achieved must be given the necessary attention.

Internationally, the SLIMKABEL innovation is viable wherever there is a drive to reduce railway operating costs and where older diesel locomotives that would benefit from such a retrofittable device are used.

9. Conclusion

SLIMKABEL is an innovative and effective diesel fuel saving product for application on multiple header diesel locomotive consists. Fuel savings of 5-10% are achieved. It is a retrofit or "plug and play" addition to locomotives. SLIMKABEL has been designed and developed with features that suit the demanding railway environment. This has been achieved during the course of a project conducted by Spoornet. During on-track tests it was confirmed that SLIMKABEL does not cause any detrimental effects on locomotives.

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 activities, especially those held within their assigned region and monitor membership activities on those railroads so assigned.

E. Promote and solicit support for LMOA by helping to obtain advertisers.

Section 6 - Duties of General Executive Committee:

A. Monitoring technical papers for material considered unworthy or inaccurate for publication.

B. Approve topics for the **Annual Proceedings** and Annual Meeting program.

C. Approve the schedule for the Annual program.

D. Administer all Association activities not specifically assigned to the Board of Directors.

Section 7 - The Advisory Board shall act in a consulting capacity. Past Presidents still in official active railroad service shall automatically become members of the Advisory Board.

Section 8 - The Board of Directors are entrusted with all public relation decisions within LMOA and coordinated associations with confidentiality.

Article VII - Technical Committees

The technical committees will consist of:

Section 1 - A chairperson, appointed by the President and approved by the Board of Directors.

Section 2 - A vice chairperson, selected by the chairperson and approved by the President.

Section 3 - Committee members will be made up of:

A. Representatives of operating railroads and regional transit authorities submitted by their Senior Mechanical and Materials Officers and approved by the President of LMOA.

B. Representatives of locomotive builders designing and manufacturing locomotives in North America.

C. The Fuel and Lube Committee will include members from major oil companies or their subsidiaries as approved by the General Executive Committee.

D. At the discretion of the General Executive Committee, non-railroad personnel may be allowed to participate in committee activities, subject to annual review.

E. All individuals who are on technical committees must be LMOA members in good standing. (See dues and fees, Article 3, Section 5).

Subjects for technical papers will be selected and approved by the General Executive Committee.

Article VIII - Proceedings

The Locomotive Maintenance Officers Association encourages the free interchange of ideas and discussion by all attendees for mutual benefits to the railroad industry. It is understood that the expression of opinion, or statements by attendees in the meeting, and the recording of papers containing the same, shall not be construed as representations or statements ratified by the Association.

Article IX - Rules of Order

The proceedings and business transactions of this Association shall be governed by Roberts Rules of Order, except as otherwise herein provided.

Article X - Amendments

The Constitution may be amended by a two-thirds vote of the active members present at the Annual Meeting.

DIESEL MECHANICAL MAINTENANCE COMMITTEE
NINETEEN YEAR INDEX

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
NINETEEN YEAR INDEX

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 Management
2. Railroad Industry Group (RIG) Exchange Standard for Parts Catalog Information

1994
1. Material Consignment.
2. The Next Step in Electronic Information Management - Interactive Technical Manuals.
3. Electronic Catalog Alternatives.

1993
1. Technology Transfer
2. Electronic Cataloging from a Material Perspective
3. Computerized Reordering from the Mechanical Employee's Point of View
4. Electronic Catalogues: OEM /Supplier Point of View

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

1991
1. The World of Recycling.
2. Problems with Solutions.
3. Problems with Opportunities.

1990
1. Waste Minimization.
2. Hazardous Materials End Cost
3. The Role of the Suppliers.

1989
1. Packaging and Containerization for Today's Railroad.
2. Innovations in Material Distribution Resulting from Shop Consolidations.
3. Outsourcing! Does Anyone Really Understand the Difference Between UTEX and Repair and Return and the Affect on the Budget?
4. "Stuff" Happens! - A Skit About the Necessity of Feedback from Suppliers - Suppliers to the end User.

1988
1. Communication - The Vital Link in Materials Acquisition.
2. Quality Assurance Through Communications and Feedback.
3. Paperless Requisitions.
4. A Practical Application of Bar Coding in the Railroad Industry.

1987

1. Suppliers Selection for Component Failure Analysis.
2. Vendor 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 PROCESSESCOMMITTEE NINETEEN YEAR INDEX

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 Evnironmental 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 Preparation with Sodium Bicarbonate Based Abrasive Blasting
5. Trainline Continuity Tester
6. BN - Railroad Power Assembly Shop of the 1990's.

1991
1. Economic Separation of Emulsified Oil from Waste Water Using Ultra Filtration Membranes.
2. EMD Cylinder Head Valve Seat Machining.
3. Automated Barring Over Machine for EMD Diesel Engines.
4. New Equipment for Testing EMD Engine Protectors.
5. Compressed Air for Railroad Facilities Issues and Solutions to Achieve Clean, Dry, Oil Free Air.

1990
1. EMD Valve Bridge Machine
2. GE Traction Motor Roller Suspension Bearing Replacement Equipment and Procedure.
3. Locomotive Component Replacement Forklift Attachment.
4. Locomotive Sanding, Fueling and Drop Tables.

5. Hazardous Waste Disposal.

1989
1. Automated Locomotive Wheel Shop.
2. Laser Guided Material Handling Vehicles.
3. Bulk Rail Lubrication Storage & Fill System.
4. Pilot Plate Straightening Equipment.

1988
1. Fuel Management Control Systems.
2. Locomotive Mounted Rail Lubrication Fill Systems.
3. Comparison of Shop Air Compressors.
4. Locomotive Toilet Servicing Equipment.
5. Innovations in Blue Flag and Derail Protection.

1987
1. Modern Servicing Facility for Improved Reliability and Availability.
2. New Developments in GE Tools.
3. Implementation of a Quality Process.
4. A Quality Traction Motor Shop.
5. Wheel Truing Machine Technology.

1986
1. Robotics Update 1986 - Now What?
2. CNC Machine Tools.
3. A New GE Power Assembly Area.
4. Locomotive Wash System - 1986.

1985
1. Computer-Assisted Preventative Maintenance.
2. New Tools for Material Handling and Overview of Balancing Technology.
3. Effect of Governmental Regulations on Locomotive Finishing.

1984
1. Shop Tools.
   A. New Tools.
   B. Shop-Made Tools.
2. Traction Motor Shop Equipment Up-Date.
3. Hazardous Waste Handling and Disposal.

1983
1. Locomotive Maintenance Using a Production Line Process.
2. Shop Tools to Increase Productivity and Improve Quality.
3. Dynamic On-Line Performance of Locomotives Without On-Board Tele-Metering.
4. Management in Action.
5. New GE Training Center.
6. Welding Qualifications.

1982
1. Tools.
2. Rebuild line for EMD turbochargers.
3. Air brake equipment line.
4. Industrial robots.
5. Automated machines.
6. Safety related items and equipment.

1981
1. Training Aids.
2. Testing Devices Inspired by New FRA Laws.
3. Tools and Training for Productivity.
4. Changes to Shop Facilities Required by Newly Adopted EPA & OSHA Regulations.
5. Tour Through Conrail Altoona Shop.
6. Supply/Service Facilities.
7. GE Assembly Shop.

DIESEL ELECTRICAL MAINTENANCE COMMITTEE
NINETEEN YEAR INDEX

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.

NEW TECHNOLOGIES COMMITTEE
SEVENTEEN YEAR INDEX

Equipment.
4. Locomotive Durability, Reliability and Availability - Understanding Your Abilities.

1989

1. A Rational Approach to Testing Locomotive Components.
2. New Developments in Locomotive Cab Design.

1988

1. Amtrak F69 PH AC Passenger Locomotives
2. New Component Developments Retrofittable to Older Model Locomotives
3. Locomotive Applications of Catepillar Engines.
4. Wheelslip Control for Individual Axles.

1987

1. Electronic Fuel Injection Systems.
2. Update on Electronic Governors.
3. Recent Advances in Steerable Locomotive Trucks - the E.M.D. 4 Axle, 4 Motor HT-BB Articulated Truck.
4. Converting an F40 Locomotive to A.C. Traction.

1986

1. Future Train Control Systems.
2. Bringing Future Train Control Systems Back to Earth.
3. Low Maintenance Locomotive Batteries.
4. Electronic Engine Control Systems.

1985

1. The Sprague Clutch for E.M.D. Turbocharged Engines.
2. A.C. Traction Locomotives Update.
3. Natural Gas Locomotive Update.
4. Ceramic Coated Engine Components.
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 NINETEEN YEAR INDEX

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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