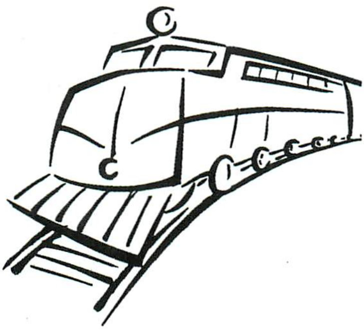
LMOA

Locomotive Maintenance Officers Association



Proceedings of the 69th Annual Meeting

September 13 -14, 2007

Chicago Hilton & Towers

720 S. Michigan Ave.

Chicago, Illinois

2007 ADVERTISERS INDEX

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2006 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 2006.

Name	Company	Committee
Dan Agler	Kansas City Southern Rwy.	Diesel Mechanical Maintenance
Ron Delevan	National Electrical Carbon	Diesel Material Control
Mike Drylie	CSX Transportation	Diesel Electrical Maintenance
Chuck Kunkel	Union Pacific RR	Fuel, Lube & Envrironmental
Dr. Arnold Miller	Vehicle Projects, LLC	New Technologies

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

LMOA EXECUTIVE COMMITTEE

THE LMOA EXECUTIVE BOARD WOULD LIKE TO EXPRESS THEIR SINCERE APPRECIATION TO BOB BOURG OF WABTEC CORPORATION FOR HOSTING OUR JOINT TECHNICAL COMMITTEE MEETING IN GERMANTOWN, MARYLAND ON APRIL 30, AND MAY 1, 2007 AND FOR PROVIDING A TOUR OF THEIR FACILITIES.

WE WANT TO GIVE A SPECIAL THANKS TO DIANE HOPKINS OF WABTEC FOR COORDINATING THE MEETING DETAILS AND THE LUNCHEONS AND TO STUART OLSON, FROM WABTEC WHO IS ALSO CHAIRMAN OF THE DIESEL ELECTRICAL COMMITTEE.

THE LMOA EXECUTIVE BOARD WOULD LIKE TO THANK RICK ORTYL OF METRO EAST INDUSTRIES FOR HOSTING THE JOINT TECHNICAL COMMITTEE'S LUNCHEON IN GERMANTOWN ON MAY 1, 2007

THANK YOU RICK.

WE ALSO WANT TO THANK LMOA 1ST VICE PRISIDENT, MIKE SACRINGE. MIKE MADE ARRANGEMENTS FOR THE COMMITTEES TO MAKE A SHOP TOUR OF AMTRAK'S IVY SHOPS.

PAST PRESIDENTS

1939 & 1949 -	F. B. DOWNEY (Deceased) Shop Supt., C & O Ry.
1941 -	J. C. MILLER (Deceased), MM, N.Y.C. & St. L.R.R.
1942-1946, Inc. -	J. E. GOODWINN (Deceased) Exec. Vice President, C. & N.W. Ry.
1947 -	S. O. RENTSCHILLER (Deceased) Chief Mechanical Officer, Bessemer and Lake Erie R.R.
1948 -	C. D. ALLEN (Deceased) Asst. C.M.O. - Locomotive, C. & O. Ry. & B. & O. R.R.
1949 -	J. W. HAWTHORNE (Deceased) Asst. Vice-Pres.- Equipment, Seaboard Coast Line R.R.
1950 -	G. E. BENNET (Deceased) Vice-Pres.-Gen. Purchasing Agent, C. & E. I. Ry.
1951 -	P. H. VERD (Deceased) Vice-Pres.-Personnel, E. J. & E. Ry.
1952 -	H. H. MAGILL (Deceased) Master Mechanic, C. & N. W. Ry.
1953 -	S. M. HOUSTON (Deceased) Gen. Supt. Mech. Dept. Southern Pacific Co.
1954 & 1955 -	F. D. SINEATH, Retired Chief of Motive Power, Seaboard Coast Line R.R.
1956 -	T. T. BLICKLE (Deceased) General Manager - Mechanical, A .T. & S. F. Ry.
1957 -	J. T. DAILEY (Deceased) Asst. to Pres.-Mech., Alton & Southern R.R.
1958 -	F. E. MOLLOR (Deceased) Supt. Motive Power, Southern Pacific Co.
1958 -	F. R. Denny (Deceased) Mechanical Supt., New Orleans Union Passenger Terminal
1959 -	E. V. MYERS (Deceased) Supt. Mechanical Dept., St. Louis-Southwestern Ry.
1960 -	W. E. LEHR (Deceased) Chief Mechanical Officer, Pennsylvania R.R.
1961 -	O. L. HOPE, (Deceased) Asst. Chief Mechanical Officer, Missouri Pacific R.R.,
1962 -	R. E. HARRISON (Deceased) Manager-Maintenance Planning & Control, Southern Pacific Co.
1963 -	C. A. LOVE, (Deceased) Chief Mechancial Officer, Louisville & Nashville R.R.
1964 -	H. N. CHASTAIN, (Deceased) Gen. Manager-Mechanical, A. T. & S. F. Ry.
1965-	J. J. EKIN, JR. (Deceased) Supt. Marine & Pier Maintenance, B. & O. R.R.
1966 -	F. A. UPTON II (Deceased) Asst. Vice-President-Mechanical, C. M. St. P. & P. R.R.
1967 -	G. M. BEISCHER, Retired Chief Mechancial Officer, National Railroad Passenger Corp. Washington, D.C. 20024
1968 -	G. F. BACHMAN, (Deceased) Chief Mechanical Officer, Elgin Joilet & Eastern Ry.
1968 -	T. W. BELLHOUSE (Deceased) Supt. Mechanical Dept., S. P. Co., - St. L. S.W. Ry.
1970 -	G. R. WEAVER (Deceased) Director Equipment Engineering, Penn Central Co.,
1971 -	G. W. NEIMEYER (Deceased) Mechanical Superintendent, Texas & Pacific Railway
1972 -	K. Y. PRUCHNICKI (Deceased) General Supervisor Locomotive Maintenance, Southern Pacific Transportation Company
1973 -	W. F. DADD, (Deceased) Chief Mechanical Officer, Chessie System
1974 -	C. P. STENDAHL, Retired General manager M.P.-Electrical, Burlington Northern Railroad
1975 -	L. H. BOOTH, (Deceased) Retired Assistant C.M.O.-Locomotive, Chessie System,
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, (Deceased) Manager Locomotive Dept., Chessie System
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1982 -	N.A. BUSKEY (Deceased) Asst. General Manager-Locomotive, Chessie System
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1984 -	R. R. HOLMES, Retired, Director Chemical Labs and Environment, Union Pacific
1985 -	D. M. WALKER, Retired, Asst. Shop Manager, Norfolk Southern Corp., 793 Windsor St., Atlanta, GA 30315
1986 -	D. H. PROPP, Retired Burlington Northern RR & Vice President, Ontrack, 8913 West 161st St., Overland Park, KS 66085
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1994 -	M.A. COLES, Senior Mgr.-Loco. Engineering & Quality, Union Pacific R.R. 1400 Douglas St., Stop 1050, 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, Retired, Supt. - Mechanical, Amtrak, 14142 S.E. 154th Pl., Renton, WA
1997-	D.M. WETMORE, General Supt. - Fuel Opns., NJT Rail Opns. 1148 Newark Turnpike, Kearny, NJ 07032
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2000-	RON LODOWSKI, Asst. Shift Supt., CSX Transportation Selkirk, NY 12158
2001-	LOU CALA, Consultant, LJC Rail, Duncansville, PA 16635
2002-	BOB RUNYON, Engineering Consultant, Roanoke, VA 24019
2003-	BRIAN HATHAWAY, Consultant Port Orange, FL 32129
2004-	BILL LECHNER, Senior General Foreman-Insourcing-Air Brakes, Governors & Injectors, Norfolk Southern Corp., Altoona, PA 16601
2005-	TAD VOLKMANN, Director-Mechanical Engineering, Union Pacific RR, Omaha, NE 68179
2006-	BRUCE KEHE, Mgr.-Maint. Locomotive, EJ & E Rwy. Gary, IN 46402

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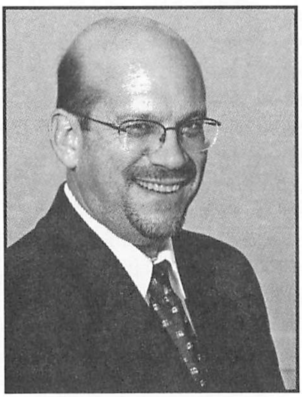

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Manager-Maintenance Locomotives
EJ&E Rwy. Co.
Gary, IN 46402

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Canadian Pacific Railway
Calgary, Alberta T2P 4Z4

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Union Pacific Railroad
Omaha, NE 68179

MR. WEYLIN R. DOYLE
Project Manager
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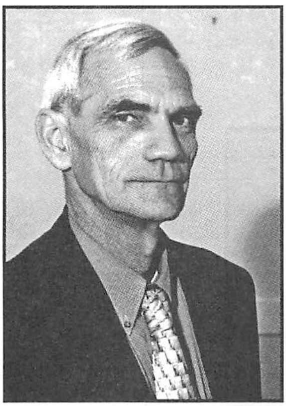
Seattle, WA 98104



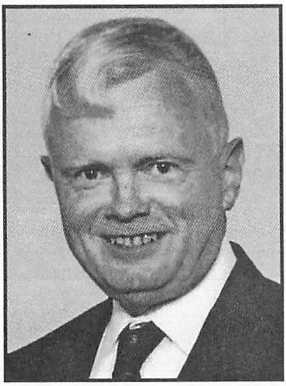
MR. BRIAN HATHAWAY
Consultant
Port Orange, FL 32129

MR. BILL LECHNER
Sr. General Foreman
Insourcing-Air Brakes, Governors & Injectors
Norfolk Southern Corp.
Altoona, PA 16601
Bill also doubles as Regional Executive of the Diesel Material Control Committee

OUR PAST PRESIDENTS

MR. RONALD R. LODOWSKI
Asst. Shift Superintendent
CSX Transportation
Selkirk, NY 12158

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



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

OUR PAST PRESIDENTS

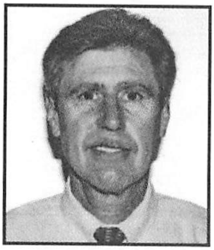
MR. DAVID M. WETMORE
General Supt. - Fuel Operations
NJT Rail Opns
Kearny, NJ 07032

MR. TAD VOLKMANN
Director-Mechanical Engineering
Union Pacific Railroad
Omaha, NE 68179

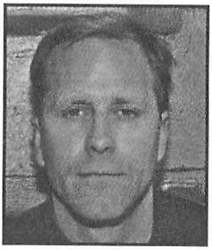
OUR REGIONAL EXECUTIVES

MR. RON BARTELS
Director Electrical and Engine Sys.
Via Rail-Canada
Montreal, Quebec

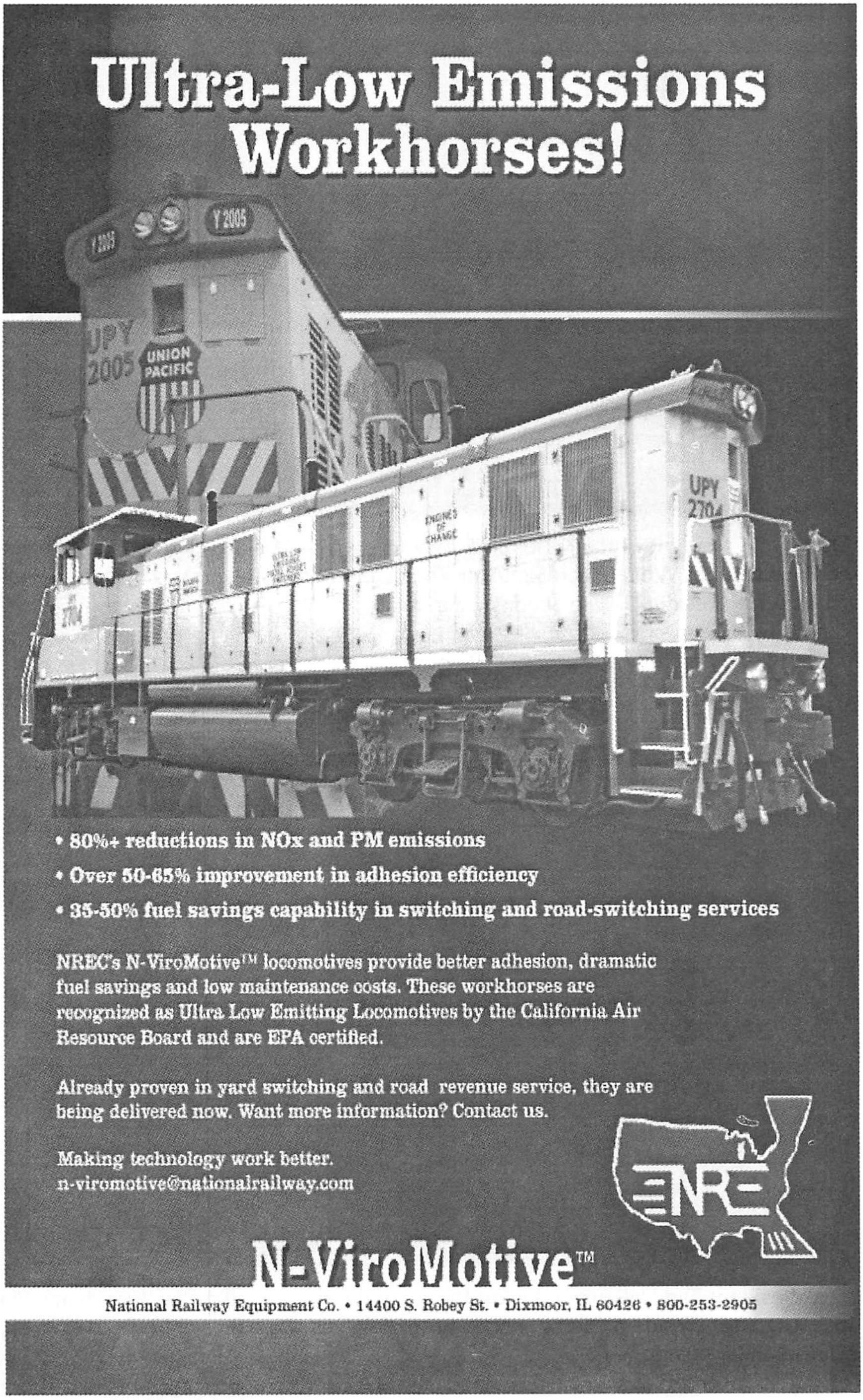
MR. GLENN BOWEN
Director - Lab Services
BNSF Railway
Topeka, KS



MR. JACK KUHNS
Vice President - Sales
JMA Railway Supply
Ponte Verdra Beach, FL



R. BRAD QUEEN
General Foreman-Locomotives
BNSF Railway
Barstow, CA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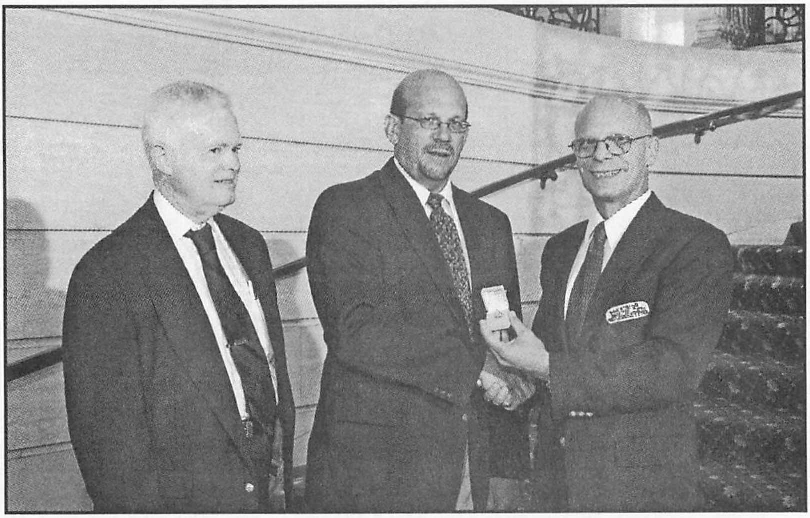
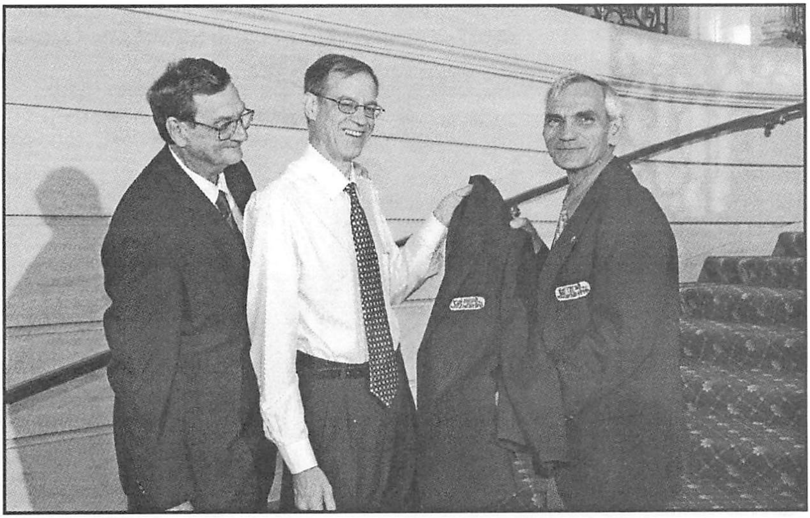
Outgoing President Bruce Kehe, EJ&E Rwy (center) passes the gavel to newly elected President Les White, Bach Simpson. The ceremony was witnessed by newly elected 1st Vice President, Mike Scaringe, Amtrak.

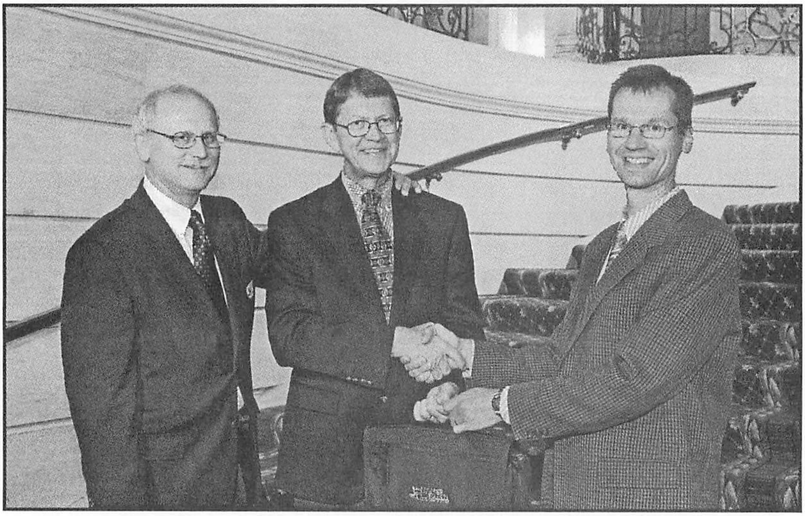


Past President Tad Volkmann, Union Pacific (right) presents the Past President's Pin to Outgoing President Bruce Kehe, EJ&E Rwy, as Past President Bob Runyon, Consultant, looks on.



Past President Brian Hathaway, Consultant (right) presents the LMOA blazer to newly elected 3rd Vice President Bob Reynolds, Canadian Pacific Rwy which was witnessed by newly elected President Les White, Bach Simpson

Past President Dave Goehring, retired-Amtrak (far right), presents the LMOA watch to Outgoing President, Bruce Kehe, EJ&E Rwy (second from left) in honor of his term of office as President. In attendance were Past President Ron Lodowski, CSX (far left) and Past President Tad Volkmann, Union Pacific.



Newly installed Regional Officer Ron Bartels, Via Rail Canada (right) presents LMOA attache bag to newly appointed Chairman of the Diesel Electrical Committee Stuart Olson, WABTEC as newly elected 2nd Vice President Dennis Nott, Northwestern Consulting looks on.

LMOA officers (past and present) Bottom row (left to right) - Past President Bob Runyon, Consultant, newly elected 1st VP Mike Scaringe, Amtrak; Past President Tad Volkmann, Union Pacific, newly elected 2nd VP Dennis Nott, Northwestern Consulting; Past President Brian Hathaway, Consultant; Ron Pondel, Secretary Treasurer; top row (left to right) - Past President Dave Goehring, retired (Amtrak); Past President Ron Lodowski, CSX; newly elected President Les White, Bach Simpson; outgoing President Bruce Kehe, EJ&E Rwy; newly elected 3rd Vice President Bob Reynolds, Canadian Pacific Rwy.

STATE OF THE UNION SPEECH
President Bruce Kehe
September 18, 2006

Good afternoon ladies and gentleman and welcome to the 68th annual meeting and technical conference of the Locomotive Maintenance Officers Association. My name is Bruce Kehe, Manager Maintenance - Locomotives for the Elgin Joliet and Eastern Railway and president of the LMOA for 2006. In addition to some terrific presentations during our technical meetings the next two days, make sure to peruse the exhibition halls on the lower level of the hotel to see the latest and greatest innovations from our supply partners.

Before I begin my official "state of the union" remarks, several acknowledgments are in order. This past May, our six technical committees met in London, Ontario for our ninth annual joint meeting. We were very graciously hosted by four outstanding vendors: Electro-Motive Diesel, ZTR Control Systems, Bach-Simpson, and International Technical Services. LMOA members enjoyed excellent accommodations and meeting facilities, as well as informative plant tours from our hosts. A special thank you to Les White and Tom Nudds for helping coordinate and finalize the arrangements. In addition, I would like to thank all of the railroads and suppliers who hosted our individual committee meetings during the past year. Without their continuing support, LMOA could not survive.

We have two individuals that deserve special recognitions well. The first is Dwight Beebe. For many years Dwight Beebe represented Nalco Chemical Company, which sponsored our annual LMOA Tuesday luncheon. Several years ago, Dwight formed his own company, Temple Engineering, and continued this tradition. In May of this year, Dwight's military reserve unit was called to active duty and he is now currently serving our country in Iraq. Before he left, he contacted Ron Pondel and myself and insisted that the LMOA luncheon go on this fall despite his absence. We owe a debt of gratitude to the staff at Temple Engineering for their dedication to LMOA, and we all wish Dwight godspeed.

Secondly, we need to recognize the untiring efforts of our Secretary-Treasurer, Ron Pondel. Ron has devoted himself to this organization for 19 years - working closely with RSI on the preparations for the annual convention, manning the LMOA registration booth, preparing badges, securing advertisers for our annual proceedings booklet, along with coordinating its publication, collecting dues, and paying the bills. Ron is indeed the glue that holds this organization together. Thank you Ron.

Now, for my thoughts on the state of LMOA in 2006. The transition from 2005-2006 for LMOA was largely successful. Under past president Tad Volkmann's direction, LMOA survived its first non-exhibit year convention, without the financial backing from Railway Supply Institute. I use the world "survived", because the four Coordinated Associations had no idea how we were going to fund the convention in September of 2005 - when original cost estimates exceeded $100,000. Collectively, we pursued the idea of renting table top display space to augment our income, even though 2005 was a non-exhibit year. As it turned out, LMOA registration fees and our share of the table top income covered our portion of the convention costs. Barring any changes in RSI's financial support status, LMOA will continue to have its annual conventions and fund the "non-exhibit" (off-years) with registration fees and table top display income. I should mention, that in future non-exhibit years, LMOA will continue to rely heavily on the registration fees from its railroad members and our supply partners. As 2005 was a "new adventure" for LMOA, I think it is appropriate that we recognize the following supply companies that recognized our financial need and sponsored us exclusively through their registration fees last year: Peaker Services, ZTR Control Systems, Bach-Simpson, Wabtec, Motive Power, National Electrical Carbon Products, and Standard Car Locomotive Group. These companies are on the LMOA wall-of-fame as they routinely offer their facilities for committee meetings and tours, as well as allow their employees to participate in committee work.

In 2006, we saw an encouraging influx of new technical committee members from several suppliers and railroads. We extend a warm welcome to our new members, and thank their respective management teams for allowing these individuals to participate. We continue to seek new members from the Class 1's, regionals, shortlines and our supply partners. LMOA also wants to welcome back several of our past presidents to active committee work - including Ron Lodowski (Fuel, Lube and Environmental), Tad Volkmann (New Technologies), Bill Lechner (Materials), and Brian Hathaway (Electrical). This is truly an indication of these individuals dedication to LMOA. As Douglas MacArthur would have said, "LMOA presidents never retire, they just fade back into committee work and start writing papers."

As for this convention, you will observe several underlying themes in our papers. First, the topic of fuel efficient and low emission locomotives will be addressed by several different committees. New approaches to locomotive field repairs will also be addressed. We'll look at making successful field repairs - which were formerly only accomplished in a heavy repair shop. Finally, several of our committees will continue with our "Best Practices Series" - covering a variety of locomotive maintenance issues. Looking ahead to 2007, I'm extremely happy to report that LMOA will not conduct our paper presentations in this room. For years, we have had to dodge pillars, endure split video screens, and noise distractions from the two adjacent meeting rooms. I don't believe that too many of you will be sorry to see the Williford B room go unused next year. In 2007, we'll see everyone in the Stevens room on the lower level.

In conclusion, I'm very excited about the technical papers that LMOA is presenting during this convention, and I hope you will find them interesting and beneficial as well. I want to thank you again for the opportunity to serve as your president of the LMOA in 2006. Enjoy the rest of the convention.

ACCEPTANCE SPEECH
President Les White
September 19, 2006

Ladies and gentlemen, the Executive Committee and fellow members. It is with great pride I accept the position of President in this the 69th year of the LMOA.

As I look back through the years I have had the opportunity to work for CN, a class 1 railroad, GM EMD a locomotive builder and presently Bach-Simpson a supplier. I would personally like to thank each one for the support they have given me and continue to give the LMOA. The experience of working for an operator, builder and supplier has given me a very good perspective on what the LMOA and Coordinated Associations can offer each function.

Our industry has gone through many changes recently in mergers, downsizing, operations and equipment. This has increased the dependency on each other and made it very important to network and communicate more than we have ever done in the past. Gone are the days where railroads had sufficient staff to take on large modifications to improve locomotives or have large engineering and R & D groups or think tanks that could develop new systems. In addition the regulators are impacting what we see on locomotives with new safety equipment; also the AAR is setting new standards to meet, all positive things but making it very difficult to keep up.

It does not matter whether you are a class 1 or short line railroad, locomotive builder or supplier you have to ask yourself the question. How can we best keep up with these new developments and or provide the railroad with the products they need to be more efficient and cost effective? Not an easy task by any stretch of the imagination but I will ask you to look at the people in this room and Our New Technologies Committee prepared to give you their presentations after my speech. If you have also been attending our previous meetings you have had the opportunity to see presentations by our Mechanical, Electrical, Fuel and Lube, Materials and Shop Equipment and Processes Committees. Where else would you find such a diversified wealth of knowledge related to locomotives and their operation? The answer is no where else!

Each year our committees conduct individual meetings to set up and review presentations in their area of expertise. In addition a joint committee meeting is held prior to this convention to review and critique presentations by all of the committees. It should also be noted that tours of varous facilities, plants and shops are also arranged at these meetings througout North America. Over the years I have heard misinformed officials, managers or company heads say such things as where is the cost effectiveness or value added by having people in these communities. Sure we may sit down to supper and have a Coke, glass of lemonade or an ice tea when attending these meetings but guess what! The main topic of conversation is what is going on in our industry, such as new products, new regulations and/or problems being experienced. This list goes on and on. It is through these meetings our members grow in all aspects and knowledge that is passed back to their job and employer. I would say that if you want to repeat mistakes, conduct tests that have already been done, develop products that are trouble prone, be unaware of what is happening in the industry or waste precious time, then by all means do not put anyone on the committees. Whether it is the LMOA or any of our Coordinated Associations that best suits your area of operation, if you wish to enrich your company and employees as well as being efficient and cost effective then supporting the LMOA and Coordinated Associations is the way to go. There is no better tool available for networking and growing in our industry. Remember LMOA can also stand for Learning Maintenance of Assets.

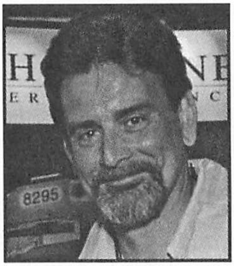
Dedication is something we all look for in our industry and we have four prime examples of this in our organization and I would like to take a moment to recognize these individuals. They are four of our past presidents who have elected to serve again on various committees: Ron Lodowski, Brian Hathaway, Bill Lechner and Tad Volkmann. Gentlemen, you personify how experience and knowledge of our industry can be passed on to others and on behalf of the LMOA and myself I thank you. In addition Tad I must commend UP for building its participation in the committees with new employees. This helps bring in new perspective to the committees while allowing these new members to network and grow with the experience on their respective committees. I know as well as you do that UP will reap the rewards of this decision in the years to come.

Before I get to my closing remarks I would like to address the RSI and their decision not to support us and our Coordinated Associations during non-exhibit show years. Last year was a non-exhibit show year that we had to support ourselves but I noted that RSI members took full advantage of networking with customers attending our presentations. Should we have trouble supporting this convention on non-exhibit years, we will all regret the outcome. Gentlemen, I would urge you to have another look at your decision as I have pointed out in my presentation there is no other "gathering of the minds", that can best support our industry than through an organization such as ours, and guess what ...even during non-exhibit years!

In closing I must thank my First Lady, Lynn and my two sons Stephen and Shawn for their moral support through the years. Good times and bad. I can now officially call Lynn the First Lady as I am the President and we do live in the White House althought a tad smaller than Mr. Bush's but still the White House. I would also like to thank Ron Pondel our Secretary Treasurer who does all the hard work getting things together for us. Thank you, Ron for all the hard work & especially your friendship that has grown over the years. Thank you all for your attention.

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

THURSDAY, SEPTEMBER 13, 2007 10:15 A.M.



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Providence & Worcester RR
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G. Winsel	Asst. Manager	Canadian National	Edmonton, Alberta

Note: Tim Standish of EMD will be joining the committee

PERSONAL HISTORY

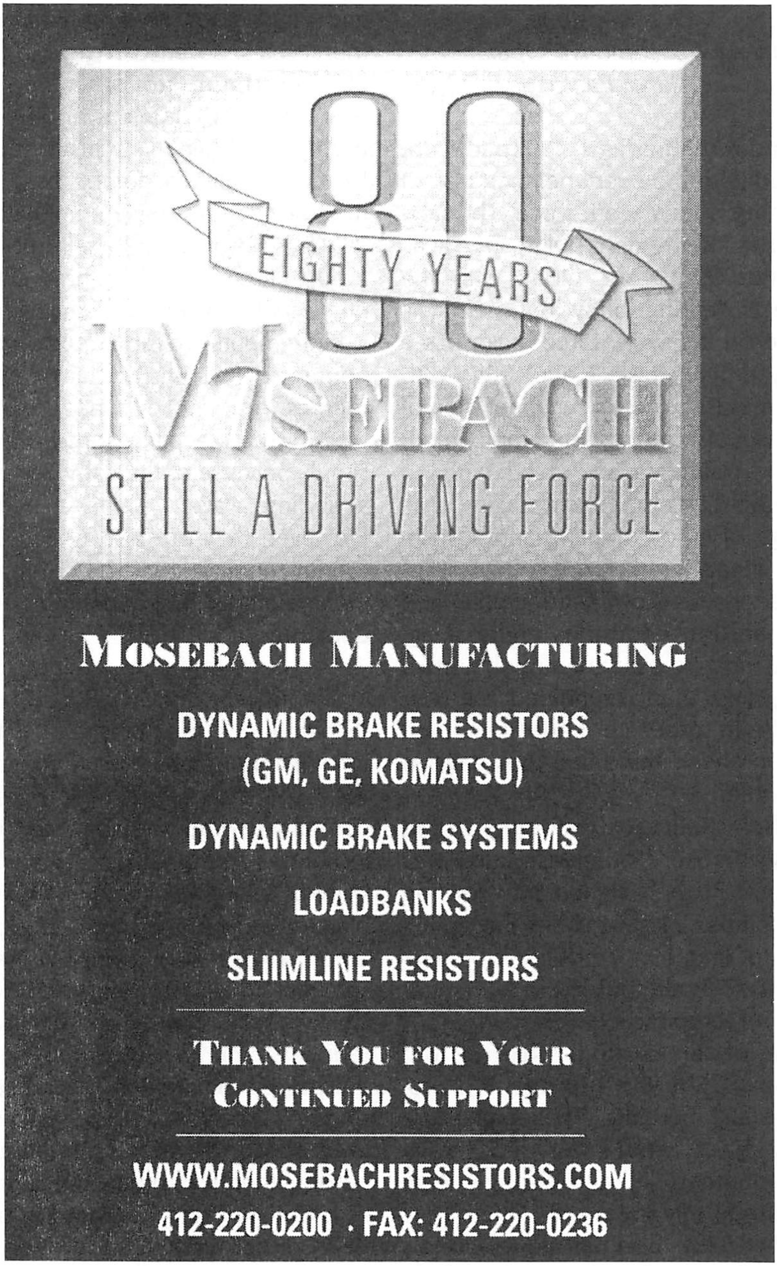
Dave Rutkowski

Dave has 31 years of railroad experience. A journeyman Machinist by trade Dave has worked at five railroads; The Reading Company, Conrail, Alaska Railroad, St. Lawrence & Atlantic and presently the Chief Mechanical Officer at the Providence & Worcester Railroad Company. Dave has participated in the LMOA since 1999. Dave and his wife Katarina have one son Kristofer who is attending the University of Connecticut majoring in Kinesiology

THE DIESEL MECHANICAL MAINTENANCE COMMITTEE

WOULD LIKE TO EXTEND THEIR SINCERE APPRECIATION TO GRAHAM WHITE FOR HOSTING THEIR COMMITTEE MEETING IN ROANOKE, VIRGINIA ON FEBRUARY 28, 2007

THE COMMITTEE ALSO WISHES TO THANK VISTA CORPORATION AND JEFF CUTRIGHT AND THE NORFOLK SOUTHERN FOR PROVIDING SHOP TOURS OF THEIR RESPECTIVE FACILITIES IN ROANOKE


80
EIGHTY YEARS
MOSEBACH
STILL A DRIVING FORCE
MOSEBACH MANUFACTURING
DYNAMIC BRAKE RESISTORS
(GM, GE, KOMATSU)
DYNAMIC BRAKE SYSTEMS
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1. TRAINING A NEW WORK FORCE

Prepared By
Don Freestone,
Manager Locomotive Operations
Alaska Railroad

Today, America's Railroads are faced with the overwhelming task of training a new work force. The new Railroad Retirement Rules, specifically, the 60/30 act, along with the effects retiring baby boomers will have on the work force make this a very difficult task. Couple this with the mindset of the new generation of individuals entering the employment world, railroads are faced with an unprecedented and painstaking challenge of hiring, training and sustaining a new work force. While all of these issues combined create and demand an enormous undertaking, they must be examined on their own first, and then, combined together again in order to understand and comprehend the effect they have as a whole.

The "Railroad Retirement and Survivors Act", otherwise known as the 60/30 act, signed into law on December 21, 2001, has the potential to create a landslide of retirements. This act lowers the retirement age of employees with thirty (30) years of service from sixty-two (62) to sixty (60) years of age and provides full benefits. These rules are very basic, straightforward, easily comprehensible, and strongly contribute to this issue.

The Baby Boomer generation is typically considered to be those individuals born between the years of 1946 and 1964. *Simple subtraction* reveals the first Boomers are now at or reaching sixty (60) years of age and eligible for retirement. During these years, seventy-six million people were born. No generation has ever obtained, totaled or equaled this figure. While this statistic applies to the overall workforce, there is a ratio of baby boomers employed by railroads who naturally fall into this group. Only recently have these numbers been seriously reviewed..

Retirements are irrefutable and are going to occur. Initially, these retirees may not choose to stop working at the pace some predict, simply because of the Baby Boomers spending and saving habits. However, they are also not looking for full time or long term employment such as railroads require or demand.

Also contributing to the lack of an available workforce is the Generation X mentality and behavior. Generation Xers have watched their parents devote their lives to companies who provided full-time, long-term employment. As time went by, it appears that this situation ultimately developed into an expectation and created a false sense of security. These expectations were shattered as companies began to reduce the number of employees on the payroll mainly due to poor economic periods, productivity improvements and technological advancements. People were suddenly forced to learn new trades, seek new employment and change careers in the middle years of their lives. As the Xers watched, grew and matured, they began to view secure, prolonged employment as a fleeting occurrence.

These three main individual factors combined to create the tremendous challenge America's railroads face. For the most part, nothing can be changed or revised to prevent the first two prevailing issues. The remaining issue, however, has several possibilities for correction, improvement and resolution. These solutions will require both railroad management and labor organizations to re-think their positions, past practices and investigate new methods of strategic planning, development and implementation in order for the railroads to survive. It will require new recruitment avenues to be explored, more media attention, job fairs and advertising techniques to expose potential new recruits to the world of railroading. It will require the antiquated thinking, standard rules of the past, to change in order to continue the growth and prosperity of Americas railroads.

Let us dispel what is highly regarded to be at the very forefront of the railroads failure in the replacement of a new workforce. These factors are wages, salaries and benefits. Research into this idea has produced no substantial proof or evidence this is the case. In fact, wages and salaries are good. They are above the norm. Pay is not an issue or hindrance when it comes to hiring practices.

Using contract maintenance service companies rather than hiring employees is also not a reasonable solution. These companies are also faced with the same employee shortages as the major railroads. In addition, it is very costly to build servicing and maintenance facilities in order to satisfy the needs of he major roads. Utilization of pre-existing facilities reduces the costs involved in the manufacture of facilities, but this type of adventure usually results in new management being assigned to run the shops utilizing the current employees. These types of situations create poor morale which in turn contributes to low production and volatile work situations.

In today's world, the new generation does not want to work the shifts previously utilized in the past; specifically, the midnight shift with rest days during midweek. Railroads have historically been twenty-four hour, seven (24-7) day a week operations.

In addition, the new generation does not find the job challenging. It is believed the positions are mediocre, lacking in excitement and not rewarding enough to warrant an exemplary effort. Even though mechanical repair operations involve troubleshooting computers, software programming, electronics requiring detailed techniques and processes to resolve problems, the perception is that these issues are not challenging enough to create a sense of self belonging, worthiness or stimulation. In other words, once learned, it is felt the same troubleshooting techniques can be utilized over and over again. This belief, in itself, becomes an educational opportunity. From our own personal experiences, we know otherwise. Locomotives and other rail equipment require and demand multiple approaches to solve failures. Most defects, breakdowns and malfunctions rarely result in the same root cause failure.

Hiring techniques need serious review. New ideas for attracting future employees should be sought out, considered and implemented. Perceptions in regards to railroad operations need to change. The methods to do this are to educate the public by saturating colleges and other educational facilities with factual information.

Railroads may have to reconsider and redesign their operations. Through increased and improved maintenance practices, the possibility exists for companies to change their repair operations from the traditional 24/7 schedules to more suitable, more attractive shifts. 4/10 schedules may be an option, but usually these types of shifts require additional manpower to provide the same coverage as the typical five-day/eight-hour workweek. Current management techniques may view this idea as a completely impractical solution, but it may end up simply being forced upon them in order to survive.

The railroad industry, both labor organizations and management, must consider, negotiate and implement new bargaining agreements. A tremendous opportunity will present itself courtesy of the attrition rates which will undoubtedly occur.

The opportunity is the elimination of craft lines amongst the bargaining agreements between the various labor organizations. Now is the time to introduce the elimination of craft lines because a new group of employees make it simpler to change the behaviors and cultures of the prior workforce. Craft lines are an outdated mentality, desperately in need of change. They are inefficient, non-productive and extremely costly. Surviving in today's world will require new organized work rules that provide new capabilities, responsibilities, in turn producing new efficiencies.

These new agreements will offer and provide the needed flexibility, increased production, lower costs and greater stability. For the labor organizations, the benefits include increased job satisfaction, a more challenging work environment through the learning and training of new skills and more variety of work. It also increases their job stability and makes them much more valuable to the employer due to the increased level of skills and knowledge obtained.

Initially, implementation of these new agreements will require a vast and strong commitment to cross training the existing and incoming workforce. Current training programs will need to be changed, redesigned and updated. The traditional apprenticeship programs must decrease the amount of time spent learning the skill needed to perform the work These programs can be reduced by specific, detailed and organized study classes and educational agendas.

Several companies now offer these types of intense instructional classes. These structured programs include hands-on training and need to be utilized to the fullest extent. Further cross training can be accomplished by placing qualified individuals with non-qualified individuals, strong utilization and enforcement of Job Safety Briefings, Job Safety Analysis and operational monitoring. This allowance will occur through the new bargaining agreements.

The final factor in the accomplishment and successful implementation of the new work rules will require excellent management skills. Supervisors will need intense training courses, strong expectations and above all, must demonstrate patience. Upper management must provide strong support both in expecting first line supervisors to implement the new rules and gaining their commitment to the process. In addition, they must realize, initially, production will be reasonably hindered due to the training processes.

Can the training and implementation of new work rules be accomplished? The answer is yes. It can. It has to be. Competition, survival and the ability to remain profitable in the business world today requires and demands the railroad industry to change with the times. Furthermore, railroads need to address future retirements now. It is recommended to not view the current situation as an insolvable problem. Rather, view it as the perfect challenge and opportunity to provide a much improved workplace environment in which future railroaders can survive and prosper.

2. LOCOMOTIVE HORN TESTING

Prepared by
Jeff Cutright,
Senior General Foreman
Norfolk Southern

On August 17, 2006 the Federal Railroad Administration (FRA) published the final rule Code of Federal Regulations (CFR) 49 Part 229.129 concerning locomotive horn use and horn testing. The changes to train horn use required in the new "Horn Rule" should already be integrated into the railroad's operating rules as the municipalities along the way re-established "no blow" areas and as grade crossings are improved. Therefore, this paper will only address horn testing. All the railroads need to consider how the locomotive horns governed by the FRA in America could be tested according to the rules by the deadline of June 24, 2010. That seems like a long time away until the weeks are divided by the locomotive fleets. On June 24 of this year there will be 3 years or about 150 weeks left to test horns on locomotives. If a railroad needed to test 2250 locomotives in the hypothetical three years left, about 15 locomotives would need a horn test each week. Now that the need to test has been established, let's explore the horn test parameters.

General Testing Requirements

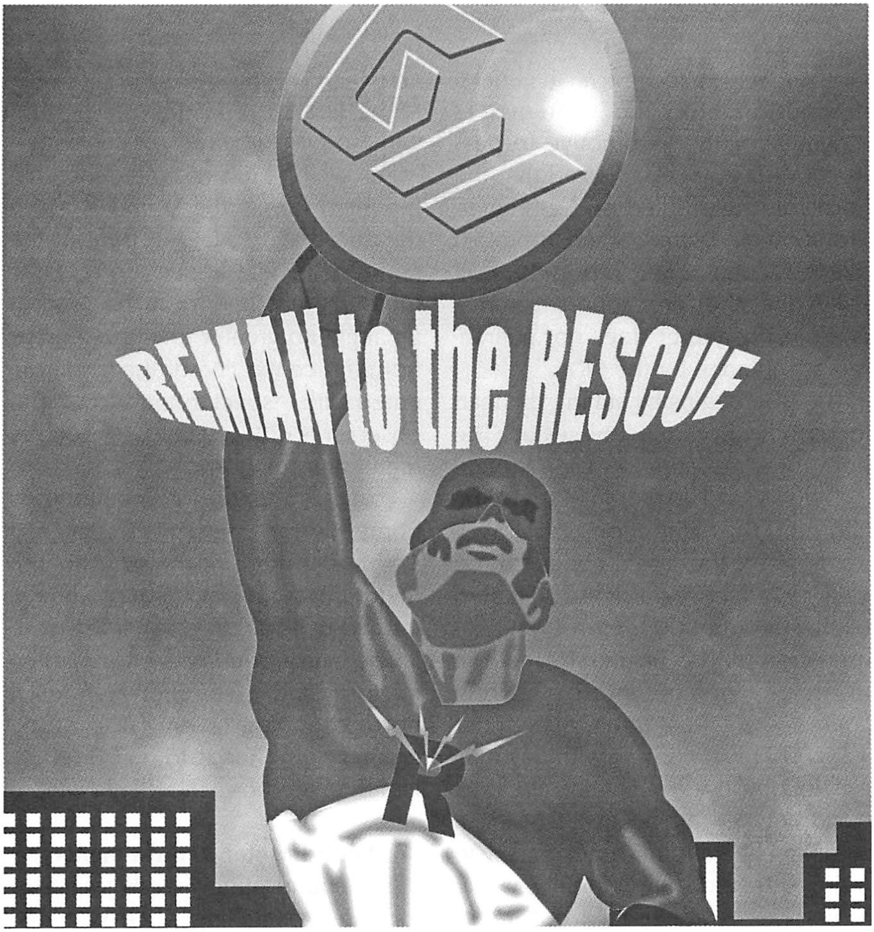
The first two items on the list that are needed to horn test are the proper area and a meter. The area requirement is one of the toughest items for most railroads to meet, as there are not many locations that have an area where a locomotive can be placed on straight level track and have 200 feet to each side and 200 feet in front without any reflective surfaces, as seen in Figure 1. Some trees are permissible, but the rule reads that "the test site shall be clear of large reflective structures, such as barriers, hills, billboards, tractor trailers, and other large vehicles, locomotives, rail cars, on adjacent tracks bridges or buildings within 200 feet of the front or sides of the locomotive." Finding an area, convenient and not in a residential area, where blowing a horn for two minutes straight may be accomplished without community complaints is hard to find near most locomotive shops.

Locomotive Horn Testing

The next requirement is the Sound Pressure Level Meter (i.e., decibel meter). This device needs to be of the latest technological standards in order to meet the requirement in the final rule. The detail can be found in the rule, but the standard is from the International Electrotechnical Commission (EIC) Standard 61672-1 (2002-05) for a Class 2 instrument. There were very few options for this instrument a year ago. One railroad used a meter produced by Quest Technologies that met the new standard, shown in Figure 2.

Horn Test Compliance Parameters

After a suitable location is found and the meter is secured, most of the other criteria for testing are relat-


REMAN to the RESCUE

ed to the weather and the operation and location of the horn on the locomotive. The following is a general description of the parameters required for the locomotive to pass the horn test. It is suggested that the horn rule be studied and any interpretation be discussed and approved by the Local FRA representative. Following the procedures summarized in this paper does not guarantee acceptance by the FRA.

The rule begins by stating the lead locomotive horn must be tested. The horn must measure between 96 and 110 dB (A) at 100 feet forward of the cab in the direction of travel. Remember the area needs to be clear of reflective barriers 200 feet to each side and 200 feet in front. The meter should be placed 100 feet in front of the locomotive. Note: Locomotives built after September 18, 2006 must comply with this rule, but locomotives built that are built exactly alike can be tested using a sampling technique, as opposed to being tested individually. The requirements are spelled out in the rule.

All locomotives built before September 18, 2006 must be tested prior to June 24, 2010. Anytime a locomotive is remanufactured, the locomotive must have its horn tested in accordance with this rule. If a horn is replaced, it must be re-tested, unless the horn is replaced with the same model horn.

A microphone windscreen must be used and if mounted on a tripod it can not interfere with the sound being measured. Ambient air temperature must be between 32 degrees and 104 degrees Fahrenheit with a relative humidity between 20 and 95 percent. Wind velocity needs to be less than 12 miles per hour with no precipitation.

For all but low-mounted or cab-mounted horns, the sound is to be measured at 100 feet in front of the knuckle, 15 feet above the rail. The measurement needs to be read at an angle no greater than 20 degrees from the center line of the track, oriented with respect to the sound. The observer is not to stand between the meter and the horn.

For low-mounted or cab-mounted horns the measurements are taken at 100 feet in front of the knuckle, but meter is positioned 4 feet off the rail instead of 15 feet.

The background noise needs to be minimal and taken between each horn sounding event. The background noise needs to be 10 dB (A) less than the horn sounding event.

Sound Meter Requirements

The sound meter needs to be set for the A weighing scale with the slow response. The meter needs to be calibrated before and after each use in accordance with the manufacturer's instructions. Any change in the calibration readings greater than 0.5 dB indicates a problem with the sound meter and voids the results of the test. After the horn has reached a stable level, the A weighted equivalent sound level shall be obtained directly using an integrated-averaging sound level meter or recorded once per second and calculated indirectly. The arithmetic average of a series of at least six 10-second duration readings shall be used to determine compliance. The standard deviation of the readings shall be less than 1.5 dB. The math can be done manually or with standard statistical software found in most spreadsheet programs.

Reports of the testing are to be kept on-file and available for inspection. The locomotive horn type, date, place, manner of testing, and sound level measurements need to be recorded. The reports shall be signed by the persons performing the tests.

Fine Schedule

The following fine schedule is included with the new horn test rule. The fine is for each violation for each locomotive test.

The fine schedule is set below:

Violation Description	Violation	Willful Violation
Prescribed Sound Level	$2,500	$5,000
Arrangement of horns	$2,500	$5,000
Failure to perform sound level tests	$2,500	$5,000
Sound level test improperly performed	$2,500	$5,000
Record of sound level test improperly executed or not retained	$1,000	$4,000

Summary

The best thing to do is get the equipment, find a suitable location, and perform the required testing. It is actually very simple and only requires a few minutes, once all the parameters are satisfied. The meter seems to be expensive so be ready for sticker shock. Once the testing is finished be sure to keep good records, including weather data for the day the test was performed. Databases like one in Figure 3, are very helpful in keeping this information, but paper forms will work for folks with smaller fleets. Be sure to replace all horns in kind once the testing has been done so the locomotive will be in compliance and sound as loud as required at the crossings.

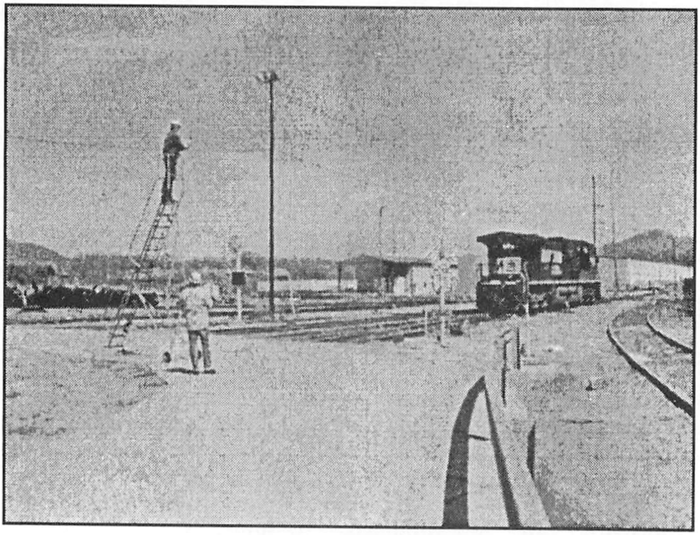


Figure 1
Testing

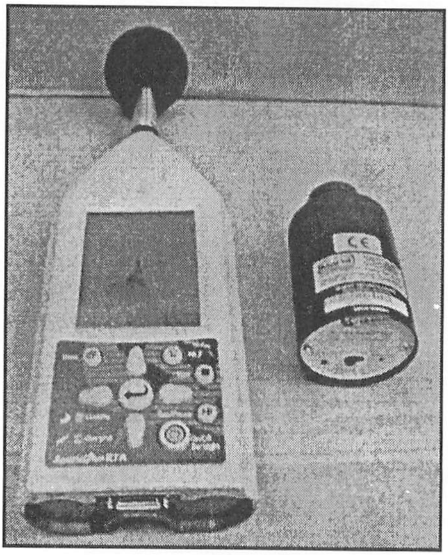


Figure 2
Meter and Calibrator

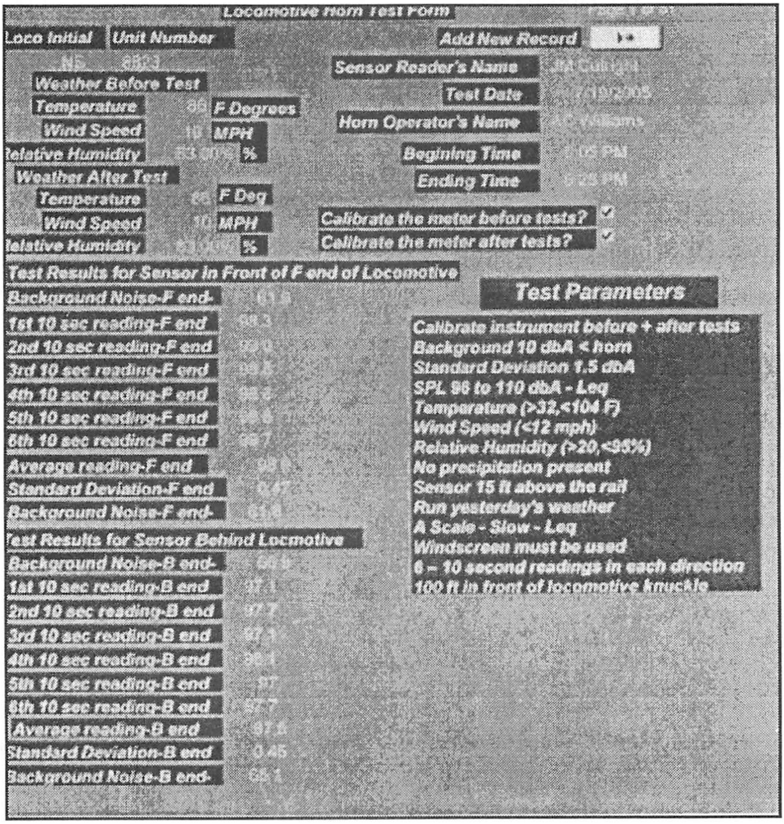

Locomotive Horn Test Form
Loco Initial
Unit Number
Add New Record
Sensor Reader's Name
Weather Before Test
Test Date
Temperature
F Degrees
Wind Speed
10
MPH
Horn Operator's Name
Relative Humidity
%
Begining Time
Weather After Test
Ending Time
Temperature
F Deg
Wind Speed
10
MPH
Calibrate the meter before tests?
Relative Humidity
%
Calibrate the meter after tests?
Test Results for Sensor in Front of F end of Locomotive
Background Noise-F end-
1st 10 sec reading-F end
98.3
2nd 10 sec reading-F end
3rd 10 sec reading-F end
4th 10 sec reading-F end
5th 10 sec reading-F end
6th 10 sec reading-F end
Average reading-F end
Standard Deviation-F end
Background Noise-F end-
Test Results for Sensor Behind Locmotive
Background Noise-B end-
1st 10 sec reading-B end
97.1
2nd 10 sec reading-B end
97.7
3rd 10 sec reading-B end
4th 10 sec reading-B end
5th 10 sec reading-B end
6th 10 sec reading-B end
Average reading-B end
Standard Deviation-B end
0.45
Background Noise-B end-
Test Parameters
Calibrate instrument before + after tests
Background 10 dbA < horn
Standard Deviation 1.5 dbA
SPL 96 to 110 dbA - Leq
Temperature (>32,<104 F)
Wind Speed (<12 mph)
Relative Humidity (>20,<95%)
No precipitation present
Sensor 15 ft above the rail
Run yesterday's weather
A Scale - Slow - Leq
Windscreen must be used
6 – 10 second readings in each direction
100 ft in front of locomotive knuckle

Figure 3

3. DIAGNOSTIC TECHNIQUES FOR PREDICTIVE/PREVENTATIVE MAINTENANCE - EXPLOITATION OF NEW TECHNOLOGY

Prepared by
Tom Kennedy,
Manager Locomotive Engineering Quality,
Union Pacific Railroad

The fast paced world of technology revolution has affected everyone providing opportunities never even dreamed of less than fifty years ago. Industries like consumer products, aerospace, military, automotive, and petrochemical have embraced and exploited this technology to their competitive advantage. Other industries such as the rail industry have been slower to accept and deploy this new technology. Perhaps this slower response is due to multiple reasons such as the added complexity which requires additional technical expertise, a fear of the unknown, "not invented here" syndrome, or just simply there has not been a strong competitive pressure between the Railroads, OEM's, and Suppliers to voyage into this new arena. Whatever the reason, the time has come, indeed it is overdue, for the railroad industry to exploit technology for preventative and predictive maintenance. This paper will challenge the railroad industry to develop and exploit new technology for the future of the rail industry.

Historically railroad maintenance programs have been typically time based, either calendar or megawatt hours, in which the service or component replacement interval is driven by elapsed time. The principal disadvantage to a time based program is that systems are being serviced and components are being replaced where there may still be significant life remaining in the serviceable systems and components. The introduction of Reliability Centered Maintenance (RCM) into maintenance program has provided the capability to optimize maintenance practices based on historical data with the goal of extending service and maintenance intervals to the most cost effective point. The next step in the evolution of maintenance program planning is the ability to predict imminent failures and the end of the useful life of serviceable items such as fluids and filters. Some diagnostic and predictive technologies are embedded withing the locomotive control systems on newer locomotives but are not always accessible or easily useable by the railroads. This technology is limited in the systems it monitors and assesses and will need to be expanded to enhance its predictive capabilities. Other industries such as aerospace, maritime, petrochemical, nuclear, and the military have employed embedded technology for years to monitor component and system performance and provide fail safe derating or shutdown and predictive maintenance requests. For example accelerometers have been used on aircraft engines for decades to detect an imbalance and allow operation at a lower engine speed and notification of required maintenance.

The development and deployment

of predictive technologies to the rail industry needs to be an open and honest discussion between the suppliers and the railroads with the objective of maximizing locomotive availability and reducing Life Cycle Cost (LCC). The shortcomings in locomotive performance that have been experienced in the past have in part stemmed from the suppliers having different business models than the railroad's business models. The discussions should focus on aligning the business models to exploit existing technology and stimulate research into new predictive technologies to develop a common standard. Development of a common standard is required to avoid proprietary architectures, systems, and components which are a significant disadvantage to the railroad's operation.

There are multiple areas of opportunity for the incorporation of predictive technologies into a locomotive, a few of which are used to some degree today. These areas are discussed in the following paragraphs along with current technology used for these locomotives areas. This discussion is a starting point and is not inclusive of all potential technologies that could be used. Discussion of the possible technologies is the intent of the following paragraphs.

Oil Analysis

Chemical analysis of the lube oil of engines, air compressors, and gear cases is imperative for early detection of conditions that may result in catastrophic equipment failure. Currently this analysis is performed on samples taken from a locomotive with the testing performed either on-site or at an off-site facility. The testing is usually comprised of hot plates to detect free water in the oil, fuel sniffers to detect the presence of fuel in the engine oil, and laboratory analysis to detect wear metals, soot, etc. Hot plates and fuel sniffers are quick and can be done at the service track but to detect wear metals and other compounds like Pentane Insolubles a laboratory analysis is required. Laboratory testing is thorough and accurate however the lag time from sampling to results may result in missed opportunities for corrective action resulting in possible road failures.

This technology, although very useful, needs to be taken to the next logical step of incorporating appropriate sensor technology into a locomotive so that real time continuous analysis can be performed. For example the auto industry is developing dielectric type sensors that would be permanently installed in the engine's lube oil system for continuous monitoring of oil condition of oils. The output of these sensors would be input to the locomotive control system for the issuance of crew messages, maintenance messages, and system shutdown protection. Ease of data extraction from the locomotive control system is a key customer requirement.

Coolant Analysis

Chemical analysis of the engine coolant is also imperative for early detection of conditions that may result in catastrophic equipment failure. Currently, this analysis is performed on samples taken from a locomotive with the testing usually performed at an off-site facility. This laboratory testing is critical for verification that the corrosion inhibitor concentration is correct thus avoiding under treatment which could lead to corrosion and equipment failure. Equally important is the detection of over treatment that could lead to plugged sensors from precipitation of the inhibitor in small passage lines and low to no flow areas. Other situations that could be detected real time could be lube oil in the coolant, entrained air in the coolant which could be an indicator of pump and piping cavitation and temperature and pressure trending analysis. Again this technology, although very useful, needs to be taken to the next logical step of incorporating appropriate sensor technology into a locomotive so that real time continuous analysis can be performed. The same technologies used for onboard oil analysis may be applicable or adaptable to engine coolant systems. As in the case with all the onboard sensors the output of these sensors would be input to the locomotive control system for the issuance of crew messages, maintenance messages, and system shutdown protection. Ease of data extraction from the locomotive control system is a key customer requirement.

Vibration Monitoring

The monitoring of vibration and acceleration signatures has successfully been incorporated into rotating machinery in multiple diverse industries such as aerospace, maritime, petrochemical, and military equipment for early detection of out of balance conditions, fluid cavitation, and trending analysis. There has been some use of vibration monitoring on locomotive turbochargers but has been confined to temporary installations or hand held monitors. The data was collected and analyzed off the locomotive to determine the health of the turbocharger. This process is useful but is very labor intensive and requires a vibration signature map to be developed for every locomotive model configuration. There are also other components that would benefit from vibration or acceleration monitoring such as main generators, air compressors, equipment blowers, radiator fans, dynamic blowers, and traction motors. To manually conduct vibration data sampling from all of these areas using current technology would be a time and cost prohibitive endeavor and may be unsafe during certain operating conditions. Therefore onboard embedded sensors integrated into the locomotive control system architecture are required. With this data collected real time, it could be analyzed onboard and compared to preset limits with crew messages and maintenance messages generated automatically or for imminent failures or a safety condition the locomotive could self protect and shutdown. The data would also be available through downloads or remote transmission for fleet performance monitoring and vibration trending analysis.

Impact Loading

Impact loading is fact of life on the railroad but the consequences of impact loading may not be fully appreciated or understood. For example in the aerospace industry design requirements for operational impact loading are specified in all three axis and the design and installation of components has to be such that the component will operate when exposed to these shock loads. When conducting failure analysis on locomotive components, it has become apparent that equipment designed for the railroad has not always taken into consideration these shock loads. For example long runs of coolant pipes are subject to telescoping in their Marmon and Vitaulic seals during repeated buff loads leading to seal failure and water leaks. Another example is the mounting of electronic circuit card, contactors, and relays such that impact loads loosen the circuit cards or cause inadvertent action of the relay or contactor contacts which results in inadvertent system actuation. The incorporation of impact detection sensors could help during maintenance planning to identify areas for focus after the locomotive has been subjected to high impacts or repeated impacts. This data would also be useful for the suppliers to better understand the railroad environment and thus improve their design. As with the oil, fluid, and vibration data the shock data too would be input to the locomotive control system for the issuance of crew messages, maintenance messages, and system shutdown protection.

Smart Structures

This is a technology that is being explored in advance technology industries such as military aircraft employing carbon composite structure. It may not have direct application to a locomotive or be cost effective on a Life Cycle Cost basis but it is an area of technology that could be discussed. Essentially the technology embeds sensors into the structure for measurement of vibration and impact loads over time with the data stored onboard. Unlike the previous sensor applications this data would most likely be off loaded from the locomotive for detailed analysis to determine the remaining fatigue life of the structure and when proactive maintenance should be performed. The data would also be useful for trending analysis across the fleets and identification of track areas needing repair since they are causing increased locomotive loading.

Electronic Fault Prediction

The electronics industry is an extremely dynamic industry with the processing power increasing year after year while at the same time requiring less volume and power. For example the processing power and memory capability in a modern laptop computer exceeds the capabilities of the computers used twenty to thirty years ago for aircraft and missile guidance. With the ever increasing technological density of electronics it has spawned the growth of automated diagnostics. Most computers today can perform a self-diagnostic routine and identify the component(s) most likely requiring inspection, repair, or replacement. Redundant circuits are often used to enhance mission reliability but it introduces added complexity to the diagnostics and potentially increased base rate since there are more components in the system. The next logical step in locomotive control system evolution is to research and develop "Artificial Intelligence" (AI) for a locomotive application. Overly simplified, the definition of AI is simply that the machine learns from its past experiences. The use of AI allows the software to modify itself and be able to adapt to changing situations so failures can be averted and also possibly predict imminent failures so repair action can be taken prior to a road failure. Additional information on the science of AI can be obtained from the Association for the Advancement of Artificial Intelligence (AAAI) website, http://www.aaai.org/home.html. Although AI will take extensive research and development to bring to fruition, this is a fertile area for future locomotive performance and capability enhancement.

Summary

The information discussed above is just a starting point and there are additional areas of opportunities for predictive technology limited only by imagination and the desire to pursue the opportunities. Of the many benefits of onboard predictive technology two of the largest payback items are increased locomotive availability and the capability to schedule maintenance that fits the railroad's operation instead of continuing to live with unscheduled shoppings. With the economic factors at work today, like fuel cost, the rail industry is in an excellent competitive position to Carpe Diem (Seize the Day) through the use of new technology. As always, any technology should be assessed for the Life Cycle Cost benefit not only the acquisition cost. And finally, this is an area for the suppliers to align their business models with the railroad's business model to provide a product that meets the railroad's needs for the thirty year life cycle of the locomotive.

4. LOCOMOTIVE PARTICULATE MATTER EMISSIONS REDUCTION THROUGH APPLICATION OF EXHAUST AFTERTREATMENT SYSTEMS

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The use of exhaust aftertreatment will likely be required to meet the future Tier IV locomotive emissions standards that have been proposed by the US-EPA. While particulate matter (PM) emissions aftertreatment devices are currently being used in all 2007 on-highway diesel truck applications in the United States, and a few aftertreatment systems fitted to smaller diesel locomotives in Switzerland, these systems are only now beginning to be sized and demonstrated for application in a locomotive environment here in the United States.

This paper will discuss the recently proposed EPA emissions standards, the make up of particulate matter (PM), the different technologies that are currently available to reduce PM emissions, and three different projects that are demonstrating these experimental PM reducing technologies in Class 1 locomotive applications.

Proposed EPA Locomotive Exhaust Emission Standard

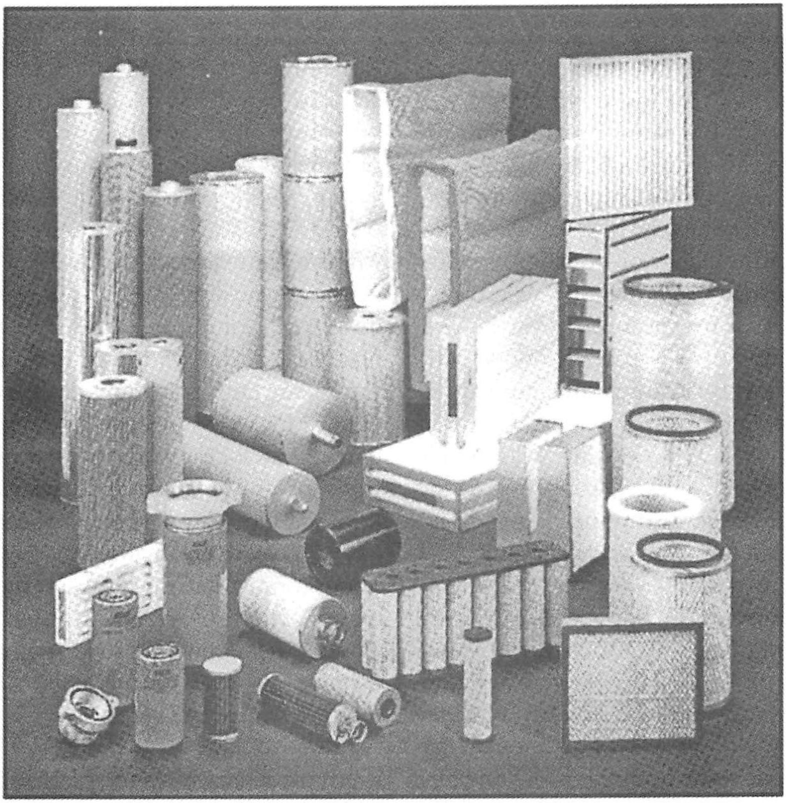
The United State Environmental Protection Agency (US-EPA) has issued a proposed rule, which once enacted will require significant reduction in emissions from both new and existing locomotives. The proposed emissions regulations are presented in Table #1 as percent reductions from the current emissions standards. The proposed emission levels, for the different Tiers, are shown in Table #2, along with their proposed applicable dates.

The proposed Tier 0 through Tier III emissions standards may require aftertreatment for the control of PM emissions. There are engine component changes that can greatly reduce the engine out PM levels, but only time will tell if market place chooses to meet the emissions limits with aftertreatment or engine modifications. The Tier IV emissions level will likely require aftertreatment to meet the proposed PM, NOx, and hydrocarbons (HC) emissions levels.

Additional details on the proposed US-EPA emissions regulations can be found in 40 CFR Parts 92, 94, 1033, et al.; "Control of Emissions of Air Pollution From Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder; Proposed Rule." This information can also be found on the EPA web site at: http://www.epa.gov/otaq/locomotv.htm#pns.

PM Makeup

Particulate Matter (PM) is a complex combination of soluble organic fraction (SOF), non-soluble components, and sulfates. The soluble components are typically unburned oil & fuel (Hydrocarbons), while the non-soluble organic fraction components are elemental carbon, ash from engine oil, and wear metals. Sulfate portion of PM is produced by the



oxidation of sulfur, which is found in the fuel and engine lubricating oil. An illustration of a typical particulate makeup is shown in Figure #1.

The ratio of the components that make up PM varies greatly with the engine design. Typically the 2-cycle EMD engine has high SOF fraction, due to relatively high oil consumption. The higher oil consumption levels also causes higher levels of ash and wear metals in the PM. The contribution of these components to the total PM is illustrated in Figure #2 for a Tier-0 EMD 710 engine. The new Tier II EMD 710 engine will provide a much lower SOF levels due to the lower oil consumption rings and liners that are used in the engine.

In general the 4-cycle GE engine has lower SOF than the 2-cycle EMD engine. This is due to the low oil consumption of the 4-cycle engine. However, the GE engine typically has higher levels of elemental carbon, or soot, than the EMD engines.

These general observations about PM make up and the SOF levels can vary from engine to engine. Engine to engine variability can be a function of engine age, components used during the last engine overhaul, level of maintenance (air filters, aftercooler, turbo screen, etc), operating duty cycle, type of engine oil used (multi vs single viscosity oil), sulfur level of the fuel, and other factors.

What is a Diesel Particulate Filter

A Diesel Particulate Filter (DPF) literally is a filter installed in the exhaust system to capture diesel particulate emissions. Because the DPF filters the exhaust, the DPF system must be capable of handling exhaust temperatures and possible chemical attack from the exhaust constituents. Additionally, these DPF's need to be capable of self cleaning of the carbon that collects on the engine side of the filter and the DPF must be easily removed for mechanical cleaning of ash.

There are two basic types of DPF's in use today; wall flow and through flow. Both of these types of DPF have advantages and disadvantages. Wall flow DPF is a ceramic honeycomb block that has opposite holes plugged in such a way that the only way for the exhaust gas to pass through the honeycomb is for the gas to pass through the wall of the honeycomb filter material. A photo of a section of DPF is shown in Figure 3 and an illustration of the exhaust gas path through the filter block is shown in Figure 4.

The advantages of a wall flow DPF is a typical high efficiency and good reduction in exhaust noise (can replace an exhaust silencer). The disadvantages of a wall flow DPF is that they require more maintenance to remove ash build up on the filter material and high back pressure on the engine.

Regeneration is needed to "burn off" collected carbon/soot to keep back pressure on engine to acceptable levels. The soot that collects in the DPF will self-ignite at 600ºC (1,112ºF). Lower temperature regeneration is possible with the addition of catalyst material in the filter blocks, which allows for passive regeneration when the exhaust reaches the regeneration temperature for the catalyst makeup. However, if the exhaust temperatures are low, like in the typical US locomotive, active regeneration is likely to be needed to burn out the elemental carbon from the DPF.

Active regeneration can be completed by the following techniques

- Engine management by running the engine at high loads for extended period of time or injecting a small amount of fuel during the exhaust stroke of the engine, if the engine is fitted with a common rail injection system, to provide fuel to burn the carbon.
- Fuel burner in the exhaust system can be used to heat the exhaust to the required temperature.
- Catalytic oxidizer can be added to DPF to oxidize hydrocarbons in the exhaust that will generate the heat needed to regenerate the DPF.
- Resistive heating coils (electric) can be added to the exhaust system to heat the exhaust, but this may result in a significant fuel economy penalty because of the amount of heat required to heat the mass of the exhaust flow and the DPF blocks.
- Fuel additives being used in European automotive applications to help oxidize the carbon on the DPF surfaces.

Typical materials found in wall flow DPF are cordierite and silicon carbide. Cordierite has a maximum operating temperature of approximately 2,200ºF (~1200ºC), while silicon carbide has a higher maximum operating temperature of approximately 3,100ºF (~1700ºC). The maximum operating temperature of the DPF filter material is critical to the DPF design because of the elevated temperatures during regeneration

If the regeneration temperatures exceed the maximum operating temperature of the DPF filter material, the bricks will melt and a failure of the filter system occurs. Even with appropriate design, melted DPF filters are possible with a run-a-way regeneration that could be caused by excessive build up of soot or other "fuel" in the DPF at the time of ignition due to extended periods of operation before a regeneration event occurs. Additionally, engine component failures that would put an excessive amount of fuel or oil into the exhaust can cause a run-a-way regeneration. These failures could include, failed/dropped injector tip, turbo oil seal failure, cold weather idling with excessive exhaust souping, and a host of other possible engine issues.

The second style of DPF is a flow through type. The flow through DPF typically has lower engine backpressure and will have fewer issues with ash buildup in the DPF. This is due to the design of the flow through DPF, which is not built like a traditional filter where the exhaust gas must pass through the filter media. In place of flowing through a media, the exhaust gas must travel an arduous path around the filter and the particulate matter has an opportunity to impact on the media and stick. With the PM material on the surface of the filter, a regeneration of the filter will allow the PM to be oxidized. An example of the mesh that can be used to make a flow through DPF is shown in Figure 5.

The disadvantage of a typical flow through filter is that the DPF will be less efficient at filtering PM than the wall flow DPF. Typically these flow through filters will be less than 60% efficient and the system will also require elevated exhaust gas temperature (EGT) to regenerate. The system required to regenerate the flow through DPF would be identical to the ones listed for the wall flow DPF system.

One company is developing a new style flow through DPF system that will have many of the advantages of a wall flow DPF. Although the manufacturer of this new system call it a "flow through system", the operation and the potential efficiency of the DPF will be high and the back pressure should be low. An example of this prototype "flow through" DPF is shown in Figure 6.

Note that the ash lubricating oil, which will collect on the engine side of the DPF filter media, will not burn and will ultimately need to be removed mechanically, through a service interval. The time between maintenance intervals, to remove the ash buildup, will be dependent on the amount of oil consumed by the engine, the ash level of the engine oil, the porosity of the filter, and the surface area of the filter.

One approach for regeneration of a DPF on a locomotive is a diesel burner, as shown in Figure 7. The burner allows extended idle in cold climates and for light load operation in a yard or switching operation. All of the systems that are needed to support a diesel burner on a DPF system are shown in Figure 8.

It is expected that the duty cycle of a DPF burner would be on the order of 10 to 20 minute burn every 8 to 12 hours of engine operation, provided that the exhaust temperature did not reach the regeneration temperature during that period of time. If the engine was able to reach a high enough temperature to regenerate during the 8 to 12 hours since the last regeneration, the DPF controller would "reset the clock" and the count down to the next regeneration would start over.

There are currently two locomotives equipped with experimental DPF systems in the United States. These units are part of a California Emissions Program that is sponsored by Union Pacific Railway Company (UP) and the BNSF Railway. The locomotives that are being used in this demonstration are both 1,500 horsepower MP15DC units that have been recently overhauled to a Tier 0 configuration.

BNSF3703 was released from overhaul on 30-JUN-06 and at the time of overhaul was equipped with idle reduction systems that consisted of both a Diesel Drive Heating System (DDHS) and an idle reduction system that also controls the DDHS. This locomotive was rebuilt using a kit that allowed the locomotive to meet T-0 emissions levels. Additionally at the time of overhaul the engine was fitted with low oil consumption rings and liners to provide reduced engine out PM emissions. Figure 9 shows BNSF3703 before the installation of the DPF system.

The second locomotive in this demonstration is UPY1378. UPY1378 was overhauled in the Fall of 2005 and routed to SwRI in February 2006 for a DPF mounting design concept meeting. This locomotive is also equipped with an idle reduction system, but there is no DDHS installed in this locomotive. Figure 10 shows UPY1378 before the installation of the DPF system.

The installed DPF on UPY1378 is shown in Figure 11. The DPF system was mounted on top of the long hood, over the main generator, directly in front of the cab. The car body was extensively modified to support the weight of the DPF system, which was in excess of 2,500 pounds. Although this is not a perfect DPF mounting solution, this project is a demonstration and this mounting location allowed for the installation of the DPF with minimal modifications to the locomotive and the locomotive systems.

Emissions testing before and after the installation of the DPF system, was performed on UPY1378 to determine the emissions benefits of the DPF system. As shown in Figure 12, the DFP system reduced the PM emissions by 83% from the baseline emission levels. The gaseous emissions levels were not greatly affected by the addition of the DPF to the locomotive.

UPY1378 released for revenue service October 2006 and is working in the UP yard in Oakland California, and has been used for yard and industrial jobs. The locomotive is fitted with a data logger system that includes a Global Positioning System (GPS). One week's worth of locomotive's activity is shown in Figure 13. At the end of one year, UPY1378 will be returned from service to complete additional emissions testing to determine if there has been any degradation in the performance of the DPF over the one year of field operation.

As shown in Figure #14, BNSF3703 had the DPF system installed in the same location as UPY1378. However, due to the differences in the long hood car body over the main generator, BNSF3703 required more effort to reinforce the long hood body to support the DPF's. This locomotive is working in a yard in San Antonio Texas. After additional testing, the locomotive will be delivered to California late in 2007.

What is a Diesel Oxidation Catalyst

A Diesel Oxidation Catalyst (DOC) reduces PM by oxidizing the SOF portion of PM. The high levels of SOF offer a lot of opportunity to reduce the PM emissions, if the DOC is efficient at oxidizing these heavy hydrocarbons. In addition to PM, a DOC also oxidizes nearly all hydrocarbons (HC) and carbon monoxide (CO) emissions. The DOC can increase the nitrogen dioxide ($N0_2$) emissions and $N0_2$ has some adverse health affects. However, the formation of $N0_2$ can increase the efficiency of Selective Catalyst Reduction (SCR) aftertreatment system, if it is installed after the DOC for the reduction of NO_x. The DOC can also increase the PM emissions, if high sulfur fuel is used, due to the increase in sulfate emissions, therefore the operation of the locomotive is limited to use with low sulfur diesel fuel to prevent the formation of sulfate emissions from the fuel.

There are two typical types of DOC catalyst, ceramic as shown in Figure 15 or a metal substrate foil construction as shown in Figure 16. Both of these catalyst substrates are equal in their capacity to reduce PM emissions, but there are obviously differences in packaging, weight, and size of the DOC system. There are also different durability issues with the two types of catalyst materials. For example the ceramic material is generally considered to be more susceptible to impact damage due to debris in the exhaust flow.

Application of an Experimental DOC

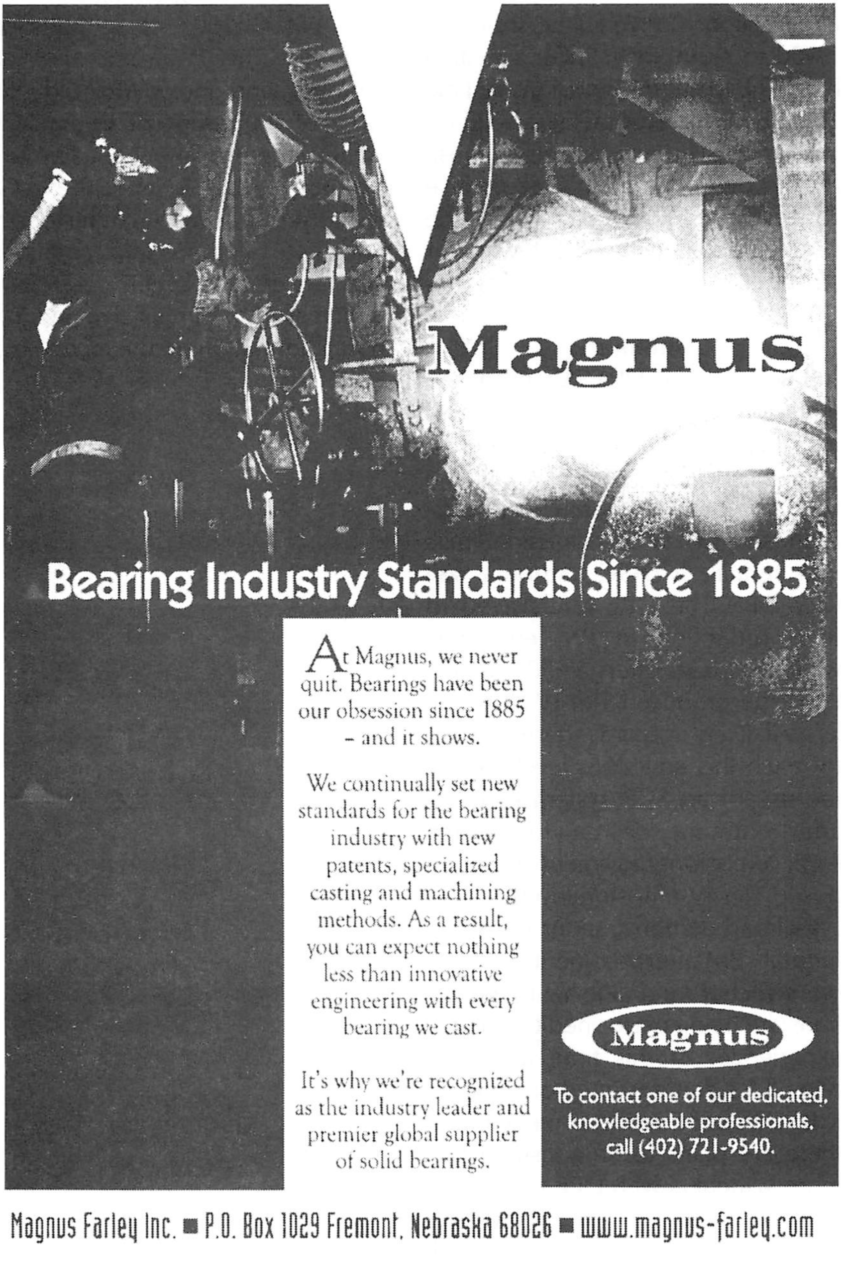
An experimental DOC has been installed in EMD SD-60M, which is a line-haul, turbocharged 16-710 EMD engine, rated at 3,800 traction hp (2.8 MW), that has been rebuilt to meet Tier 0 emission standards. The locomotive has also been upgraded by installing an aftermarket automatic engine start stop system. This locomotive typically operates in southern California in a "helper hauler service" in the Los Angeles Basin.

As shown in Figure 17, from exterior of locomotive there is no way to tell that a DOC system is installed on this locomotive. This locomotive has been fitted with a novel pre-turbo DOC's, that are mounted in specially designed exhaust manifolds. A drawing of the cross section of the manifolds with catalyst sections are shown in Figure 18 and photos of the prototype manifolds can be seen in Figure 19.

The DOC manifolds replace the stock EMD exhaust manifolds and they are designed to use all of the EMD exhaust manifold gaskets and expansion joints. These prototype manifolds have been set up so that the experimental catalysts drop into the top of the manifolds and into a frame inside the manifold. The design does not hamper engine maintenance/repair. For example, a power assembly (PA) and cam segments on the EMD engine can be removed without removing the prototype exhaust manifolds.

The design of the prototype manifolds adds a large amount of surface area to the exhaust manifold system. This causes increased heat transfer from manifold and requires the use of manifold blankets to retain heat in the manifold to provide adequate exhaust energy for the turbocharger. Additionally the blankets help keep the long hood of the locomotive from becoming excessively hot, due to the added heat lost from the surface of the prototype exhaust manifolds. A photo of the blanketed manifolds is shown in Figure 20.

Emissions testing of the locomotive before and after the installation of the DOC's in UP2368 established that the experimental DOC system reduced PM emissions by 52% over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the EPA line-haul test cycle (See Figure #21). The fuel used for both of the tests contained only 17 Parts Per Million (PPM) Sulfur, not the 2,000 to 4,000 PPM Sulfur specified by CFR Part 92 for emissions testing. This 17 PPM Sulfur fuel was valid for the series of emissions tests because UP will be operating this locomotive in Southern California where the fleet is fueled with ultra low sulfur diesel.

Summary

Based on the UP-EPA's proposed emission regulations exhaust aftertreatment will likely be needed to meet the proposed EPA T-III & T-IV locomotive emission standards. Proposed Tier IV PM emission limits may require a DOC and/or a wall flow DPF. The DPF offers a 90 to 95% reduction in PM emissions while the DOC offers a ~50% reduction. The proposed Tier IV NOx limits will likely require aftertreatment to reach this emissions level. Expect the use of an SCR system or other aftertreatment device to reduce NOx emissions to meet the proposed Tier IV emission levels.

Railroad demonstrations of experimental PM aftertreatment systems on switcher and line-haul applications are being performed to gain rail experience. At this time there are two DPF's demonstrated on an EMD MP15DC's in North America and there are plans to demonstrate two more switchers with DPF systems by the end of 2007. These demonstrations will last over one year and will help the industry identify the practicality of DPF systems in the locomotive environment.

There is also one experimental DOC system being demonstrated in an EMD SD60 in Southern California. This is also a one year demonstration and will help identify some of the issues of using DOC exhaust after treatment in a line haul locomotive. At this time, the active parties are looking for other opportunities to demonstrate additional DOC systems on other locomotives to increase the sample size and gain more information on the technology.

Table #1 Percent Reduction from Current Emission Standards

Proposed Standards by Tier	PM	NOx
Remanufactured Tier 0	60%	15 – 20%
Remanufactured Tier I	50%	No Change
Remanufactured Tier II	50%	No Change
Tier III	50%	Tier II Level
Tier IV	90%	80%

Table #2 Proposed EPA Locomotive Emissions Standards

Standards Apply to:	Date to be Applied	PM	NO_x	HC	CO
Remanufactured Tier 0 & I	2008 as Available, 2010 Required	0.22	7.4 [a]	0.55[a]	5.0
Remanufactured Tier II	2008 as Available, 2013 Required	0.10	5.5	0.30	2.2
New Tier III	2013	0.10	5.5	0.30	1.5
New Tier IV	PM & HC 2015, NOx 2017	0.03	1.3	0.14	1.5

(a) The NOx limit is 8.0 g/hp-hr and 1.00 g/hp-hr for HC for locomotives originally built without separate circuit aftercooler system

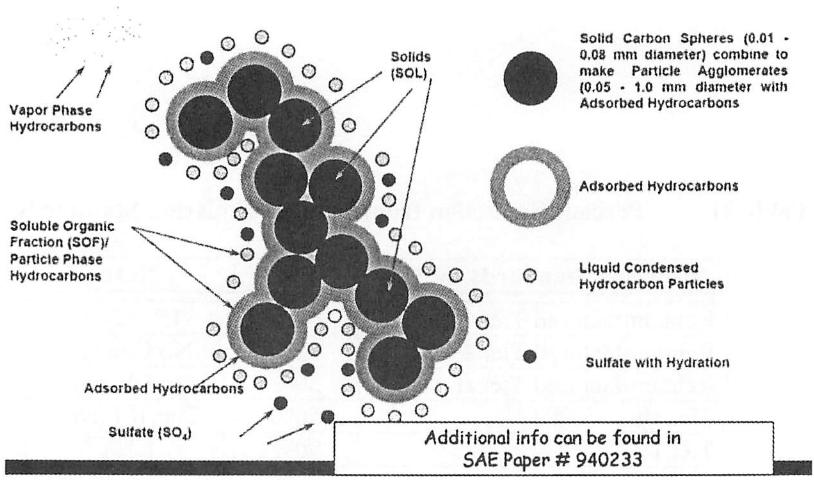

Figure #1 Illustration of Typical Diesel Particulate

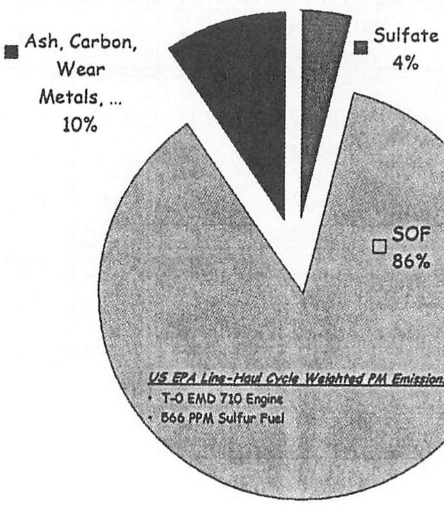

Figure #2 An Example of PM from a EMD T-0 710 Engine

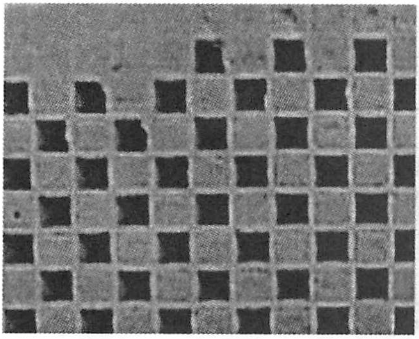
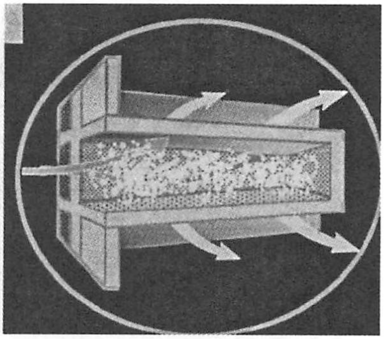

Figure #3 Close Up View and Illustration of a Wall Flow DPF

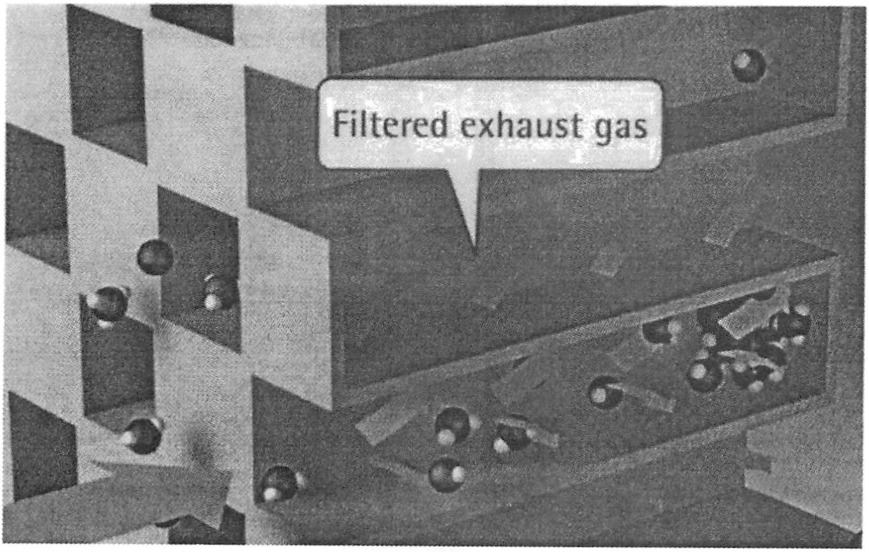

Figure #4 Illustration of Wall Flow DPF

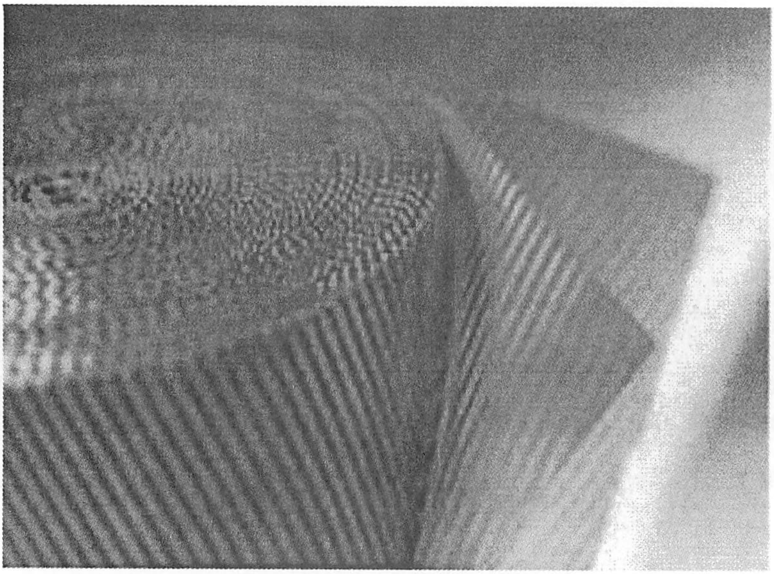

Figure #5 Example of Mesh Used to Construct a Flow Through DPF
Reference: http://www.ecocat.com

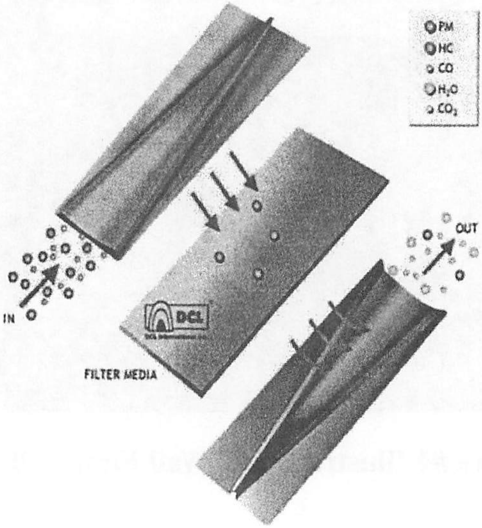

Figure #6 Example of a New Style Flow Through DPF
Refrence: http://www.dcl-inc.com

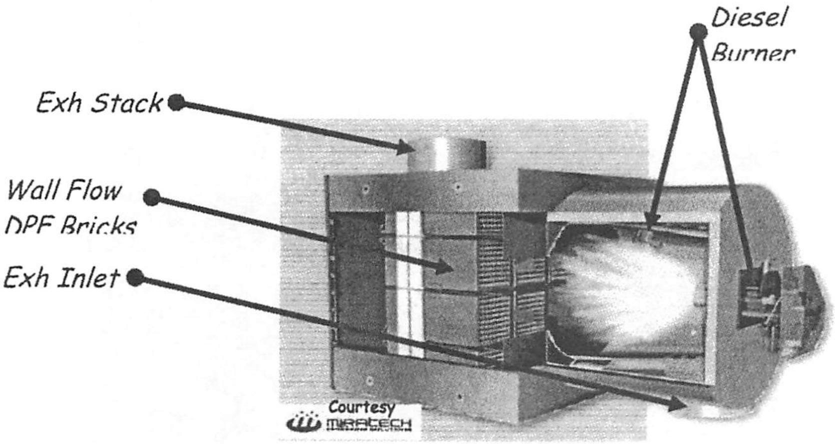

Figure #7 Example of Diesel Burner Mounted on DPF System

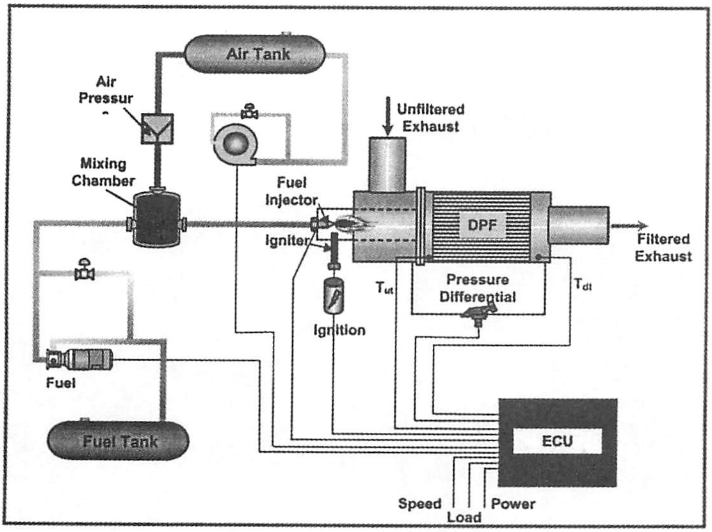

Figure #8 Infrastructure Needed for a Diesel Burner for a DPF System

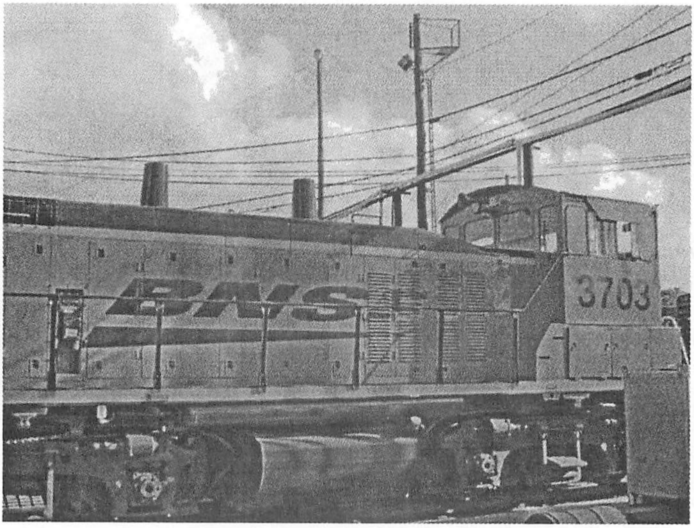

Figure #9 BNSF3703 Before Installation of DPF System

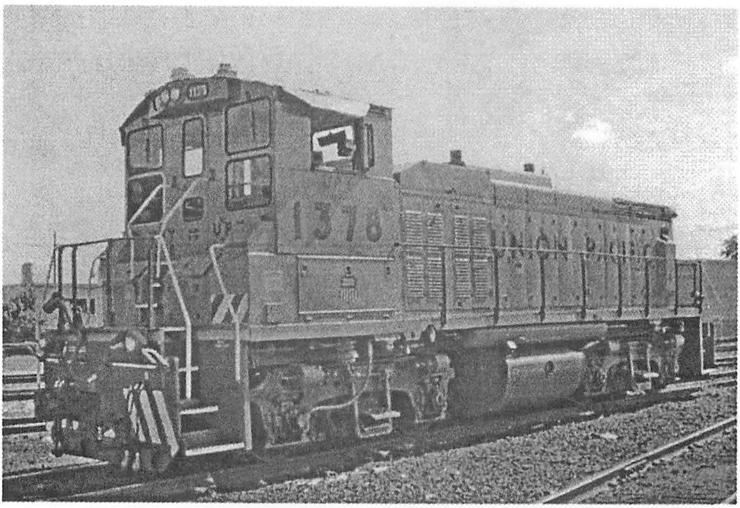

Figure #10 UPY1378 Before Installation of DPF

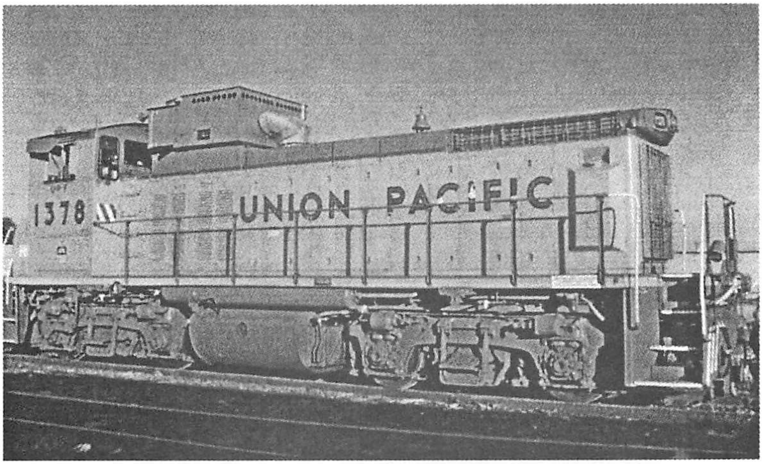

Figure #11 UPY1378 with DPF Installed on Long Hood

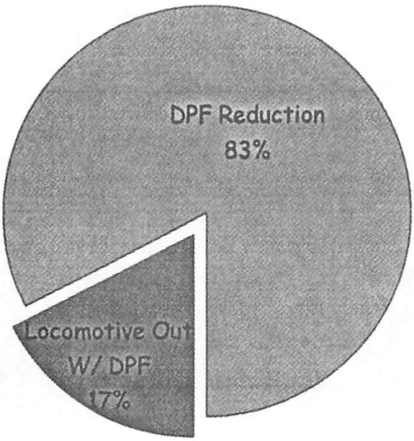

Figure #12 PM Emissions Reductions on UPY1378 Using the Experimental DPF

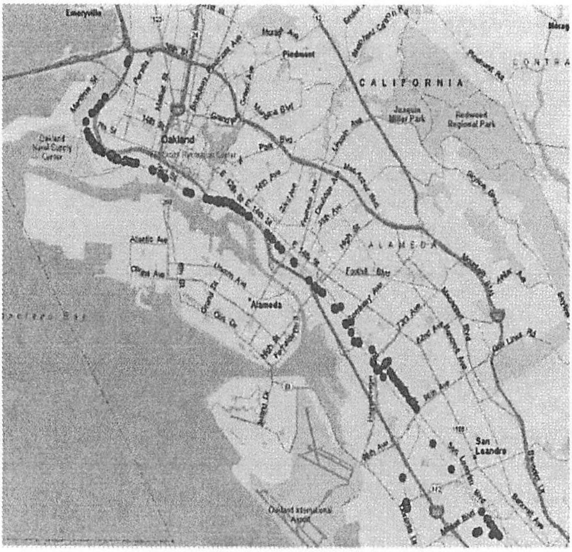

Figure #13 One Week Activty of UPY1378
in Oakland California

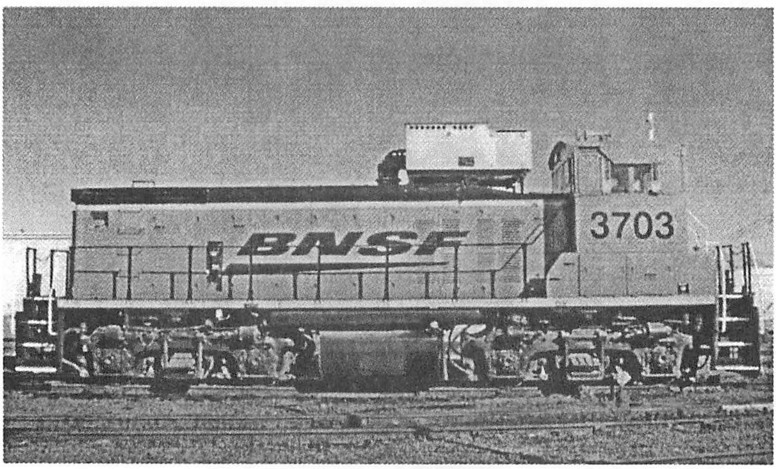

Figure #14 BNSF3703 with DPF System Installed

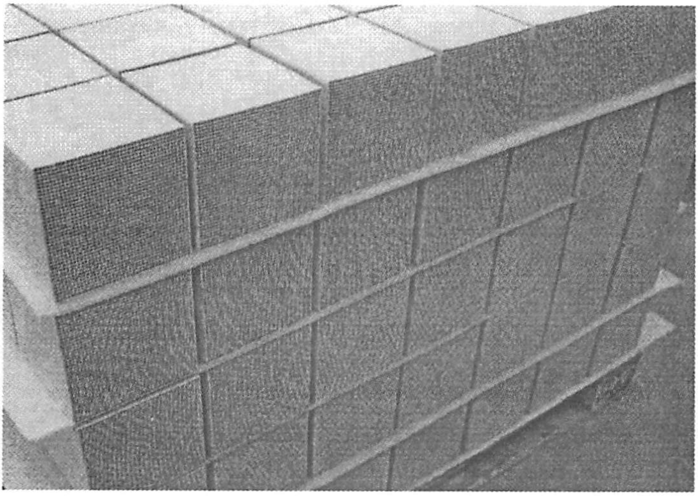

Figure #15 Ceramic DOC Blocs (Before Being Packaged)

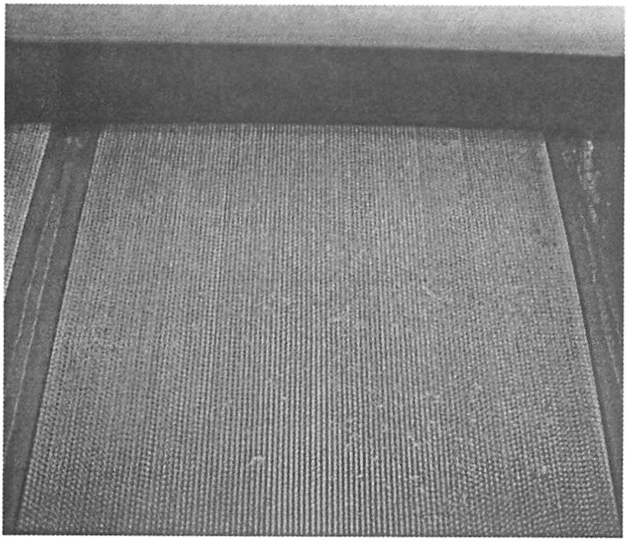

Figure #16 Foil Type DOC Mounted in and EMD 16-710 Exhaust Manifold

Figure #17 SD60 Line Haul Locomotive Fitted With Experimental DOC System

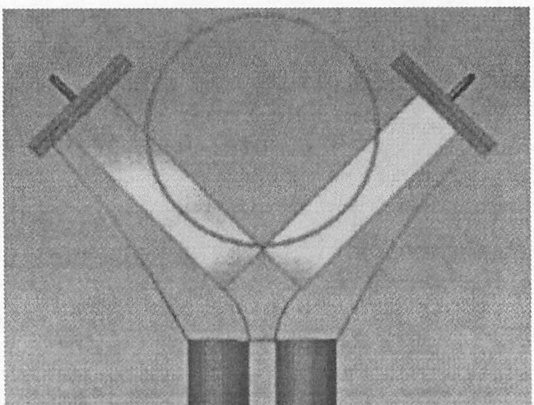

Figure #18 Cross Section of Prototype Manifold with DOC

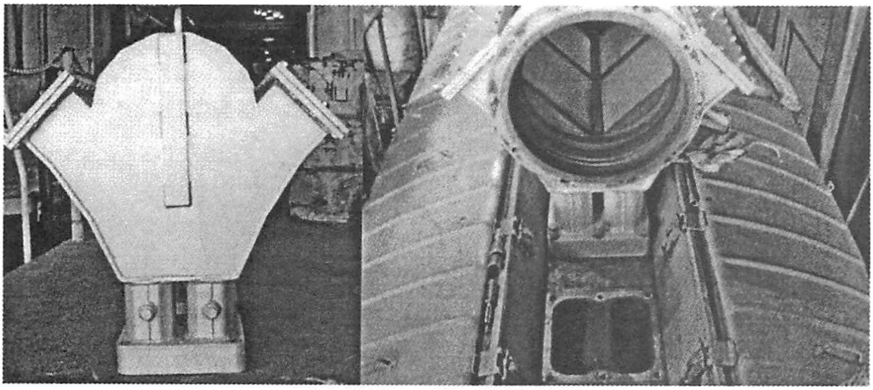

Figure #19 Manifolds That House the DOC's

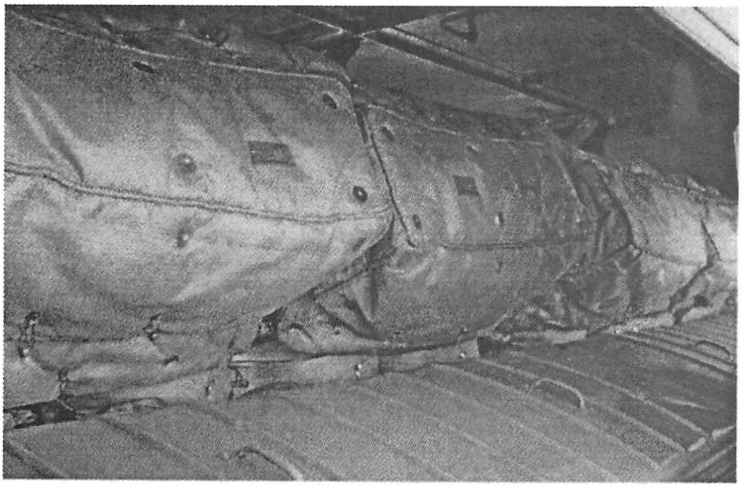

Figure #20 Manifold Blankets Cover the Prototype DOC Exhaust System

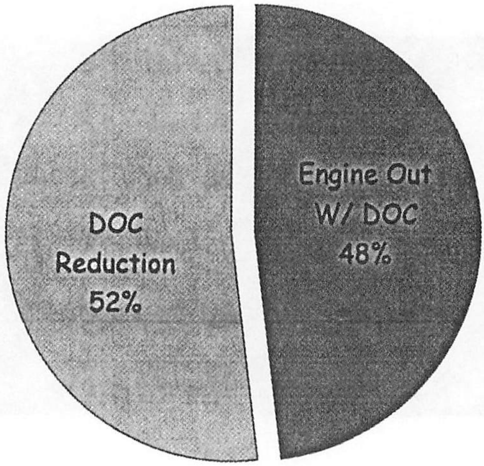

Figure #21 PM Emissions Reduction Over EPA Line Haul Cycle Using Experimental DOC System

Reference: Osbone, D.T. , et.al, "Exhaust Emissions from a 2850 kW EMD SD60 Locomotive Equipped with a Diesel Oxidation Catalyst," ASME Paper JRC-ICE2007-40060, 2007

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT AND PROCESSES

THURSDAY, SEPTEMBER 13, 2007
1:45 P.M.

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

Vice Chairman
TOM STEFANSKI
President
Tom's Locomotives and Cars
Plainfield, IL

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R. Collen	VP-Sales	Simmons Mach. Tool Corp.	Albany, NY
C. Fette	President	TESCO	Erie, PA
R. Herdegen	Mgr. Qual. Production	BNSF Railway	Minneapolis, MN
D. Louder	Product Manager	Macton Corp.	Mount Airy, MD
J. Morin	President	NEU International Inc.	Paoli, PA
B. Savage	Sr. Mech. Supervisor	CN Railway	Memphis, TN

THE SHOP EQUIPMENT AND
PROCESSES COMMITTEE
WOULD LIKE TO EXTEND THEIR
SINCERE APPRECIATION TO BOTH
THE AAR AND TTCI FOR HOSTING
THEIR COMMITTEE MEETING IN
PUEBLO, COLORADO
ON MARCH 13, 2007
AND FOR PROVIDING SHOP TOURS

THE COMMITTEE ALSO WISHES TO
THANK RON BEGIER OF PORTEC
FOR COORDINATING THE
NECESSARY ARRANGMENTS

EVOLUTION AND IMPROVEMENTS IN LOCOMOTIVE RERAILING CRANES

Prepared by,
Bill Peterman, President,
Peterman Railway Technologies

History and Transition from Steam to Diesel Cranes

During the early days of railroading, locomotives were small enough to be rerailed manually using block and tackle.

With the introduction of the heavy Pullman steel cards in 1890, steam crane and winches entered the picture. In 1910, railroad cranes reached their peak of development. Cranes were so powerful they remained in service until the 1980's. Quick firing boilers and steam winches could only be improved a little so they remained in service.

Original Locomotive Wrecking Cranes (Figure 1)

These cranes could handle up to 250 tons. The biggest disadvantage was they were limited to rail only. The crane was sent in from both ends of the derailment.

Arrival of the Hi-rail Diesel Cranes (Figure 2)

In the 1960's, big hydraulic controlled diesel cranes, with safer winding drums, arrived. The advantage in using the cranes was that they had the ability to travel on the road to get to the scene of an accident. They were very mobile and were able to maneuver around an accident site better than a crane which was limited to rail access, only.

Many improvements were made to the mobile hi-rail cranes from the 1960's to 2000 (Figure 3) They went from 60 to 150 ton, had telescopic booms (with 50 ton boom capacity extension), were equipped with full load monitoring, rotating outriggers, self erecting counterweight and were all hydraulic. NOTE: A picture of a modern mobile rail crane designed especially for rail service with telescopic boom is depicted at the end of this article (Figure 4). Also, pictured are European railroad cranes (Figure 5).

Railroad Rerailer vs All Terrain

Some of the features of both (for comparative sake) are listed below:

RAILROAD RERAILER	ALL TERRAIN
• Custom designed for railway use	• Adapted from lift crane
• Capacity of 2 feet from rear	• Capacity of 16 feet from rear
• Road/Rail capacity	• Road/Rail capability
• 8'-6" legal width	• 10' legal width-need permit
• 87,500 lbs. legal weight	• Too heavy-need permit
• Deck winch standard	• No deck winch
• Light plant standard	• Need to add light plant
• Direct drive	• Hi-rail hydraulic drive
• Main host free fall	• No free fall on hoist
• Side shift for rail on/off	• No side shift
• Pick and carry	• No pick and carry
• Rotating outriggers	

Side Booms

Side booms arrived on the scene in the 1970's (Figure 6). They are very versatile and have the ability to get into tight spots and operate

in various terrains in order to pick-up, transport and put equipment back on the track.

Railroad Crawler Crane

This equipment was introduced in 2000 (Figure 7). It is versatile like the side boom, has a low profile which is good for tunnel and bridge work and is a tracked vehicle. It offers 360 degree rotation. It is wider and heavier than a side boom. It is capable of operating in all types of terrain (Figure 8) and is used for both road and rail operations. It is equipped with a telescopic boom.

Listed below are comparative features of the side booms and railroad crawler crane:

	Side boom	Crawler Crane
Weight:	117,00 lbs	123, 700 lbs
Counterweight:	28,400 lbs	30,000 lbs
Load Line:	8 strand	10 strand
Width:	11 feet	width adjustable 12-18 ft
Auxiliary boom :	No	Yes
Jib boom:	No	Yes
Rail Travel:	No	Road/Hi Rail Travel
Side Shift:	No	Yes

NOTE: As previously indicated, the Crawler Crane has more lift capacity, has a telescopic boom with a 360 degree rotation and offers more stability.

In conclusion, there have been and continue to be advancements made in locomotive re-railing cranes which makes the job of the personnel charged with re-railing locomotives a lot easier.

Original Locomotive Wrecking Cranes

Up to 250 tons

Disadvantage-
Rail Only

Have to send
cranes in
from both
ends of a
derailment

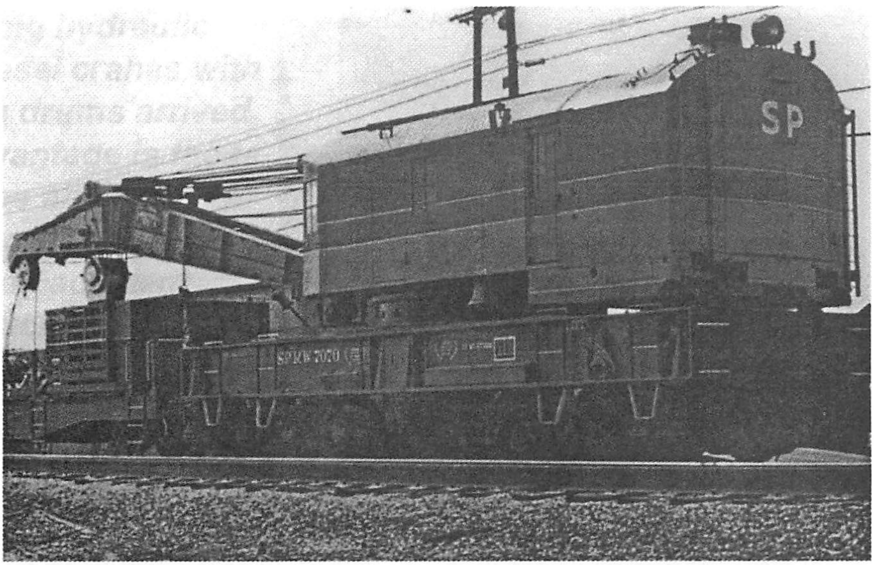


Figure 1

Arrival of the Hi rail Diesel Crane

- ***In the 1960s big hydraulic controlled diesel cranes with safer winding drums arrived. The extra advantage is these cranes had the ability to travel on the road to get to the scene of an accident . They were much more mobile and were able to maneuver around an accident site better than a crane limited to only rail access***

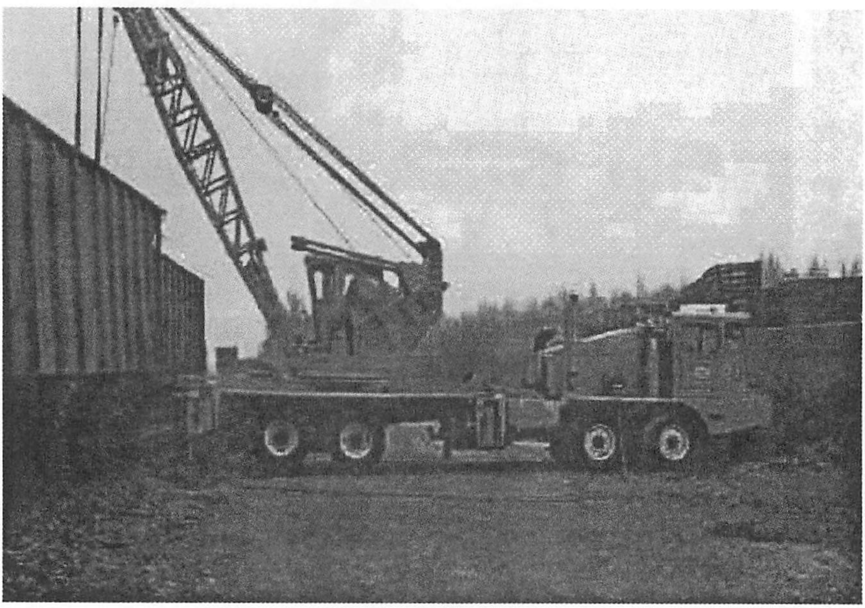


Figure 2

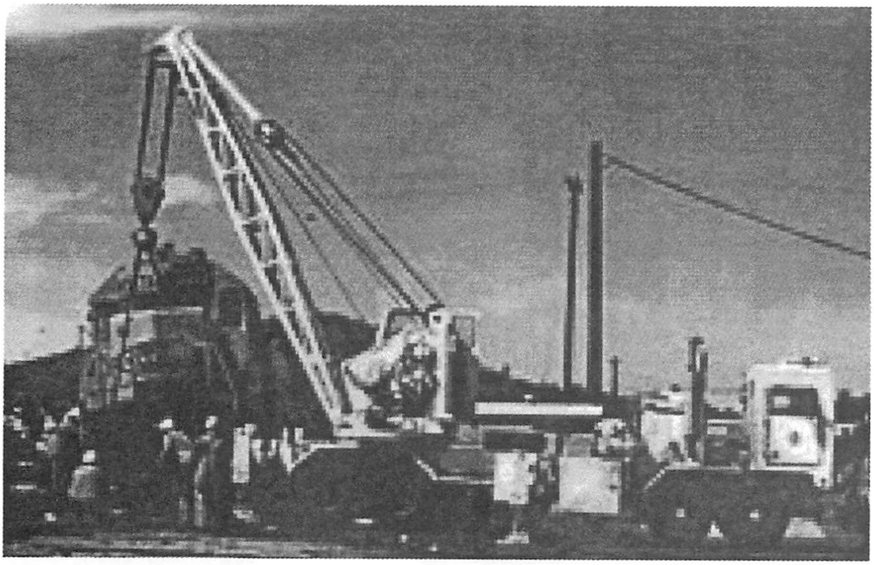


Figure 3

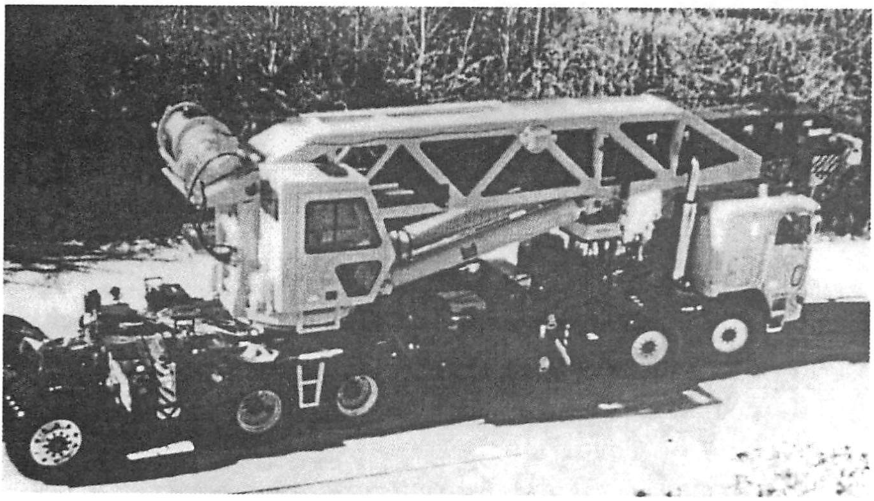


Figure 4

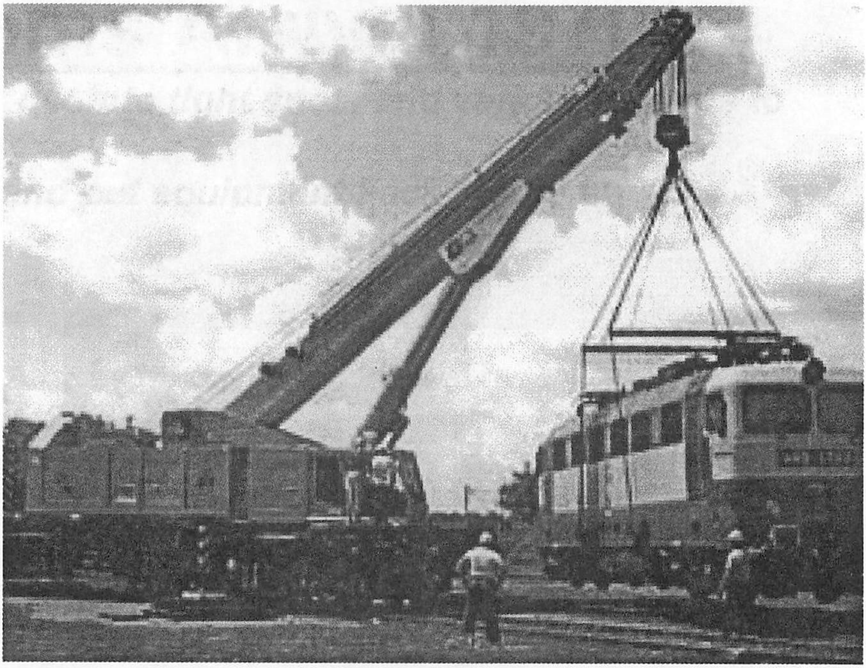
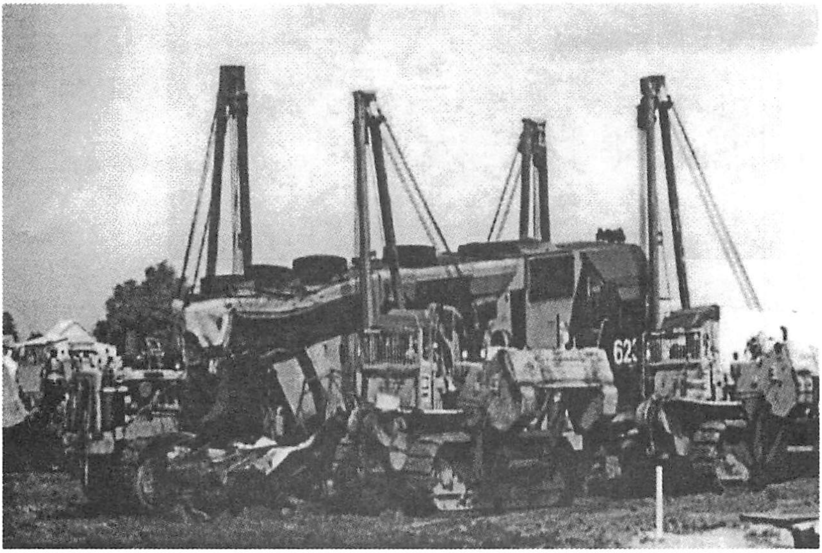


Figure 5

Side Booms Arrival 1970s

Versatility and Ability to get into tight spots and various terrains to pickup, transport and put equipment back on the track.



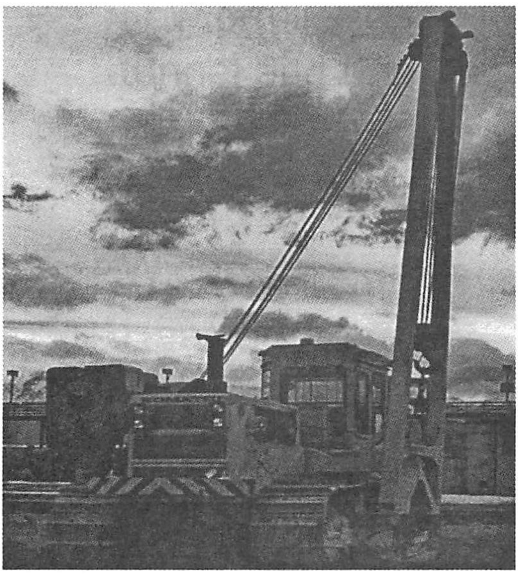


Figure 6

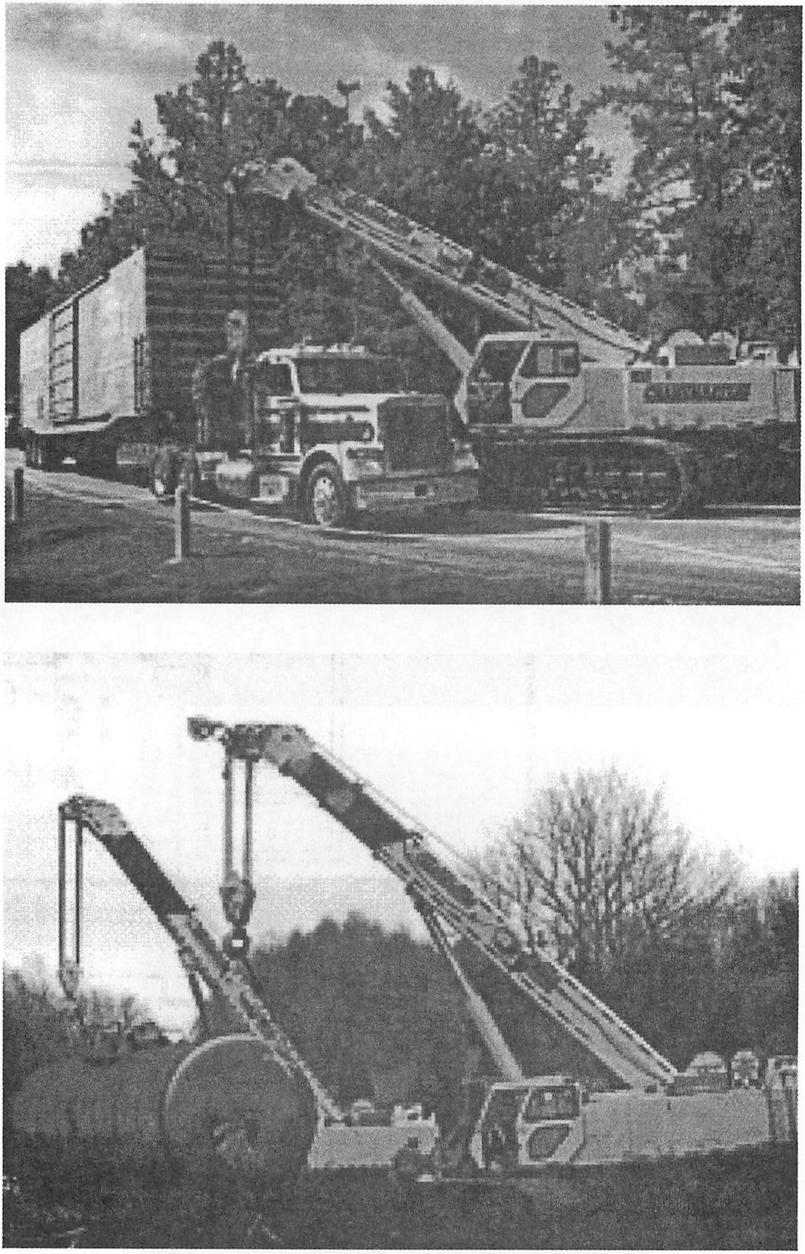
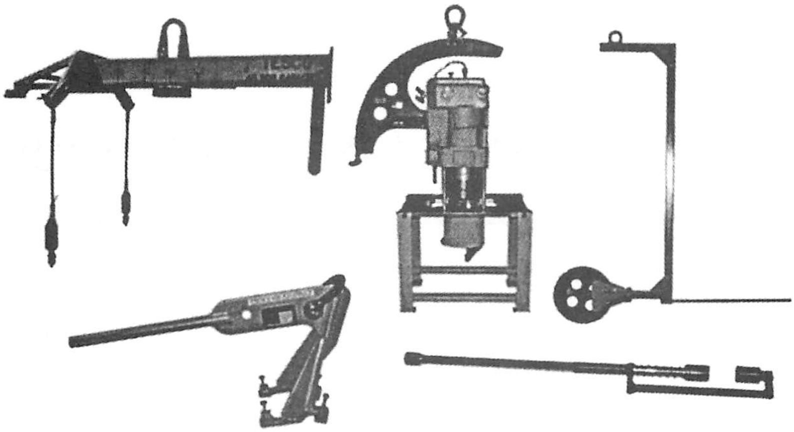
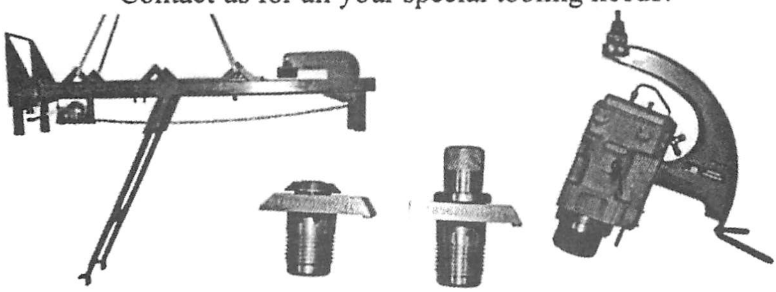


Figure 7





Crawler Road / Rail Flexibility

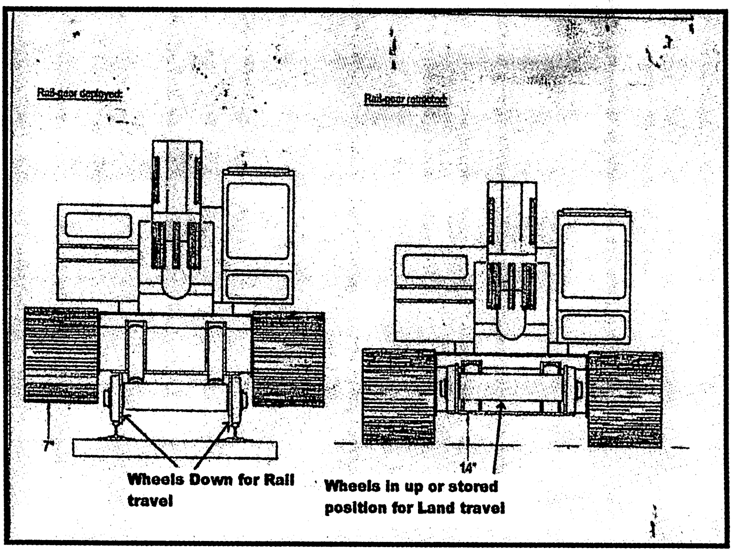


Figure 8

REPORT OF THE COMMITTEE ON FUEL, LUBRICANTS AND ENVIRONMENTAL

THURSDAY, SEPTEMBER 13, 2007
3:15 P.M.

Chairman
TOM PYZIAK
Senior Account Executive
Safety-Kleen Systems
Palatine, IL

Vice Chairman
BOB DITTMEIER
Customer Technical Service
Afton Chemical Corp.
Richmond, VA

COMMITTEE MEMBERS

K. Bahnline	Product Manager	Electro Motive Diesel	LaGrange, IL
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F. Eberhardt	Purch. Mgr.	Belt Rwy. of Chicago	Bedford Park, IL
T. Eitzen	Sr. Staff Engineer	Chevron Lubricants	Richmond, CA
S. Fritz, P.E.	Mgr. Med. Spd. Dsl. Eng.	Southwest Research Inst.	San Antonio, TX
F. Girshick	Sr. Tech. Advisor	Infineum USA L.P.	Linden, NJ
A. Haas	Production Mgr.	Lubrizol Corp.	Wickliffe, OH
L. Haley, Jr.	Chief Chemist	Norfolk Southern Corp.	Chattanooga, TN
D. Koehler	RR Business Mgr.	Predict	Cleveland, OH
C. Kunkel	Sr. Mgr.-R& D	Union Pacific RR	Omaha, NE
G. Lau	Sr. Rel. Specialist	Canadian Nat'l	Edmonton, Alberta
R. Lodowski	Asst. Supt.	CSX Transportation	Selkirk, NY
M. Maddox	Tech. Support	Industrial Specialty Chem.	Harvey, IL
D. McAndrew	Fuel & Lube Spec.	GE Transportation Rail	Erie, PA
K. Myles	Mech. Engineer	Amtrak	Wilmington, DE
D. Mattey	Key Acct. Mgr.	Alfa Laval, Inc.	Hermitage, PA
D. Salvesen	CVL National Flt. Sls.	Exxon Mobil	Sterling, VA
W. Strickland	Mgr.-Test & Lab Svcs.	CSX Transportation	Jacksonville, FL
D. Tuttle	Mgr.-RR & Marine Sls.	American Refining	Roswell, GA
K. Wazney	Chemist/Testing Spec.	Canadian Pacific Rwy.	Winnipeg, MB
P. Whallon	Mgr.-Tech. Sales	Clark Filter	Lancaster, PA

PERSONAL HISTORY

Thomas Pyziak

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

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

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

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

THE FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE WOULD LIKE TO EXTEND THEIR SINCERE APPRECIATION TO CSX CORPORATION AND ROD LODOWSKI FOR HOSTING THEIR COMMITTEE MEETING IN JACKSONVILLE, FL ON JANUARY 22, 2007

1. AUTOMATIC SELF-CLEANING LUBE OIL FILTERS AND CENTRIFUGES

Prepared by
Don Mattey, Key Account Manager,
Alfa Laval, Inc.

The locomotive industry is exploring more efficient and environmentally friendly technologies due to more stringent emissions standards, demand for more power, increasing labor costs, renewed focus on the environment, and the high cost of hazardous waste disposal.

The technology of self-cleaning lube oil filters has been around for over 30 years. However, recent improvements in filter design and the concept of using a centrifuge to enhance the filtration efficiency make these systems highly advantageous versus disposable paper cartridge filters.

The purpose of a lube oil filter is to protect critical engine components from harmful particles. Maximum engine and oil life is dependent on the efficiency and durability of that filtration system. During normal engine operation, a wide variety of contaminants can be introduced into the lubricating oil such as carbon, water, acids, partially burned fuels, dirt, varnish and sludge. Although many contaminants may be small enough not to cause immediate engine damage, they can combine to form larger particles that directly lead to a significant decrease in both oil and engine life. In addition, abrasives and foreign material can enter the engine through the intake air system, combustion blow by, fuel, worn engine parts, and routine maintenance oversights. Small, abrasive wear particles in the 1-10 micron range can also lead to accelerated wear of high speed components such as turbo shafts and camshafts. Therefore, the effectiveness of an engine's oil filtration system can directly impact the durability of critical engine components and both oil and engine life. (1)

Filtration can be defined as the process of collecting solid particles from a fluid by passing it through a filter medium where the particles are retained. Two basic methods of filtration are used, namely deep–bed filtration, used in depth filters such as standard paper cartridge filters, and surface filtration, used in strainers and cake filters. (2)

The particles passing through a deep-bed filter are collected within the layers of the filtration medium (see Figure 1). As the solid particles accumulate in a depth filter, the pressure drop increases as particles are trapped. When the pressure drop reaches a certain level, the filter elements must be replaced or cleaned with chemicals.

In surface filtration, the particles are collected on the surface of the filter medium, whereby a filter cake of retained solids is created (see Figure 2). This cake is then removed by back-flushing the filter. If the filter is continuously back-flushed, the pressure drop across the filter remains constant. In practice, a filter can remain in operation without interruption provided that the back-flushing is part of the filter construction. If so, the filter can be referred to as an "automatic back-flushing filter" or "automatic self-cleaning filter."

While a deep-bed or surface filtration system is installed to prevent particles in the oil from entering the engine, a centrifuge cleans the oil. The main difference between a filter and a centrifuge is that a filter separates the impurities according to size while a centrifuge separates the impurities based on the density difference between the impurities and the oil. Separation efficiency is governed by Stoke's Law which states that the greater the density of the particle relative to the density of the fluid, the greater the efficiency. However, other parameters have a positive effect on separation efficiency including a large particle size, a high gravitational force, and a low viscosity as shown in Figure 3.

The combination of automatic self-cleaning filters and centrifuges has been used around the world in harsh environments, such as mining and locomotives, for optimal engine protection for over thirty years. Over 2,000 automatic self-cleaning filters have been installed on locomotives for the French railways alone. Installed with new engines or retrofitted to existing field units using either direct or remote mounting, this solution has proven results in reduced oil loss during maintenance, less engine wear, reduced downtime, and lower operating costs. Configuration of the automatic self-cleaning filter and centrifuge is important to achieve maximum performance and efficiency, which leads to maximum oil life (see Figure 4).

The automatic self-cleaning filter and centrifuge typically work together as shown in Figure 5 and detailed as follows.

As 100% of the total engine oil flow enters the automatic self-cleaning filter, it passes through a strainer to catch any large debris that may be in the oil. The oil then enters a distributor where it flows along the length of the filter through a series of wire mesh elements (see Figure 6).

The micron rating of the filtration mesh can be matched to the specific application. For engine lube oil, the most common mesh size is 35 micron absolute (20 micron nominal). An independent laboratory in France (Institute de La Filtration et des Techniques Separateness) conducted a test of the wire filtration mesh. 200 ml of micro-filtered water solution (filtered to 0.2 microns) with glass beads was filtered through the various mesh sizes at 333 l/min. A granulometric analysis by Coulter Counter was performed upstream and downstream of the mesh and yielded the results found in Figure 7. [3]

Upon filtration by the wire mesh elements, the oil continues its path to the engine and, since the automatic self-cleaning filter accepts 100% of the engine flow, downstream engine components are protected with the absence of bypass flow.

While approximately 97% of the oil continues to the engine for lubrication, approximately 3% is used to automatically back-flush the screen mesh and drive a hydraulic motor so an external power supply is not required. The hydraulic motor rotates a distributor in a stepwise function that flows a small stream of filtered oil in the opposite direction through one of the chambers, thereby cleaning the wire mesh of all debris and sending the concentrated particle steam directly to the centrifuge while the remaining sectors are providing filtered oil to the engine (see Figure 8). This process continues until the entire filter has been cleaned then starts again approximately every two minutes. Frequent automatic cleaning of the elements prevents retained solids from adhering to the elements, ensuring a low and constant pressure drop (approximately 3 to 6 psi depending on the application) that reduces parasitic loads on the engine and yields consistent filter performance over the life of the engine.

The load on the automatic self-cleaning filter is reduced and the efficiency of the centrifuge improved by receiving the concentrated particle stream directly from the automatic self-cleaning filter. Under normal operation, the centrifuge is spinning at 5,200 rpm generating extremely high centrifugal forces. At this high rotational speed, the heavier density particles (some below 1 micron in size) are separated from the lubricating oil and collect on the inside of the centrifuge housing. The lighter density polished lube oil is allowed to drain to the engine oil sump. Although the centrifuge is highly efficient, it will not remove lubricating oil additives since they are submicron in size (see Figure 9).

The particles removed by the filter and separated by the centrifuge are trapped within the centrifuge forming a cake of compacted solids. Maintaining this system typically involves opening the centrifuge during oil changes and simply removing the cake for disposal (see Figure 10). In doing so, oil loss and environmental risks are eliminated. In addition, the system can be configured so the engine does not have to stop during the cleaning of the centrifuge. Should the centrifuge become clogged, the filter operates in a normal manner and the captured particles are simply returned to the sump. The automatic self-cleaning filter often does not require any maintenance whatsoever until normal engine overhaul and usually only requires a set of o-rings and visual inspection of the elements at that time. This yields a sealed lube oil circuit that greatly reduces the risk of contamination entering the system.

In addition to real world experience, the automatic self-cleaning filter and centrifuge combination has been performance tested on engines in both test cells and field test applications. In 1999, for example, Cummins performed a test using a KV2000E test bench engine to review particle removal using a paper cartridge filter and an automatic self-cleaning filter and centrifuge.

A 25 micron absolute paper cartridge filter was used and samples were obtained immediately after the filter every 5 hours (see Figure 11). The results show high volumes of particles at and below 3.5 microns.

The paper cartridge did reduce the particle count during the first 10 hours but then leveled off and/or increased by the termination of the test at 15 hours when the filter clogged and the bypass opened. [4]

Similarly, a 25 micron absolute mesh was used in the automatic self-cleaning filter. Samples were obtained immediately after the filter every 5 hours but the test was extended to 35 hours since no filter clogging occurred (see Figure 12). The results show improved particle removal at and below 3.5 microns. In addition, the cleanliness of the oil continued to improve over time as the sump oil was circulated.

In another test by Pon Power in 2006, a Caterpillar 3512 engine was used to compare a paper cartridge filter with an automatic self-cleaning filter and centrifuge combination. The goal was to analyze the amount of soot in the oil over time.

15 W40 oil was retrieved from a sample drain valve immediately after the 25-micron absolute paper cartridge filter and data was recorded every 250 hours for a total of 5,750 hours, including oil changes and 2,000 and 4,000 hours. The results show a consistent increase in oil contamination until the cartridges were replaced (see Figure 13). [5]

The 25 micron absolute automatic self-cleaning filter and centrifuge had a sample drain valve immediately after the filter and initially the data was recorded every 250 hours (see Figure 14). Sampling increased in frequency around 2,000 hours, however, due to the amount of time the same oil was being used on this newly commissioned engine. It should be noted that between 1,000 and 1,750 hours the data was not recorded so the oil was drained and the test restarted. The results show not only prolonged soot removal but also levels well below those of the paper cartridge filter.

Based on the prolonged oil change interval previously tested with the automatic self-cleaning filter and centrifuge, Pon Power conducted another test in 2006 using a Caterpillar 3616 engine to measure wear elements. The same 15W40 oil was used for 5,000 hours and wear elements including copper, iron, lead, and aluminum were measured in parts per million after the automatic self-cleaning filter and centrifuge (see Figure 15). The results show that most element levels remained constant throughout the entire test. [6]

In addition to cleaner oil, an added benefit for the locomotive industry is reduced size and weight of the automatic self-cleaning filter and centrifuge. Either combined as one unit mounted directly to the engine, separated in two locations with easy access to the centrifuge, or in a number of other combinations, the automatic self-cleaning filter and centrifuge are approximately 1/3 the size and weight of cartridge filter housings (see Figure 16).

The combination of a full-flow, automatic self-cleaning filter and centrifuge has shown in tests and in real world applications to extend oil life and reduce engine downtime. It is an environmentally friendly solution to today's lube oil filtration requirements.

Contributions

1. Rob Andrews, Cummins Engine Company, "New, long life, self-cleaning lube oil filtration for diesel engines", Institution of Diesel & Gas Turbine Engineers, 1999.

2. Marine & Diesel Equipment, Alfa Laval, Inc. "It's all about protection", Alfa Laval 2002.

3. Filtration Mesh Efficiency Test Report, Institute de la Filtration et des Techniques Seperatives, report number 97/251.A

4. CCU Test Report, Cummins 1999.

5. Eliminator Efficiency Test Report, Pon Power 2006.

6. Eliminator Wear Metals Test Report, Pon Power 2006.

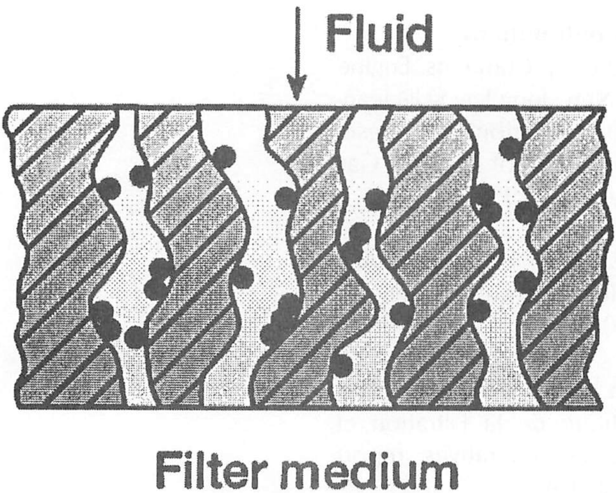


Figure 1: Deep-bed filtration

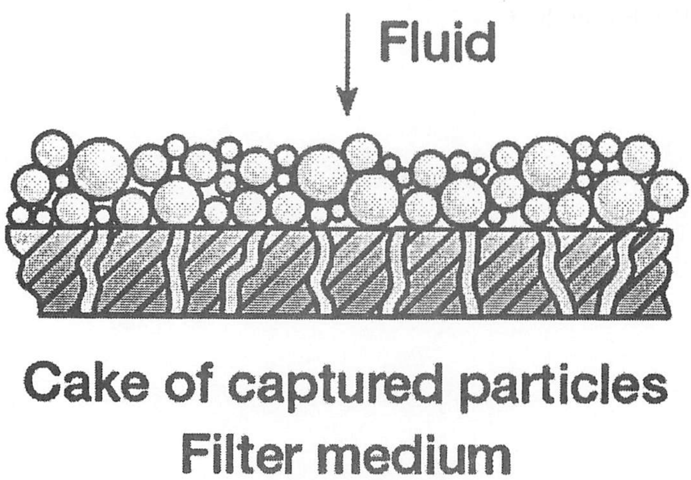


Figure 2: Surface filtration

$$V = \frac{d^2\,(p_p - p_l)}{18\eta}\,g$$

V is the sedimentation velocity due to gravity
d is the diameter of the particle
p_p is the density of the particle
p_l is the density of the liquid
η is the viscosity of the liquid
g is the acceleration due to gravity = $\omega 2r$

Figure 3: Stoke's Law

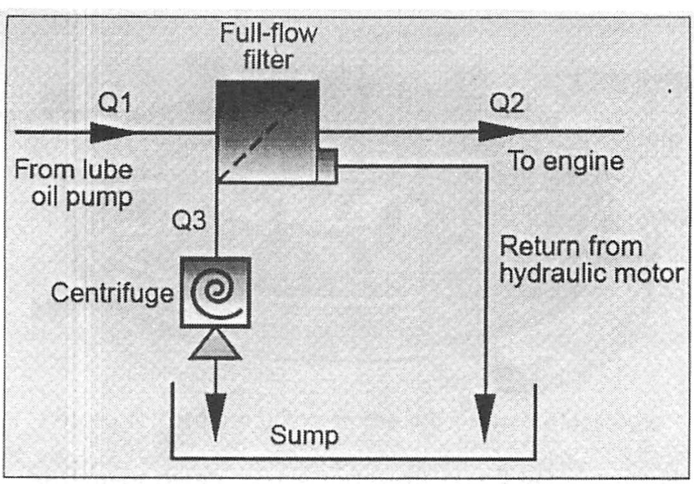


Figure 4: Automatic self-cleaning filter and centrifuge configuration

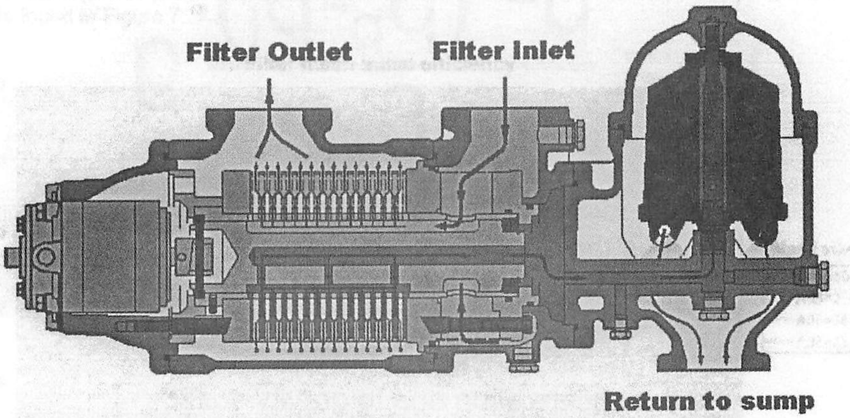


Figure 5: Automatic self-cleaning filter combined with centrifuge

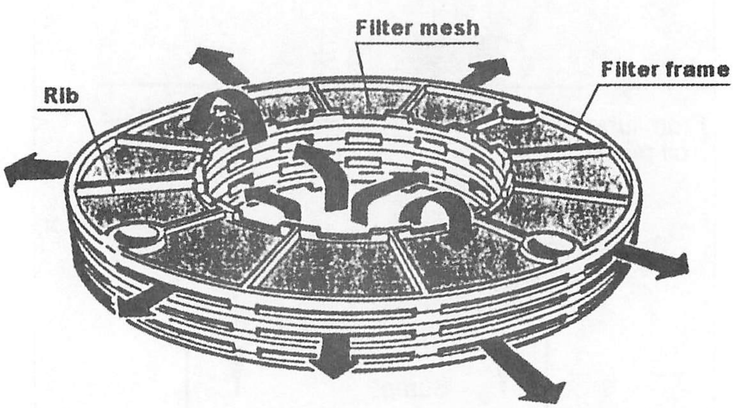


Figure 6: Oil flow through the wire mesh elements

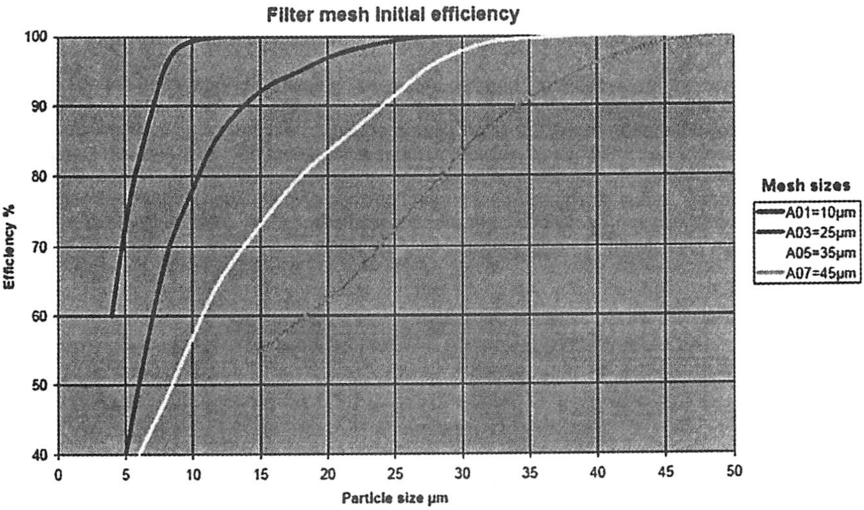


Figure 7: Wire mesh efficiency test results

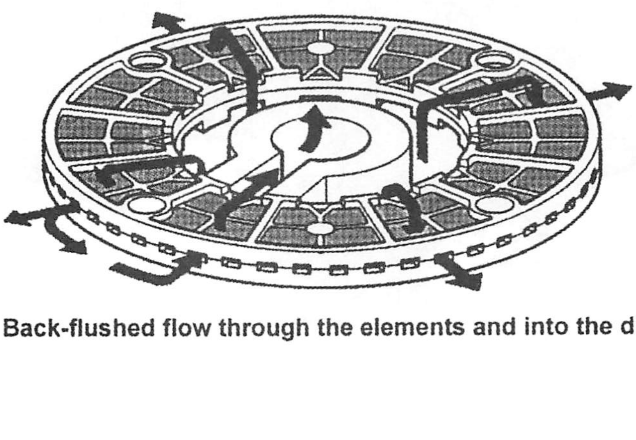


Figure 8: Back-flushed flow through the elements and into the distributor

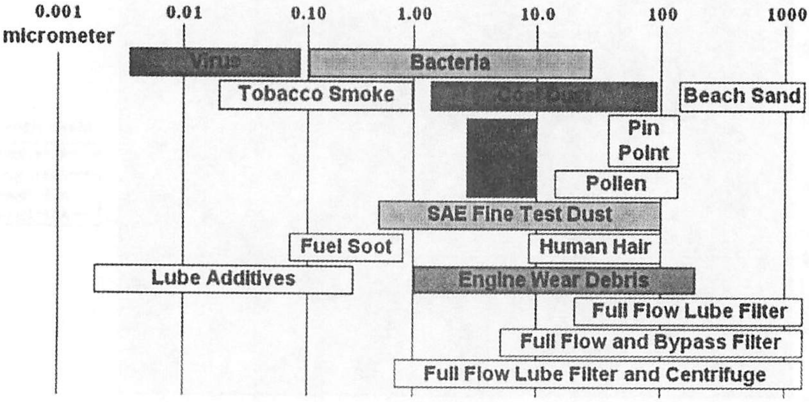


Figure 9: Centrifuge will not remove lube oil additives

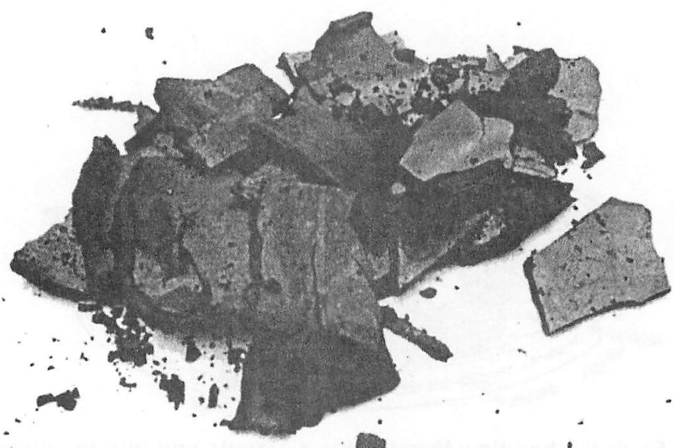


Figure 10: Sludge cake removed from Centrifuge

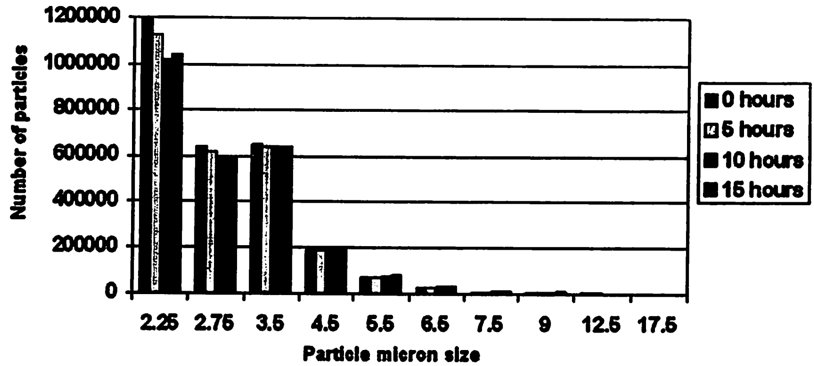


Figure 11: Paper cartridge filter particle count

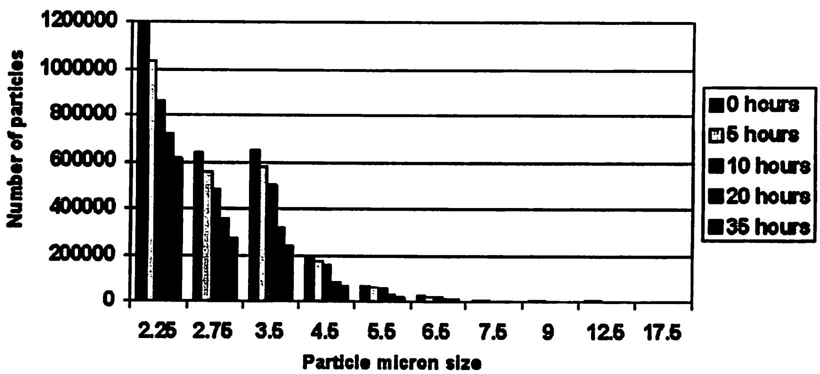


Figure 12: Automatic self-cleaning filter and centrifuge particle count

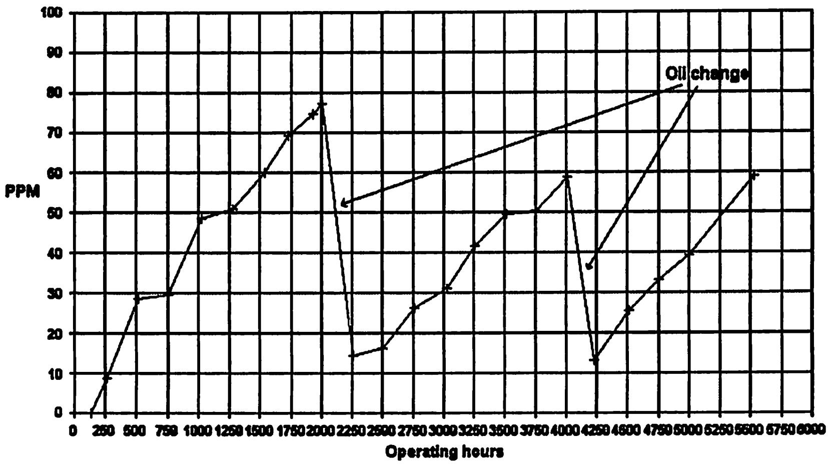


Figure 13: Paper cartridge filter particle count

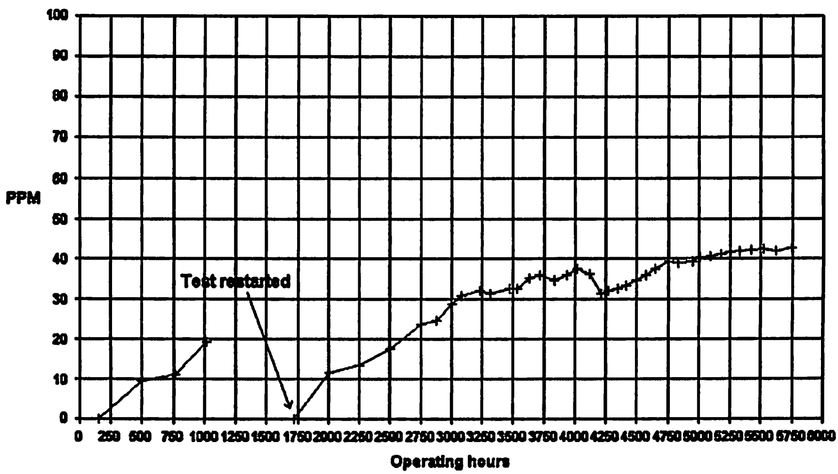


Figure 14: Automatic self-cleaning filter and centrifuge particle count

Oil Hours	1486	1654	1922	2361	2983	3800	4478	5002
Copper	4	2	0	3	4	7	5	8
Iron	7	8	8	8	10	8	8	8
Lead	1	0	1	0	1	0	1	0
Aluminum	2	2	2	2	2	2	2	2
Silicon	2	3	3	3	2	3	3	3
Sodium	0	0	1	0	0	0	1	0
Tin	0	1	0	0	0	1	0	0

PPM

Figure 15: Wear element levels during 5,000 oil hour test

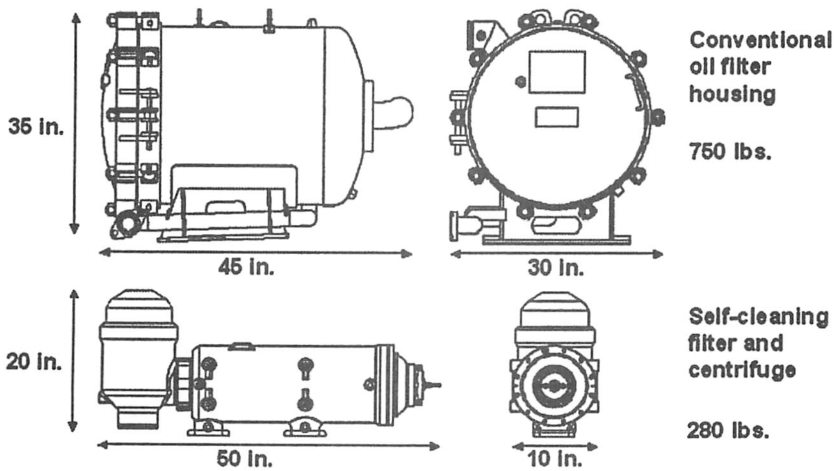


Figure 16: Approximate dimensions and weights between a standard paper cartridge filter housing and an automatic self-cleaning filter with centrifuge

2. DIESEL FUEL 2007 AND BEYOND, WHAT WILL BE IN YOUR TANKS?

Prepared by
Dennis McAndrew,
GE Transportation
George Lau, CN
Chuck Kunkel, UP

Introduction

Effective June 1, 2007, the US Environmental Protection Agency (US EPA) requires most US-based refineries to produce Non Road, Locomotive, and Marine (NRLM) diesel fuel with a maximum sulfur concentration of 500 ppm. This requirement is delineated in 40CFR 80.510[1]. This concentration was lowered from the previously allowable concentration specified by the railroads and/or locomotive manufactures. US railroads often reference the ASTM International (originally known as the American Society for Testing and Materials) specification ASTM D 975 Diesel No. 2, which specified 5000-ppm maximum fuel sulfur. The goal of the EPA fuel sulfur reduction was to assist in the reduction of emissions of particulate matter from the locomotive, and by default the sulfur emissions would be reduced.

40CFR 80.550 through .554 include provisions for some "small refineries" that may exempt such refineries from the requirements in 40CFR 80.510. Note that some railroads in North America and other locations such as Australia are already using low sulfur fuels, ultra low sulfur fuels, or if not, they will be using such fuels.

40CFR 80.510 *additionally require* US refineries to further reduce the fuel sulfur to a maximum of 15–ppm sulfur by 2012. This future reduction is intended to allow the use of advanced after treatment technology if needed. The obvious goals of the regulations are to complement the engine designs and fuel properties for a reduction in total emissions.

The rule changes on diesel fuel sulfur content have raised several questions.

- How, if at all, has this removal of much of the sulfur from the fuel changed the fuel's chemical and physical properties?
- Will all the changes be positive or some negative?
- If negative, how will or can the negative changes be offset?
- Will the fuel changes affect specific fuel consumption, useful oil life, oil drain cycle, oil chemistries, and engine reliability, durability, and performance?

This paper will address some of the questions on supply variation, and supply distribution. A brief discussion of the survey results and the chemical and physical properties differences will also be included.

Fuel Survey

The fuel survey questionaire was sent out February of 2007. There were a total of eight railroads responding to all or part of the survey in March and April 2007. The responses were from two US, two Canadian, two Mexican, and two Australian railroads. Seven railroads responded to the survey questions,

and five railroads supplied test results. There are six data sets in this paper because of the inclusion of one locomotive manufacturer's data. The survey questions were as follows.:

- Number of fuel suppliers
- Type of supply, pipeline, barges, tanker, supply truck
- Number of supply locations
- Sulfur content from each supply
- Verification of Specification (ASTM D975)
    - Supplier test all parameters
        - Frequency of testing
    - Supplier tests some of the parameters
        - Frequency of testing
    - Railroad test all parameters
        - Frequency of testing
    - Railroad tests some of the parameters
        - Frequency of testing
- Lubricity testing, Test responsibility if needed
    - Refinery
    - Distributor
    - Railroad
    - Frequency of testing
    - Control Process
- Percent of fuel greater than 500-ppm
- Percent of fuel less than 500-ppm
- Percent of fuel less than 15-ppm

The ASTM specification list three No. 2 diesel categories S5000, S500, and S15 based on the fuel sulfur maximum content. The fuel are commonly referred to as High Sulfur Diesel (HSF) maximum of 5000-ppm, Low Sulfur Diesel (LSD) maximum of 500-ppm, and Ultra Low Sulfur Diesel (*ULSD*) with a maximum of 15-ppm sulfur.

All above survey responses that were received are reported in Appendix 1. Information extracted from the survey and grouped in four general categories is as follows:

1. Number of suppliers: The US, Canadian, and Mexican railroads have multiple suppliers. The two Australian railroads have one supplier.

2. Type of supply: The method that the fuel is being supplied to the railroads varies from pipeline, barges, tankers, and supply trucks. Two railroads receive fuel by all methods listed, three by tankers and trucks, one by tanker, and one by truck. The numbers of supply locations range from 38 to only 1.

3. Verification that fuel meets a specification: Two railroads do not require the supplier to provide information on the fuel. Five rely on certificate of analysis. However, in most cases only a few selected fuel properties are determined. One railroad requires all new potential suppliers to test and meet all requirements of the specification. The frequency of testing is once a month to quarterly. Lubricity testing is as varied as the other tests. One railroad is adding a lubricity additive to the fuel only where ultra low sulfur fuels are being used. In this case the fuel is tested monthly using the ASTM D 6079 lubricity test. Another railroad receives their fuel treated and requires the supplier to test the fuel for lubricity.

4. Fuel sulfur being used: two railroads are receiving fuels that meet

all three ASTM D 975 Diesel No. 2 categories, ie. , S5000, S500, and S15. Two are using S500 fuels, and one is using S15 fuels. The last two railroads are using fuels that meet their country's S50 requirements.

Survey Fuel Properties

The fuels properties survey results are reported in Appendix 2. The results show a very diverse fuel supply. There are major differences in density, sulfur content, heat content, etc. It also shows that most fuel parameters are not tested to ensure the fuel does in fact meet the railroads or manufacturers' required specification.

When fuel test data is supplied to the railroads from a supplier, it is sent to the purchasing/sourcing department. Most technical groups (engineering, laboratory) need to request a copy of the fuel results from purchasing. Railroads with multiple suppliers do not have one standard form for all suppliers to submit analytical test results. One major railroad receives results in at least five different file types: xls, pdf, TXT, tif, and fax. Not only are the fuel properties reporting forms different from each supplier, different analytical test procedures are being used. This is not an efficient process for tracking and evaluating quality.

Discussion

The EPA regulation governing when refineries must produce diesel fuel with a maximum of 500-ppm varies. It is dependent on the amount of fuel produced by given refiners and their ability to produce such fuels. The process for removing the sulfur is left to the individual refineries. This difference in the timing and process of sulfur removal could add some variation and uncertainty in consistency. This can affect the overall fuel system's performance.

Providing fuel products with consistent properties and quality is paramount in overall locomotive performance. When refineries produce and provide fuels with consistent chemical and physical properties the resulting overall locomotive engine performance is more predictable. The engine fuel system's hardware and the fuel's properties combine to make up the fuel system and resulting performance, reliability, and durability. With locomotive run through agreements, railroad A is relying on railroad B to fuel their locomotive with quality diesel fuel that will not degrade the locomotive fuel system.

Figure 1 illustrates the US fuel sulfur trend. The United States Department of Energy has an organization called the Energy Information Agency (EIA)[2], which keeps track of U.S. refinery inputs and outputs, production, imports and exports. They keep track of diesel fuel production in three bins:

1. Less than 15-ppm sulfur
2. Between 15 and 500-ppm sulfur
3. Greater than 500-ppm sulfur

You can find them at:

www.eia.doe.gov

There is a noticeable increase in ultra-low sulfur diesel (ULSD) when the on-highway specification came into effect (October 2006). Notice the total amount of diesel hardly changed, just the mix.

Along with the engine systems controls, the fuel's properties combine to affect the fuel consumption, fuel system durability and reliability, which ensure exhaust emissions are within EPA regulation.

Diesel fuel might appear as a homogenous fluid composed of one compound. However, distillate fuels are composed of hundreds if not thousands of different molecular compounds. Figure 2 contains illustrations of a few compounds, with and without sulfur, that are found in diesel fuels.

Because of the variation in fuel properties and measurements one cannot rely completely on the laboratory test results to predict the fuels' affect on performance. "When using fuels oils, it is not wise to put complete faith in all analyses, since they sometimes appear satisfactory, but actually are not. Two different oils can have approximately the same analyses, but will burn differently."[3] Additional tests are often required to more completely understand the interactions of the fuels supplied and engine performance.

The fuel survey found variations not only in the fuel sulfur concentration, but other fuel properties as well. One major change/variation observed was with the removal of the fuel sulfur some refineries produce fuels that are less dense. The reduction of fuel density was associated with a reduction in the fuel's volumetric energy content. The fuel's volumetric energy content ranged form a high of 140,933 BTU/Lb to a low of 131,539 BTU/Lb higher heating value. This calculated to a maximum 9394 BTU/Lb (6.67% reduction) difference in volumetric energy content. Will this reduction of the volumetric energy content drive a need to change the number of fueling locations, or was this a unique maximum range?

The blow-by gases from the fuels with different concentrations of sulfur and aromatics will contain different organic species than current higher sulfur/aromatic fuels. This will require railroads using infrared spectrometer for used oil analysis to account for the difference in the fuels sulfur and aromatic content in their algorithms, i.e., recalibration of used oil programs.

Specifications are in place to control the consistency of the fuel products. Many railroads require their fuels to meet ASTM D 975 Diesel Number 2 specification. In addition to the ASTM D 975 specification, several railroads have a few additional requirements.

It is important to note the sulfur in the fuel is not free elemental sulfur, but bonded to the hydrocarbon, i.e., it is an organosulfur compound. Removal of the sulfur will affect fuel's physical and chemical properties. These changes can alter the fuel's volumetric energy content, lubricity, density, cetane number, modulous of elasticity, injection pressure, spray pattern, and other fuel/engine parameters. They can also affect engine reliability, durability, performance, and crankcase oils. The degree of these affects needs to be determined.

Moving forward how will new fuel regulation requirements drive changes to the locomotive systems, and railroad infrastructure and operating systems?

Recommendations

- LMOA FL&E develop a list of recommended tests
- Recommendation on minimum testing frequency
- Develop standard reporting form for suppliers
- Request supplier to provide fuel properties on the standard railroad form
- Recommend using a standard database, e.g. Excel where new data is added

Conclusion

The current fuel supply varies not only from railroad to railroad, but in some instances there are variations of fuel supply within a railroad. The variations observed include not only fuel sulfur content but also other fuel properties, e.g. aromatic content. volumetric energy content, density, cetane, lubricity, and other properties.

Several factors such as the crude oil source, refining process, fuel quality control, fuel delivery, and storage tank maintenance all contribute to fuels with different properties. Verification of the fuel's properties is lacking. However what data was collected, shows some fuels with low sulfur content have high aromatic content and cetane. Other fuels with low sulfur content have low aromatic content and high or low cetane. These fuels have different combustion characteristic.

The current changes and future changes to fuel supply will result in several adjustments to maintain locomotive performance, railroad operations, and railroad infrastructure. The future emission regulations and fuel supply should result in an overall improvement in air quality.

Summary

Along with the engine system controls, the fuel's properties combine to affect the fuel consumption, fuel system durability and reliability, and insure emissions are within EPA regulations.

Acknowledgements

The authors wish to thank CN, UP and GE Rail for permission to publish this work. The authors are grateful to the eight railroads for answering the survey questions and submitting data. We would like also to thank the LMOA's FL&E Committee members for their review of this paper. They also give special thanks to Gary Dudenhoefer (GE), Leighton Haley (NS), Brian Kelly (GE), and Steve Fritz (SWRI) for their assistance in the editing of this paper, and Dr. Fred Girshcik Ph.D. (Infineum) for the chemical structures.

References

1. Title 40-Protection of Environment 40CFR Part 80, Regulation of Fuels and Fuel Additives.

2. United States Department of Energy, the Energy Information Agency (EIA).

3. *Fuel Oil Manual Fourth Edition Paul F. Schmidt Industrial Press Inc. 1985.*

Appendix 1

Number of suppliers:

Railroad	Response
1	Supplied test data, but skipped survey question
2	Unknown
3	58 (but 95% from 18 major suppliers)
4	6
5	5
6	Unknown
7	1
8	1

Type of supply (pipelines, barges, tankers, supply trucks)

Railroad	Response
2	All
3	35% tank cars, balance via truck
4	Truck
5	Truck
6	Trucks and tankers
7	Tanker truck
8	Various

Number of supply locations:

Railroad	Response
2	38
3	23
4	48
5	5
6	6
7	1
8	Many

Sulfur content from each supplier

Railraod	Response
2	All fueling locations measured on a quarterly basis
3	60% supply is less than 500-ppm
4	Less than 15-ppm
5	Average 348-ppm
6	500-pppm maximum
7	Below 500-ppm
8	Less than 50-ppm

Supplier verify the fuel meets a specification and frequency (all vs. some parameters)

Railroad	Response
2	?
3	Yes, monthly
4	N/A
5	Yes, (frequent)
6	Blank
7	Yes, each cargo
8	Yes, each batch

Railroad verify the fuel meets specification and frequency (all vs. some parameters)

Railroad	Response
2	All ASTM parameters performed on new fuel suppliers. Month: thermal stability, visual for haze (particulate and water questionable), API gravity, lubricity (ultra low sulfur locatins). Quarterly: sulfur, BTU, density (all locations)
3	No
4	N/A
5	Yes (only some parameters, frequent)
6	Quarterly, three tests
7	No
8	No

Lubricity testing, test responsibility, lubricity addtive responsiblity

Railraod	Response
2	Refinery no, distributor no, Railroad yes, (monthly by HFRR) Lubricity addtive by railroad
3	Railraod on demand only
4	Refinery yes, distributor no, Railroad no, lubricity additive at refinery
5	Blank
6	Refinery tests and adds additive
7	Refinery tests and adds additive
8	N/A on testing, unsure if additive is used

Perfcent fuel that is greater than 500-ppm, less than 500-ppm, less than 15-ppm

Railroad	Response		
	5000<>500	500<15	<15
2	76.7	23.3	9.5
3	35.0	60.0	5.0
4	0.00	0.00	100
5	0.00	100	0.00
6	0.00	100	0.00
7	0.00	100	0.00
8	0.00	100	0.00

APPENDIX 2

Table 1 2007 Railroad Diesel Fuel Survey Respondent Results

Test	Test Method	ASTM D975 No2 Limits	Avg.	max	Min	StDev	no. inputs*
Flash Point (min)	D 93	52 (125.6)	69	86	54	7.65	24
Water and Sediment, %	D 2709	0.05	0	2	0	0.50	16
90% vol recovered min C (F)	D 86 Distillation	282 (539.6) Min 338 (640.4) Max	328	352	288	17.90	20
90% vol recovered min C (F)	D 2887 Sim Dist	300 (572) Min 356 (672.8)max	333	348	317	22.13	2
Viscosity cSt 40 C min	D 445	1.9 min 4.1 max	2.9	3.9	2.0	0.52	20
Ash % weight	D 482	0.01	0.001	0.002	0.000	0.001	11
Sulfur % S 5000	D 129	0.5000	0.2637	0.4320	0.0600		11
Sulfur % S 500	D 2622	0.0500	0.0028	0.0489	0.0061		14
Sulfur % S 15	D 5453	0.0015	0.0012	0.0044	0.0001		10
Copper Corrosion	D 130	No. 3 max	1	1	1	0.00	13
Cetane No.	D 613	40 min	51	61	45	7.33	4
Cetane Index	D 976	40 min (S15, S500)	51	63	35	6.79	17
	D 4737		48	49	48	0.49	2
Aromaticity, % vol, max	D 1319	35 Max (S15, S500)	23	35	9	8.27	11
Cloud Point	D 2500	Note req	-9	-1	-25	7.48	12
LTFT/CFPP	D4539 / D6371	Note req	-22	-7	-37	21.21	4
Ramsbottom carbon residue	D 542 on 10% dist residue, % mass, max	0.35	0.08	0.22	0.01	0.07	9
Lubricity, HFRR @ 60 C, max, µm	D 6079	520	396	545	280	65.77	13

Railroad's Addition Test							
Test	Test Method	ASTM D975 No2 Limits	Avg.	max	Min	StDev	no. inputs
Density 15 C kg/m3 min			840	879	811	19.69	14
Pour Point, °C	ASTM D97		-15	-6	-30	10.48	6
Colour							2
Distillation	ASTM D86						
IBP, °C			182	202	164	11.14	9
10%, °C			211	228	190	12.52	11
50%, °C			268	286	253	9.49	13
90%, °C			329	349	297	16.42	9
FBP, °C			356	376	325	18.22	9
Recovered, %			98	99	97	0.68	6
Residue, mL			1.02	1.40	0.10	0.50	6
Loss, mL			1.00	1.30	0.50	0.35	5
Simulated Distillation	ASTM D2887						
IBP, °C			117	122	112	7.21	6
10%, °C			207	216	198	13.01	6
50%, °C			271	285	258	18.74	6
90%, °C			333	348	317	22.13	6
FBP, °C			386	407	365	29.63	6

Test	Test Method	ASTM D975 No2 Limits	Avg.	max	Min	StDev	no. inputs
Acid Number	ASTM D 664						
Inflection, mg KOH/g			0.43	0.46	0.40	0.03	3
Buffer, mg KOH/g							0
IBP			178	181	175	4.41	6
10% point (F)			197	211	183	13.79	3
50% point (F)			245	260	238	12.86	3
EP (F)			334	360	309	25.55	3
Gravity API			36	41	31	2.75	10
Hydrocarbon Composition							
Aromatics			23	35	9	10.54	7
Olefins			3	5	1	1.48	6
Saturates			74	89	62	10.60	7
Conductivity, pS/m			537	756	318	309.71	2
Fuel Oil Stability, Initial			L0.5				1
Fuel Oil Stability, Aged			L2.5				1
Water, wt ppm			134	200	70	61.48	5
Mercaptain sulphur, mg/kg			17	17	17		1
BTU/US Gal			136800	140933	131539	2619.37	8

Figure 1: Fuel sulfur trends from January 1994 to January 2006

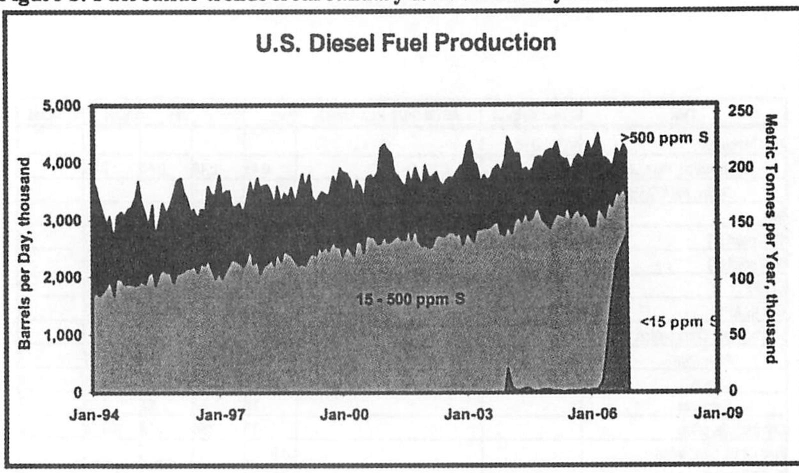
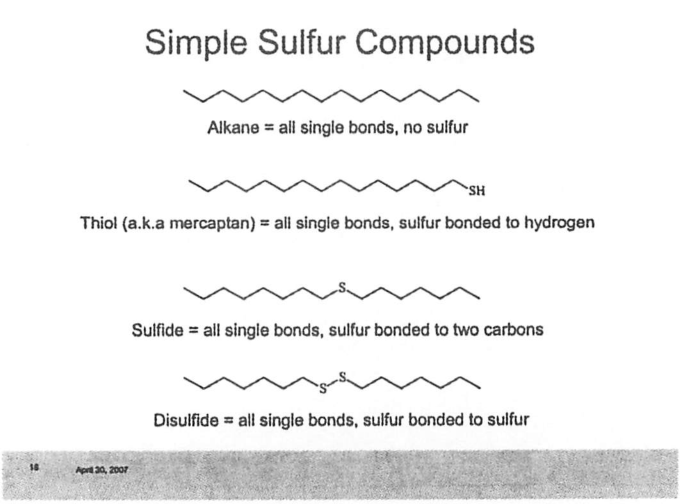
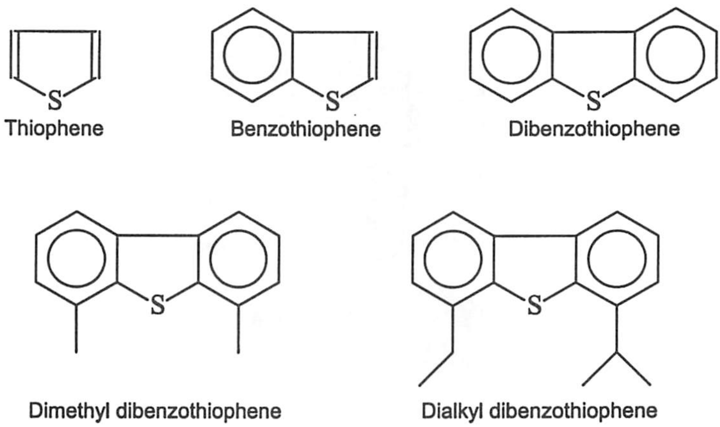


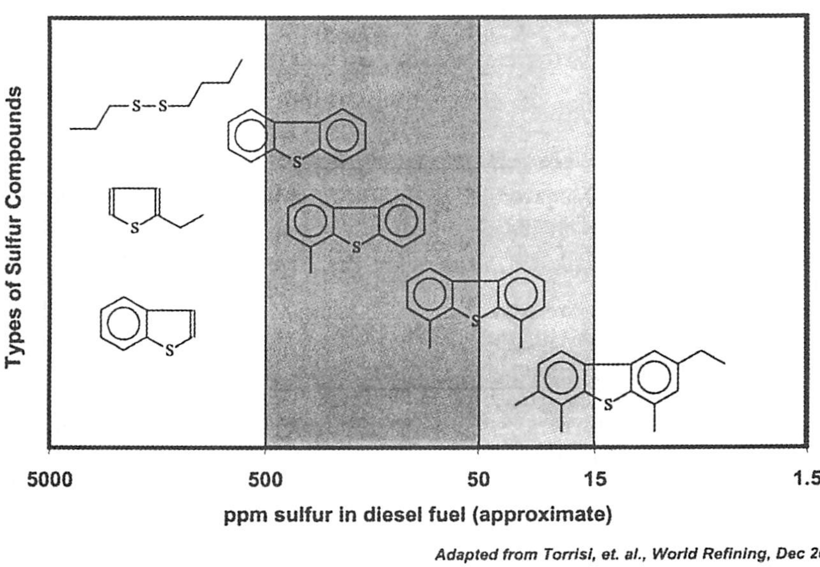
Figure 2 illustration of the diversity of a very few compounds with and without sulfur



Aromatic (Ring) Sulfur Compounds



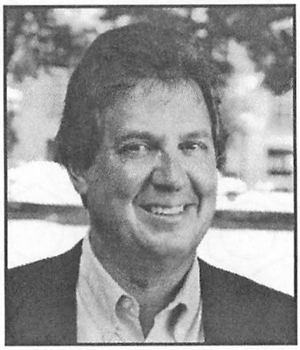
Ease of Removing Sulfur



Adapted from Torrisi, et. al., World Refining, Dec 2002

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

FRIDAY, SEPTEMBER 14, 2007 9:15 A.M.



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Note: Bill Lechner is a Past President of LMOA

PERSONAL HISTORY

Bob Harvilla

Regional Sales Manager

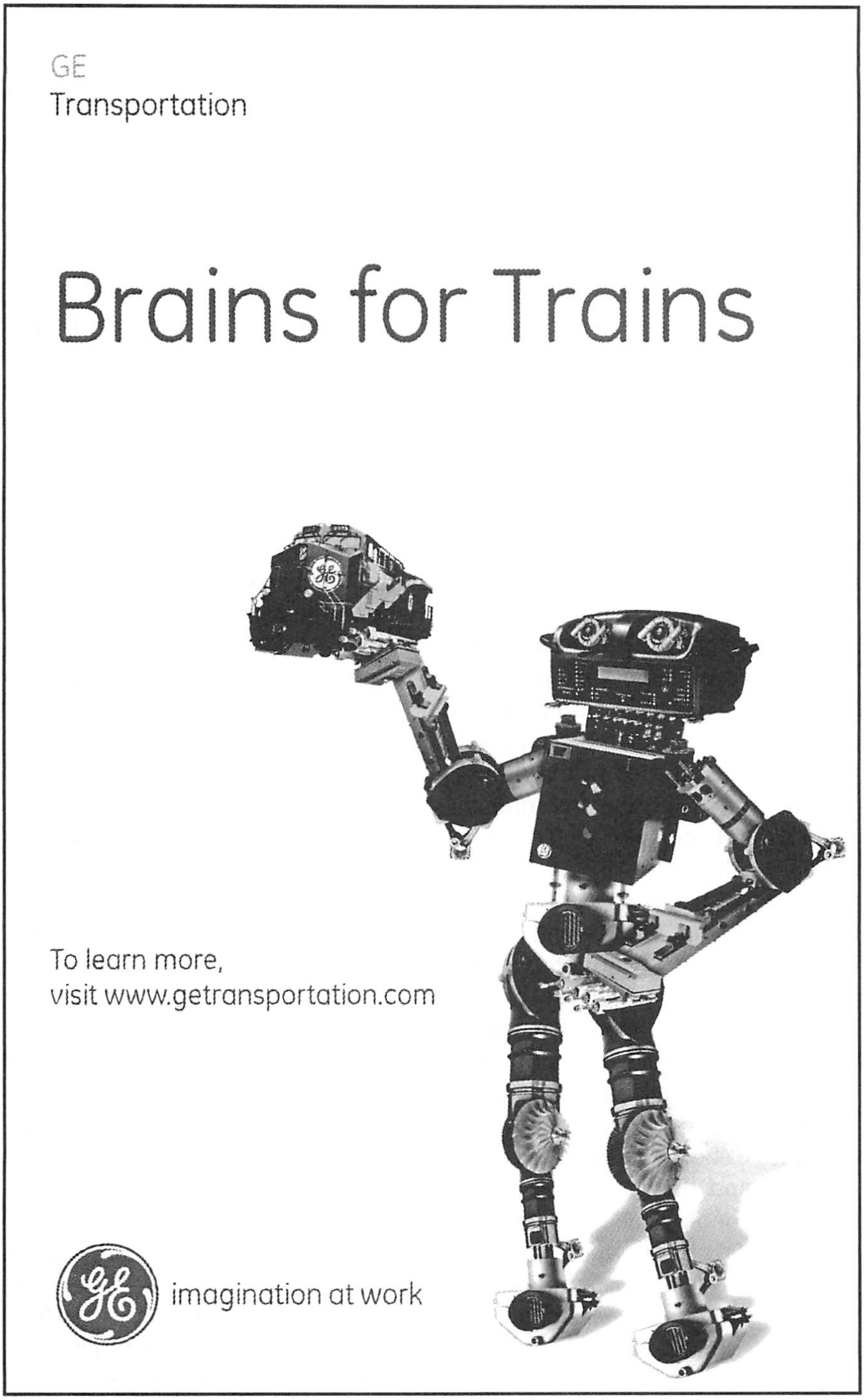
Standard Car Truck Co., Standard Locomotive Group

Bob Harvilla began his career in 1973 at the General Electric Co. Cleveland Apparatus Service Center, and had a total of 22 years of service with GE. He is currently responsible for sales of the Standard Locomotive Group Companies - Durox, Triangle Engineered Products and Railway Equipment Associates. He resides in Medina, Ohio, and works out of the Durox offices in Strongsville, Ohio.

Bob and his wife Barb have been married 31 years and have two sons: Rob, 29 and Ryan, 24.

THE DIESEL MATERIAL CONTROL COMMITTEE
WOULD LIKE TO EXTEND THEIR SINCERE APPRECIATION TO RAIL PRODUCTS INTERNATIONAL FOR HOSTING THEIR WINTER MEETING IN BROWNSVILLE, TEXAS ON FEBRUARY 26, AND 27, 2007

SPECIAL THANKS TO RON SULEWSKI FOR MAKING THE NECESSARY ARRANGEMENTS FOR THIS MEETING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imagination at work

INSOURCING
vs.
OUTSOURCING
"THE ALTOONA STORY"

Prepared by
Joe Richardella,
System Manager,
Locomotive Sales and Marketing,
Norfolk Southern Corporation

The following paper will describe the history, capabilities, and philosophies of the railroads that have owned the "Altoona Works" over the past 150 years.

Although the Pennsylvania Railroad began its Altoona operation in 1850, most of the major buildings were constructed in the 1880's and 1890's, primarily for the purposes of repairing and building new steam locomotives. Virtually every component required for the assembly process was fabricated in one of the shops within the Altoona complex. Employment peaked at approximately 15,00 in the 1920's.

The facility grew significantly throughout the 1900's and then underwent it's first modernization program in the early 1960's to enable the servicing and maintenance of diesel locomotives. Under the Conrail banner, it was again upgraded in the late 1970's to improve shop flow, increase efficiencies, and bring the facility up to the technological standards of the 1980's. Today the Altoona complex covers 70 acres with slightly less than 30 acres under roof.

At that point in time, the facility's capabilities were as follows: Overhauls of locomotives, truck assemblies including traction motors and wheelsets, engines and associated components, alternators, generators, fans, blowers, electrical components, air compressors, air brake valves, etc. The facility was also equipped to perform wreck repairs, testing, painting, fabricating and machining operations.

The upgrade that was completed in the early 1980's was done with the thought of maintaining a fleet of 5000 locomotives. Since Conrail's fleet never reached that level, a plan was developed to offer the excess rebuild capacity to other customers in the industry. After a series of proposals, Conrail's senior management approved the "Insourcing" concept in 1990. For several years, Conrail solicited all types of Insourcing work from large to small contracts. Some of the major projects during the first few years were for passenger carriers such as Amtrak, Go Transit of Toronto and New Jersey Transit (NJT). As a matter of fact, NJT's Quality Assurance Department assisted in initiating the ISO process at the Juniata Locomotive Shop. Over the next nine years, work was performed for Class I Carriers, Regional Railroads, Transit Authorities, Original Equipment Manufacturers (OEM), Shortlines, Equipment Leasing Companies and Overseas Railroad customers. Between 1995 and 1998, the Altoona facility was able to provide a major service to both OEM's and the railroad industry by assembling new locomotives at a time when both builders were operating at their maximum production capacity. In 1999, both builders requested assistance in assembling locomotives and for the first time in history, EMD and GE locomotives were assembled under the same roof. Insourcing was proving to be a successful business for the railroad.

In June 1999, the Juniata Locomotive Shop became a part of the Norfolk Southern Corporation. NS was focused on increasing revenue and reducing operating costs. Duplicate operations were consolidated and several facilities were closed. At the same time, commitments were made to make substantial capital improvements to various shop facilities, including Altoona. However, in the eyes of some Altoona customers, Norfolk Southern's commitment to Insourcing was uncertain. As a result, the Insourcing business slacked off in the period following the sale of Conrail. But in the months to come, the Juniata Locomotive workforce set out to prove to Norfolk Southern's senior management that Altoona was firmly established as a safe, productive work place providing high quality products for the railroad and external customers across the industry.

During this period of time, many cost comparisons were conducted concerning the inhouse rebuild of various components. After all, the rest of the Railroad Industry was in the "Outsourcing" mode. Through these studies, the facility's strengths and weaknesses were identified. As a result, several components that were not being repaired cost effectively, such as governors, fuel injectors and cooling fans, were "Outsourced" as the workforce concentrated on its core competencies.

Under Conrail ownership, Altoona had primarily been a five day per week; one or two shift per day operation. Norfolk Southern's overhaul schedule and expectations for reduced locomotive out-of service time drove a change in this philosophy. Soon after June 1999 adjustments were made that turned the Juniata Locomotive shop into a seven day per week, three shift per day operation, particularly with regard to locomotive overhaul activity. The employees that became available from the reduced component rebuild processes filled positions that were created to support the new 24/7 work schedule.

Over the next few years, positive financial results and successful balancing of the workload were major factors that contributed to a growing support for Insourcing within Norfolk Southern. Today, the Insourcing activity is carefully balanced with Norfolk Southern's Capital and Expense programs for maintaining the NS locomotive fleet of 3700 units.

Presently, our philosophy is to seek the type of work at which we excel at in Altoona while seeking to be price competitive. We work hard to fit such Insourcing work into a busy Norfolk Southern schedule of locomotive activity. While it is our desire maintain stable levels of employment, we remain open to business opportunities that would allow us to serve our customers and warrant higher levels of employment.

In conclusion, while many other Class One Railroads have over the years shifted to the "Outsourcing" of locomotive work, NS is committed to continue "Insourcing" through its Thoroughbred Mechanical Services group (a division of the Mechanical Department), as a means of serving not only the Norfolk Southern Corporation, but the rest of the railroad industry.

REPORT OF THE COMMITTEE ON NEW TECHNOLOGIES

FRIDAY, SEPTEMBER 14, 2007
10:45 A.M.

Chairman
JIM CHRISTOFF
Business Mgr.-Traction Segment
National Electircal Carbon Products, Inc.
Cicero, NY

Vice Chairman
RICH DALTON
Director-Project Management
Motive Power Inc.
Boise, ID

COMMITTEE MEMBERS

D. Brabb	Director	Sharma Associates	Countryside, IL
B. Kehe	Mgr-Maintenance-Locos	EJ&E Rwy.	Gary, IN
A. Miller	President	Vehicle Projects LLC	Denver, Co
C. Prudian	Senior Systems Engineer	Electro Motive Diesels	LaGrange, IL
D. Sweatt	Elect. Systems Engineer	CSX Transportation	Jacksonville, FL
T. Volkmann	Dir.-Mech. Engrg.	Union Pacific RR	Omaha, NE
J. Whitmer	Loco. Rel. Specialist	CN RR	Homewood, IL

Note: Bruce Kehe and Tad Volkmann are Past Presidents of LMOA

PERSONAL HISTORY

Jim Christoff
Business Manager, Traction Segment
National Electrical Carbon Products, Inc.
Cicero, NY

Jim who was raised in Western Pennsylvania now finds himself living in Cicero, NY. His 25 plus years in the carbon business have given him a broad knowledge of DC rotating equipment and an understanding of the operating conditions and environments that are present in railroad freight and passenger service.

Jim has worked for Morgan Crucible plc (parent company of NECP) for 18 years. From 1989 thru 2001 he handled the East Coast Transit, Industrial, and Consumer Business. In 2002 he started working exclusively on Transit, Traction business and in 2005 he was promoted to Business Manager of Traction in the Americas.

Jim and his wife Diane have 2 children and 2 grandchildren. When work is done they enjoy boating, golfing, and visiting their children.

THE NEW TECHNOLOGIES COMMITTEE
WOULD LIKE TO EXTEND THEIR
SINCERE APPRECIATION TO
MOTIVE POWER INDUSTRIES
AND
RICH DALTON
FOR HOSITING THEIR COMMITTEE
MEETING IN
BOISE, IDAHO ON
DECEMBER 7, 2006

THE COMMITTEE ALSO WISHES TO
THANK UNION PACIFIC AND
MAGNUS-FARLEY FOR HOSTING
THEIR WINTER COMMITTEE
MEETING IN
OMAHA, NEBRASKA ON
MARCH 23, 2007

1. FUELCELL HYBRID SWITCHER LOCOMOTIVE: ENGINEERING DESIGN

Prepared by
Arnold R. Miller, Ph.D
Vehicle Projects LLC
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Introduction

Fuelcell power for locomotives combines the environmental benefits of a catenary-electric locomotive with the higher overall energy efficiency and lower infrastructure costs of a diesel-electric. Catenary-electric locomotives - when viewed as only one component of a distributed machine that includes an electricity generating plant, transformers, and transmission lines - are the least energy-efficient and most costly locomotive type. Diesel-electric locomotives, while collectively worse as sources of air pollution than an equal number of catenary-electric locomotives driven by a coal-fired powerplant, are more energy efficient and have a less expensive energy infrastructure. While being zero-emissions vehicles, fuelcell locomotives are more energy efficient than and have similar fuel infrastructure costs to diesel locomotives. Elimination of high catenary-electric infrastructure costs by fuelcell locomotives is the key to economic viability of zero-emission, low-noise electric trains in low population density regions such as the western USA.

Fuelcell locomotives can help resolve the joined issues of urban air quality and national energy security affecting the US rail industry and transportation sector as a whole. The issues are related by the fact that about 97% of the energy for the transport sector is based on oil, and more than 60% is imported. Because its primary energy is based largely on combustion of fossil fuels, the transportation sector is the largest source of air pollution. Beyond local air quality, a consensus has been reached that the burning of fossil fuels is a significant factor in global climate change. The greenhouse-gas effect is the likely cause of melting of the polar ice caps and the increased severity of storms. Energy security is low because world oil reserves are diminishing, demand is increasing, and political instability threatens supply disruptions.

Furthermore, a need exists for large vehicles that serve, in addition to conveyance, as mobile backup power sources ("power-to-grid") for critical infrastructure. Power-to-grid applications include military bases and civilian disaster-relief operations. Indeed, following Hurricane Katrina, a makeshift jail in New Orleans was powered by an Amtrak diesel-electric locomotive.

A North American consortium (see Table 1), a public-private partnership, is developing a prototype hydrogen-fueled fuelcell-battery hybrid switcher locomotive (see Figure 1) for urban and military-base rail applications leading to commercial locomotives that will: (1) reduce air pollution in urban railyards, particularly yards associated with seaports, (2) increase energy security of the rail transport system by using a fuel (hydrogen) independent of imported oil, (3) reduce atmospheric greenhouse-gas emissions, and (4) serve as a mobile backup power source for critical infrastructure on military bases and for civilian disaster relief efforts. Initial demonstration of switching applications will be in rail yards in the Los Angeles Basin; initial demonstration of power-to-grid will be at Hill Air Force Base, Utah.

At 127 tonne (280,000 lb), continuous power of 250 kW from its fuelcell prime mover, and transient power well in excess of 1 MW, the hybrid locomotive will be the heaviest and most powerful fuelcell land vehicle to-date. The schedule for this fast-paced project calls for completion of the vehicle itself near the end of 2007. Contributing to the fast pace are: (1) the platform of the fuelcell-hybrid locomotive is based on a commercially available diesel-battery hybrid switcher (Green Goat™), (2) both the fuelcell powerplant and roof-mounted lightweight compressed-hydrogen storage system are derived from the Citaro™ fuelcell transit bus, and (3) private funding (BNSF Railway) supported project startup.

Vehicle Projects LLC is executing the engineering design of the fuelcell switcher. Several design and integration challenges arise when developing such a large hydrogen fuelcell vehicle. Weight, center of gravity, packaging, and safety were design factors leading to, among other features, the location of the lightweight compressed hydrogen storage system above the traction battery. Harsh operating conditions, especially shock loads during coupling to railcars require component mounting systems capable of absorbing high energy. Additionally, system design must address railway industry regulations governing safety and such events as derailment, side impact from yard traffic, refueling, and maintenance.

This paper is a status review of the fuelcell-hybrid switcher's engineering design as of June 2007. Three aspects of engineering design will be addressed: Packaging of the fuelcell power module, hydrogen storage, and shock and vibration isolation.

Background

Previous Large Fuelcell Vehicles

In previous projects, Vehicle Projects LLC has developed both hybrid and non-hybrid large industrial fuelcell vehicles. We have developed a fuelcell-battery hybrid underground mine loader [Miller, et al, 2004] [Miller et al, 2006B] and the world's first fuelcell-powered locomotive [Miller, 2000], [Miller and Barnes, 2002], and an underground mine vehicle that was not hybrid. Preliminary work on our surface railway fuelcell locomotive program has been reported in previous LMOA annual conferences [Miller, 2005], [Miller, 2006].

Fuelcells

Fuelcells are electrochemical power devices that directly convert the chemical energy of a fuel into electric power (see Figure 2). From hydrogen fuel and air (oxygen), they produce electricity and water - the reverse of water electrolysis. While fuelcells share principles of operation with batteries, they differ in that the electrochemically active materials, hydrogen and oxygen, are stored or are available externally and are continuously supplied to the device rather than being stored in the electrodes. They are periodically refueled, like an engine, rather than recharged electrically. Like batteries, individual cells are grouped together into "stacks" to provide any voltage or power required.

By separating the energy storage and power production functions, fuelcells are more convenient , more efficient, and safer than storage batteries. They are more convenient because the refueling process can be completed in a few minutes rather than the hours required for efficient battery recharging. They are more efficient because the electrochemical losses that occur in batteries during recharge, as witnessed by their evolution of heat, do not apply to fuelcells. They are safer because short-circuiting a fuelcell harmlessly dissipates only the energy associated with the small amount of hydrogen present in the cell - in contrast, short-circuiting a storage battery dissipates all of its stored energy.

Insight into fuelcells follows an understanding of the special place of hydrogen, their natural fuel, among the chemical elements. Most of the elements of nature are metals, and while most have the familiar metallic properties, not all do. Mercury (Hg), a liquid, lacks hardness. Hydrogen, a gas, would seem to lack all metallic properties. Nonetheless, the most fundamental characteristic of a metal is its tendency to donate electrons in chemical reactions, and on this basis, hydrogen is classified as an alkali metal in the first column of the periodic table. Moreover, solid hydrogen (at low temperature) has decidedly metallic properties. This construct of hydrogen as a gaseous metal allows us to readily see the fuelcell as a special type of battery: Conventional batteries use a metal such as lead, cadmium, or lithium as the anode material (negative plate), while fuelcells use a gaseous metal as anode material, and this is the basis of their advantages of separate energy storage and being refuelable.

This simple fact of using gaseous electroactive materials has far-reaching implications: (1) The energy-storage component is separated from the power-producing component. Unlike a conventional battery, in which the metal electrodes or plates serve as both the energy-storage and power-production functions, the fuelcell separates these two functions, and power and energy are not linked. (2) As implied by Figure 2, energy for the vehicle is stored in a fuel tank, analogous to the fuel tank of a conventional engine vehicle, and the vehicle may be rapidly refueled by refilling its fuel tank.

Because fuelcells are electrochemical power devices, essentially "refuelable" batteries, they are not limited in thermodynamic efficiency by the Carnot limit faced by heat engines. Fuelcells do have an analogous limit, namely, the intrinsic maximum efficiency. Depending on the fuelcell type, the intrinsic maximum efficiency is typically in the range of 80-90%. As a rule of thumb, the overall practical efficiency of a fuelcell powerplant is on the order of 50%, compared to 30-40% for an internal combustion engine.

The type of fuelcell used in our projects, and exclusively favored by the auto industry, is the proton-exchange membrane (PEM) type, which uses a solid ion-exchange membrane for its electrolyte.

Hydrogen Storage

Storage of hydrogen onboard the vehicle is a greater technical challenge than producing power from a fuelcell. Methods of storage appropriate for locomotives include (1) direct storage of hydrogen as a compressed gas, (2) direct storage as a liquid, (3) direct storage as a reversible metal hydride [Miller, 2005], (4) onboard chemical transformation to hydrogen of a carbon-based feedstock such as a hydrocarbon or alcohol, and (5) physical dissociation of liquid ammonia to hydrogen.

For industrial vehicles in general, and especially for locomotives, minimum volume of the fuel storage system or powerplant is more important than minimum weight. That is, a high hydrogen volumetric density is more important than a high gravimetric density. Table 2 displays the limits or theoretical values of hydrogen volumetric density, as kg/m³, for the five fuels abovementioned [Miller, et al, 2007]. These limits are a theoretical construct - they provide a measure of the best possible volumetric density that a given fuel can attain. They omit the volume of the container, associated hardware, and chemical processor. For example, if one had a cubic meter of hydrogen at a pressure of 350 bar, but stored in a tank, with piping, etc. of infinitesimal volume, the cubic meter would store 25 kg of hydrogen, corresponding to a volumetric density of 25 kg/m³. In the case of methanol, which requires reacting the alcohol with water at high temperature over a catalyst to produce hydrogen according to the equation

$$CH_3OH+H_2O \rightarrow 3H_2+CO_2$$

the limiting volumetric density also omits the volume of the reactant water (in principle, water can be obtained from the fuelcell). The results show that, in the limiting case, the reversible metal hydride is capable of the highest hydrogen volumetric density, namely, 125 kg/m³, and compressed hydrogen, the lowest.

A measure of energy content of these masses of hydrogen is provided by the fact that the chemical energy in one kilogram of hydrogen is approximately equal to the energy in one gallon of gasoline.

Real systems require volume for their hardware (e.g. tank, piping, and valves, as well as chemical reactors for methanol and ammonia), and thus the practical hydrogen volumetric densities shown in Table 3 are smaller than the theoretical values of Table 2. The practical densities were computed from the volumes of actual systems [Miller, et al, 2007]. For example, based on scale-up of the liquid-hydrogen storage system of the commercially available BMW Hydrogen 7™ automobile, the hydrogen volumetric density of a real liquid hydrogen system is 26 kg/m^3 rather than the 70 kg/m^3 for the theoretical system. The volume of systems using a chemical processor, a methanol reformer or ammonia dissociator, depends on power. That is, greater power of the vehicle, and thus greater hydrogen flow, requires a larger chemical reactor. Because our vehicles store hydrogen mass on the order of 100 kg and produce power on the order of 300 kW gross, we computed the densities of Table 3 for a system storing 100 kg of hydrogen and sustaining a power of 300 kW. The density of the practical methanol system includes the reactant water, as well as the reformer hardware.

"Storage Efficiency" is defined as the Practical Density / Theoretical Density x 100%. For example, liquid hydrogen has a storage efficiency of 26 kg/m^3 / 70 kg/m^3 x 100% = 37%. Storage Efficiency is a measure of how closely a storage system approaches its volumetric density limit or theoretical density; it is a measure of how well a storage system lives up to its potential, the limits of Table 2.

In conclusion, with today's technology, liquid ammonia, at 44 kg/m^3, has the highest practical hydrogen volumetric density. Compressed hydrogen, at 10 kg/m^3, has the lowest. Compressed hydrogen and liquid ammonia, at 40% each, have the highest storage efficiency, and reversible metal hydride storage, at 16%, has the lowest.

In choosing a hydrogen storage system for a vehicle, factors other than volume may be important. Four examples are weight, safety, cost, and thermodynamic efficiency.

Hybrid Powertrain

A fuelcell hybrid powertrain utilizes a fuelcell prime mover, plus an auxiliary power/energy-storage device to carry the vehicle over power peaks in its duty cycle and recover kinetic or potential energy during braking. To allow steady-state operation, the continuous net power of the prime mover must equal or exceed the mean power of the duty cycle. Figure 3 depicts the general case of such a powertrain. As we have shown in previous papers [Miller, et al, 2006 A], [Miller and Peters, 2006], whether a hybrid rail vehicle is worth its extra complexity and generally lower thermodynamic efficiency depends on the application and, in particular, the duty cycle. For example, freight trains should garner little benefit because they operate at nearly constant power and the kinetic energy is so high that practical auxiliary storage devices can recover only a small fraction of the total available energy during regeneration. On the other hand, we have shown that a hybrid switcher can offer the benefit of reduced capital or recurring costs [Miller, 2006]. The degree to which the powerplant of a vehicle is hybrid is termed its "hybridity" [Miller, 2001].

Results and Discussion

The overall design layout of the 127-tonne fuelcell-hybrid switcher, derived from the Green Goat™ by replacing its diesel-generator with a 250-kW fuelcell powerplant based on the powerplant of the Citaro fuel-cell transit bus, is shown in Figure 4. Citaro fuelcell-powered buses, widely used in European cities, have a combined operating experience of more than 1.5 million kilometers. Unlike our fuelcell-hybrid switcher, the buses are not hybrid's, that is, their hybridity h = 0 [Miller, 2001].

The rational starting point for engineering design of a fuelcell-hybrid vehicle is the duty cycle. Figure 5 shows a typical duty cycle - that is, the function P(t), where P is vehicle power and t is time - recorded from an in-service yard-switching locomotive. The vehicle's required mean power, maximum power, power response time, and power duration may be calculated from function P; its energy storage requirements are calculated from the integral of P. As shown, peak power commonly reaches 600-1000 kW for durations of no more than several minutes - usually corresponding to acceleration of train cars or uphill movement. However, between the peaks, the power requirements are minimal, as when coasting a load, or zero when idling between move operations. The idle time, varying from minutes to hours between operations, usually accounts for 50-90% of the overall operation schedule. Our analysis of multiple duty-cycle data sets from various railyards shows that the short duration of peak power and long periods of idle time result in mean power usage in the range of only 40-100 kW. The sharp peaks, low mean power, and long idle intervals of the duty cycle are ideal for a hybrid powertrain [Miller, 2001], [Miller, 2006].

For a hybrid vehicle to be self-sustaining, the prime mover, a hydrogen PEM fuelcell in this case, must provide continuously at least the mean power of the duty cycle. The auxiliary energy storage device, lead acid batteries in this hybrid, must store sufficient energy to provide power in excess of the continuous power rating of the fuelcell and must do so continuously under operation of the duty cycle. This energy must be available while not exceeding a rather shallow depth of discharge, which significantly increases the size of the battery. Allowable depth of discharge is a function of acceptable battery cycle life and recharge rate. With lead-acid batteries, depth of discharge is limited to approximately 80% of full capacity. Because the battery capacity of this vehicle was based on the original 200kW diesel prime mover, it will easily provide the storage required for our 250 kW fuelcell prime mover. The original lead-acid traction battery, in parallel with our fuelcell prime mover, allows transient power well in excess of 1 MW. For the power-to-grid application, the hybrid locomotive can provide only 250 kW of net power on a continuous basis but can provide power surges in excess of 1 MW.

The total vehicle systems diagram is shown in Figure 6. Integration of the fuelcell system has been influenced by several key factors, including safety, packaging constraints of the platform chassis, locomotive environmental operating conditions, and serviceability. Moreover, we have given consistent attention to minimizing system cost, use of off-the-shelf, proven hardware, and the possibility of future volume manufacturing. With these factors guiding design, the end product consists of five bolt-in modules: fuelcell powerplant, DC/DC power converter, cooling module, and two hydrogen storage modules. The modules will be independently tested, tested as an integrated system, and then installed in the locomotive platform vehicle.

The fuelcell powerplant, power converter, and cooling module are housed in the rear compartment. Already housed in the rear compartment are the locomotive air compressor, which is used for brakes and various other locomotive systems, and a blower motor that provides cooling to the rear traction motors located on the locomotive trucks. These two components occupy the lower left side of the rear compartment and were not modified in order to minimize redesign of the existing locomotive systems. Service points of the fuelcell powerplant greatly influenced the overall component layout in the rear compartment. All service points are located on the perimeter of the powerplant to allow full service without module removal. The powerplant resides on the right side of the rear compartment. Because the power converter requires minimal access, it is located below the powerplant; this allowed the fuelcell stack modules to be oriented symmetrically opposite on the same plane, thus allowing removal of only the stack module for access to the top cover. This layout also allows symmetric piping of air and coolant to both fuelcell stack modules, and this results in closely balanced flow for the air and coolant systems, which are driven by a single compressor and pump, respectively.

The largest of the fuelcell system modules are the hydrogen storage modules. Each module consists of seven carbon-fiber composite cylinders that collectively store approximately 35 kg of compressed hydrogen. Given the physical space required for the cylinders, it was only feasible to mount the hydrogen modules under the chassis or above the existing traction battery. A thorough safety analysis highlighted two factors that led to packaging of the hydrogen system above the battery. First, because of the buoyancy of hydrogen, storing hydrogen below void volumes in the locomotive platform, battery rack, and rear hood could lead to confinement of leaked hydrogen and increase the possibility of detonation. In contrast, roofline storage allows for harmless upward dissipation of hydrogen in the event of a leak. Based on experiments involving the burning of automobiles [Crutzen, 2003], a hydrogen fire in open space above the vehicle, without detonation, is expected to be safer than a diesel fire below the vehicle. Second, locating the hydrogen tanks on the roof minimizes the likelihood of damage from common events such as derailment, track debris, and impact from yard traffic such as fueling trucks. Because of the relatively light weight of the hydrogen storage tanks (about 100 kg each), the roof location has minimal effect on vehicle center of gravity. Indeed, after conversion to hydrogen-fuelcell power, a ballast of approximately 9,000 kg will be placed in the undercarriage to bring the locomotive weight to its specified value of 127 tonne.

Reversible metal-hydride storage, the safe and compact technology we have used in our mine vehicles [Miller, et al, 2006 B], was also considered for the locomotive. However, it was not selected because of its lack of commercial availability, high cost, and surprisingly for a locomotive, its low gravimetric hydrogen density. The most appealing attribute of a metal hydride system is its ability to store hydrogen at very low pressure and its self-limiting characteristics for hydrogen release. Weight was a limiting factor on this vehicle because of the high weight of the lead-acid traction battery, but it may not be for future locomotives with smaller or lighter batteries or other auxiliary energy/power devices. Moreover, as metal-hydride technology continues to mature, it will presumably become more readily available and cost effective.

The locomotive's compressed hydrogen fuel storage uses readily available hardware and proven safety design measures. Two modules are mounted above the traction battery (see Figure 4), each consisting of seven carbon-fiber composite tanks (with aluminum liners), measuring 416 mm diameter x 2100 mm length, with a combined storage of 70 kg compressed hydrogen at 350 bar (5,100 psi). Detailed subsystem design and manufacturing of the modules will be executed by Dynetek Industries Ltd.

Each tank incorporates an excess flow valve, two thermally activated pressure relief devices (PRD), temperature sensor, electronically controlled solenoid valve, and manual shut-off valve. In the event of a line rupture between the tank and distribution manifold, the tank excess-flow valve will close. In the event of excessive heat (above 109 C), such as could be caused by a battery fire, the thermally activated PRD's will vent the tank contents through a routed vent line pointing upward and away from the vehicle. The temperature sensors are utilized by the control system to regulate refueling speed as well as indicate any over temperature warnings. The electronic solenoid valve is normally closed, powered open for run and refueling modes, and closed if a high level system fault is detected.

Each module contains a manifold fed by each individual tank. The module manifolds, each with independent pressure sensors, are connected to a primary distribution line that includes an excess-flow valve to control any ruptures in the primary distribution line. The primary distribution line connects to the refueling line, and then continues to a filter, pressure regulator, additional electronic solenoid valve, pressure sensor, and an additional PRD. The additional solenoid valve adds a layer of shutdown capability, while the pressure sensor verifies regulator functionality. As with diesel locomotives, an emergency shutoff device will be located on each side of the vehicle to allow non-operators or refueling personnel to shut down the fuel system.

Mounting of all fuelcell system modules to the locomotive is of critical importance. Switcher locomotives are frequently coupling to other cars, which can lead to shock loads up to 10 Gs (11 ms saw tooth). Although they have a short duration, shocks of this magnitude could lead to immediate or fatigued failure of components or mounting structures. To mitigate this harsh environment, each module is isolated from impact loads through the use of elastomer isolators.

There are three key factors involved in choosing the proper isolator and configuration to deal with the impact forces. First, the isolator must absorb enough energy to make the loads experienced by the components within acceptable limits, i.e. it must reduce shock loads from 10 G to no more than 3 G. Second, the isolator must absorb this energy through a deflection distance that is acceptable from a physical packaging and system interface standpoint. For example, if a particular isolation mount requires 30 mm of movement to absorb the required energy, this may be too much movement for a coolant hose that is connected to the particular component. Finally, the mounts' natural frequency should be well below the possible disturbing frequencies of the system. Additionally, the isolation system must provide proper shock protection in the horizontal, lateral, and vertical directions. Figure 7 shows the isolation system for the powerplant. Note that the mounting system is designed so that it is at the vertical center of gravity, which will minimize any rocking motion of the power plant and transmit force directly into the mounts. The effectiveness of this design has been determined by finite element analysis.

The operating time of the fuelcell-hybrid switcher between refueling operations depends on the duty cycle. Under the most demanding duty cycles, one could expect an operating interval as short as one day, i.e., refueling on a daily basis; in less demanding yards, the interval may be 3-5 days. A major factor in the operating interval is the amount of idle time in the duty cycle. Refueling time from a 160 bar tube trailer, using a hydrogen pump and holding tank, should be between 10 and 30 minutes and depends largely on the size and pressure of the holding tank and capacity of the high-pressure hydrogen pump.

Other aspects of vehicle development besides engineering design, in particular, hardware fabrication, are executed by a technical consortium (Table 1) managed by Vehicle Projects LLC.

The Switcher Project commenced 1 May 2006 and the locomotive will be completed near the end of 2007. The overall development and demonstration project consists of six phases as described in Table 4 and will require 29 months for completion. This project is an industry-government partnership. BNSF Railway Company is the industry funder and the US Department of Defense is the government funder.

Summary and Conclusions

Led by Vehicle Projects LLC, an industry-government partnership is developing and will demonstrate a fuelcell-hybrid switcher locomotive. Initial demonstration of switching applications will be in rail yards in the Los Angeles Basin; initial demonstration of power-to-grid will be at Hill Air Force Base, Utah. This fast-paced project will retrofit the commercially available diesel-hybrid Green Goat™ switcher with a 250 kW fuelcell powerplant based on the powerplant of the Citaro fuelcell transit bus. Analogous to the Citaro's fuel storage, fourteen carbon-fiber composite tanks are located at the roofline and store a total of 70 kg of compressed hydrogen at 350 bar (5,100 psi).

Several technical challenges not found in the development of smaller vehicles arise when designing and developing such a large fuelcell vehicle. Weight, center of gravity, packaging, and safety were design factors leading to, among other features, the roof location of the lightweight 350-bar compressed hydrogen storage system. Harsh operating conditions, especially shock loads during coupling to railcars, require component mounting systems capable of absorbing high energy.

The vehicle itself is scheduled for completion near the end of 2007. Contributing to the fast pace are: (1) the platform of the fuelcell-hybrid locomotive is based on a commercially available diesel-battery hybrid switcher, (2) both the fuelcell powerplant and roof-mounted lightweight compressed-hydrogen storage system are derived from a commercially available fuelcell transit bus, and (3) private funding (BNSF Railway) supported project startup.

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Acknowledgements

I thank my coworkers and contributors to this review: David L. Barnes, Kris S. Hess, and Timothy L. Erickson. We thank the following funders for their generous support of the projects described in this paper: US Department of Energy (contracts DE-FC36-99GO10458, DE-FC26-01NT41052, DE-FC36-01GO11095, and DE-FC36-05GO85049); Natural Resources Canada (*Emerging Technologies Program* contracts 23440-991022-001 and EA9730-F01-01); Government of Canada (Action Plan 2000 on Climate Change contract 23440-0310202-001); US Department of Defense (contracts F42620-00-D0036 and F42620-00-D0028); BNSF Railway Company; subcontractors to Vehicle Projects LLC who contributed project cost-share; and the Fuelcell Propulsion Institute. *Disclaimer:* Funding support from the US Department of Energy, US Department of Defense, Natural Resources Canada, Government of Canada, or BNSF Railway Company does not constitute an endorsement by same of the views expressed in this paper.

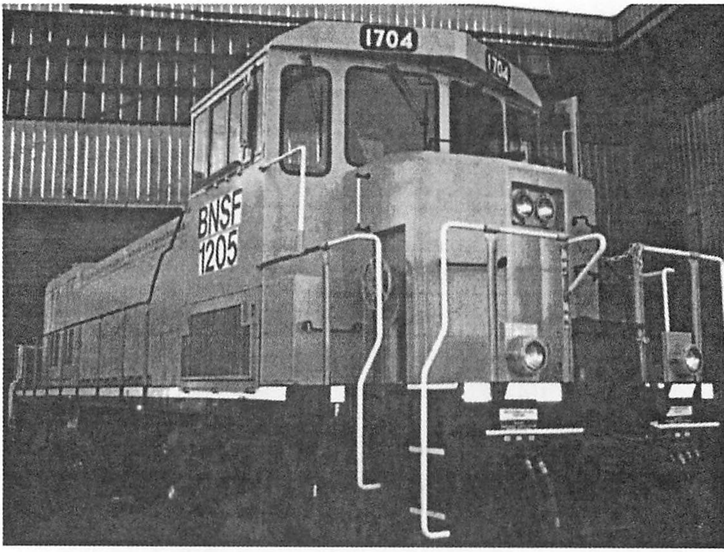


Figure 1 – Fuelcell-hybrid switcher platform vehicle. As shown, the diesel fuel tank and genset have been removed in preparation for retrofitting the fuelcell powerplant and hydrogen storage. (Photo courtesy of RailPower Hybrid Technologies)

TABLE 1: PROJECT CONSORTIUM	
Member	**Tasks**
Ballard Power Systems	Fuelcell manufacturer
BNSF Railway Company	Industry funder; vehicle integrator; rail-yard demo
Defense Gen. & Rail Equipment Center (DGRC)	Adviser on military applications; power-to-grid demo
Dynetek Industries	Hydrogen storage manufacturer
General Atomics	Power electronics developer
RailPower Hybrid Technologies	Manufacturer of Green Goat platform
Transportation Technologies Center, Inc	Railway safety regulations interpreter
University of Nevada - Reno	Refueling system
Vehicle Projects LLC	Engineering design; consortium & project management
Washington Safety Management Solutions LLC	Safety analysis

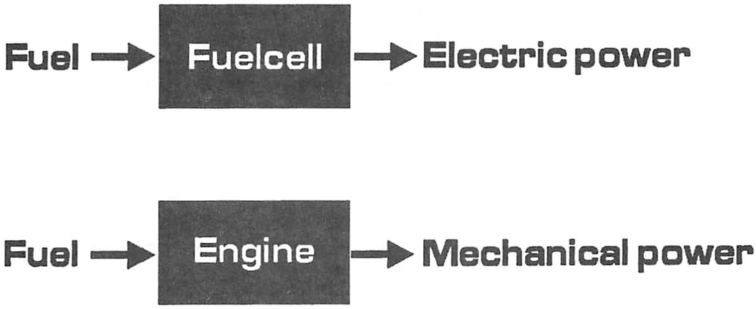


Figure 2 – Analogy between fuelcells and engines: Both are devices that convert energy to power, but the output of a fuelcell is electric power rather than mechanical.

TABLE 2: THEORETICAL HYDROGEN VOLUMETRIC DENSITIES		
Fuel System	**Conditions of Storage**	**H_2 Density, kg/m^3**
Compressed Hydrogen	350 bar (5,100 psi)	25*
Liquid Hydrogen	$\rho = .070$ g/mL (P = 1 bar, T = bp)	70
Methanol	$\rho = .79$ g/mL, (T = 25 C)	99
Liquid Ammonia	$\rho = 0.62$ g/mL, (P = 7.2 bar, T = 15 C)	110
Reversible Metal Hydride	AB_5 alloy ($LaNi_5$), $\rho = 8.3$ g/mL, wt % = 1.5, 10 bar	125

* If English units are preferred, comparable density units are lb/yd^3. The conversion factor is 1 kg/m^3 = 1.7 lb/yd^3. As a rough approximation, double the kg/m^3 densities to get lb/yd^3.

TABLE 3: PRACTICAL HYDROGEN VOLUMETRIC DENSITIES 100 kg Storage Sustaining 300 k/W Power		
Fuel System	Practical H_2 Density, kg/m^3	Storage Efficiency, %
Compressed hydrogen	10	40
Liquid hydrogen	26	37
Methanol (Reformer)	23	23
Liquid Ammonia (Dissociator)	44	40
Reversible Metal Hydride	20	16

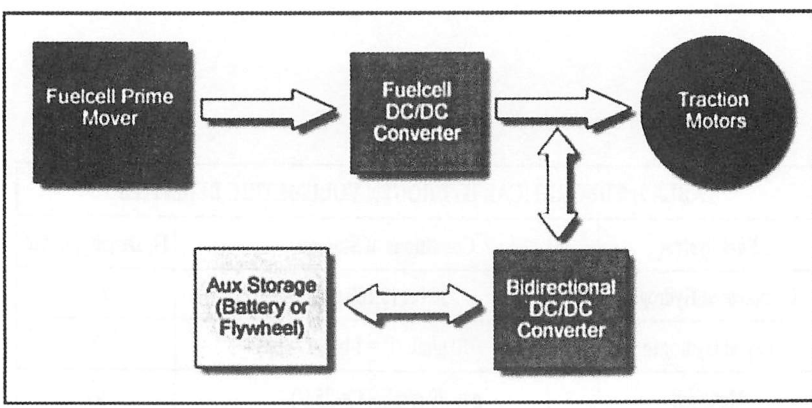


Figure 3 – Fuelcell Hybrid Powertrain: "Aux Storage" represents either a battery or flywheel auxiliary energy/power device. Arrows point in the direction of power flow. The traction motors (DC or AC) are used as generators during braking.

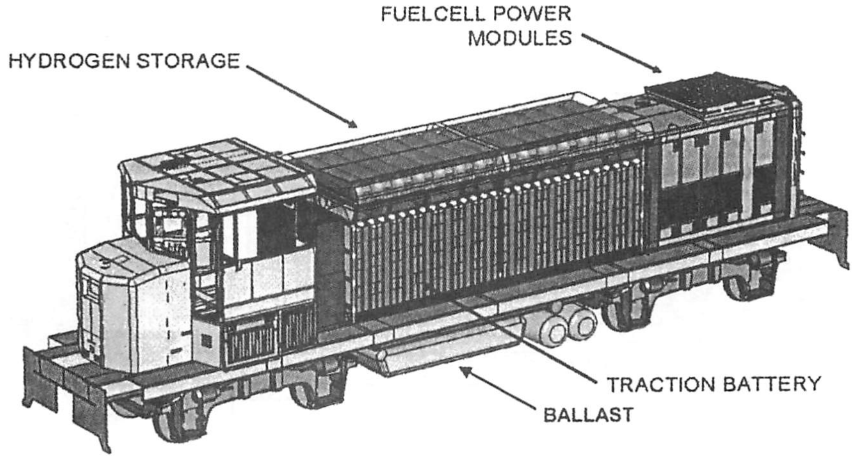


Figure 4 – Fuelcell Switcher: CAD model of the 250-kW fuelcell-hybrid switcher. The traction battery is the same as used in the Green Goat. Lightweight carbon-fiber composite tanks store 70 kg of hydrogen above the battery. Because of the lightness of the hydrogen-fuelcell system, additional ballast is equivalent to a cubic meter of steel.

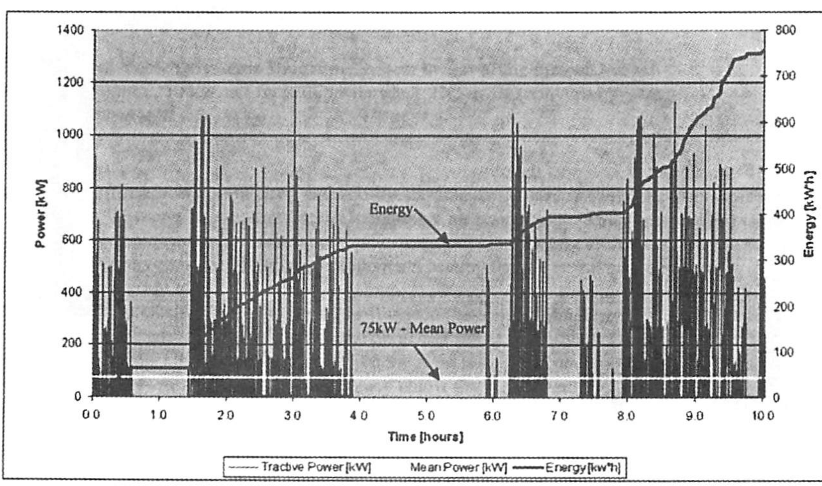


Figure 5 – Duty Cycle: Example (PHL) of a switcher locomotive duty cycle. The 75 kW mean power was computed over a total interval of 20 hours.

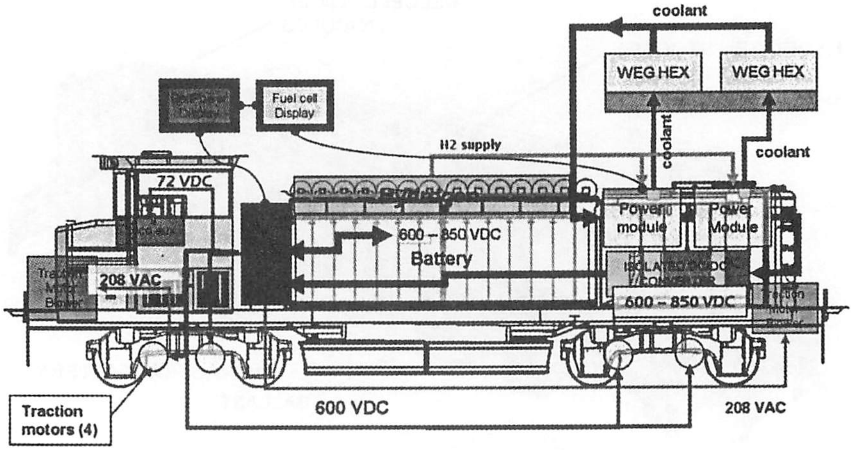


Figure 6 – Total Vehicle Systems Diagram: System layout of the fuelcell hybrid locomotive including 250 kW net fuelcell power plant, DC-to-DC converter, hydrogen storage, and control interface.

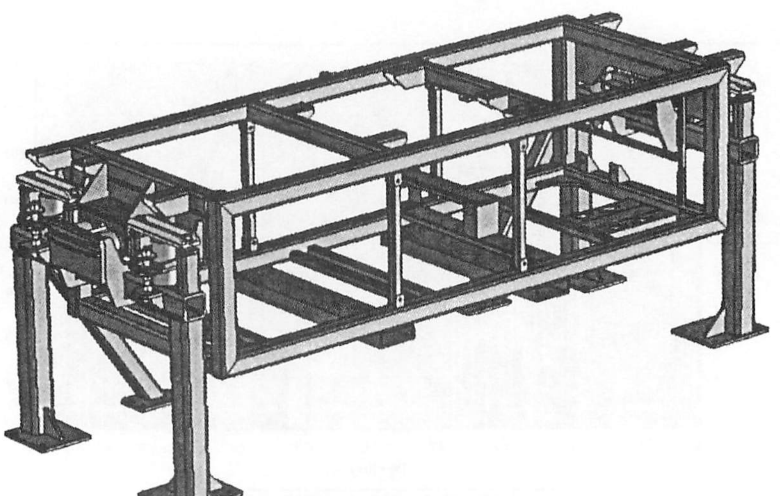


Figure 7 – Powerplant Frame: The design uses elastomer isolators to reduce shock loads from 10 G to no more than 3 G. Finite element analysis was used in the engineering design.

TABLE 4: PROJECT SCOPE			
Phase	**Executor**	**Start**	**Finish**
1. Engineering Design	Vehicle Projects	May 06	Apr 08
2. Fabrication of Green Goat Platform	RailPower	Jul 06	Mar 07
3. Fabrication of Major Subsystems:		Mar 07	Aug 07
Fuelcell power modules	Ballard, Vehicle Projects		
Power electronics	General Atomics		
Hydrogen storage subsystem	Dynetek		
4. Integration of Major Subsystems into Platform	BNSF Topeka Rail Shop	Aug 07	Dec 07
5. Demonstration in Rail Yards	BNSF	Jan 08	Jun 08
6. Demonstration of Power-to-Grid	DGRC	Jul 08	Sep 08
Total period of performance: 29 months Total project cost: $4.45 million			

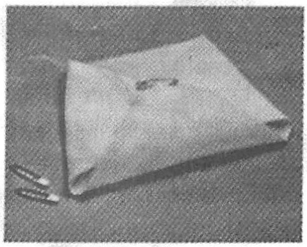
2. LOCOMOTIVE DIGITAL VIDEO RECORDER

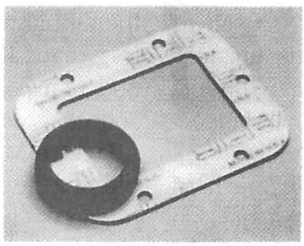
Prepared by
Derald Sweatt,
Electrical Systems Engineer
CSX Transportation

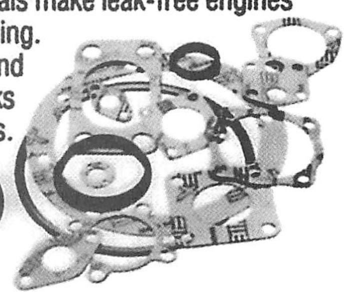
This paper will describe the different types of Digital Video Recorders that are being installed on road locomotives by Class 1 Railroads today. The paper will give details on installation, maintenance requirements and problems the recorders are having and the reasoning behind the positive effect the Digital Video Recorders are having in our court rooms.

The GE Digital Video Recorder is being installed on all CSX road locomotives. An install will take up to 8 man hours to complete. During an install, GE and CSX carefully plan where to mount the camera. There are two parts to the install; the first is to physically connect cables to the CMU (Communications Management Unit (Figure 1). The second part of the install is to route cable from the CMU to the camera. When this is completed, there is a verification test to validate that the equipment is communicating with the satellite. A clarity test is performed on the viewer before the install is signed off. An install is considered complete after the confirmation of the satellite connection. The antenna communicates with a GE satellite that is monitored 24/7. If a problem occurs, it will be caught immediately. The GE cameras that are installed at CSX are inside the cab (Figure 2). The model of the locomotive will determine exactly where the camera is mounted. Microphones are located in the brake compartment. The horn and the bell are the main audio that are heard on the video clips. CSX records on movement. When the throttle changes the LocoCam will start recording to the hard drive. The satellite antenna (Figure 3) is installed on the roof of the locomotive. This will transmit the GPS location of the locomotive at all times. When the locomotive is stopped for more than 10 minutes the video will stop recording. If an accident occurs, a road foreman of engines will pull the hard drive and deliver it to the appropriate person in CSX's legal department for viewing. A detailed chain of custody procedure is strictly followed (Figure 4). The Storage Module will hold data anywhere from 72 hours to 7 or 8 days depending on the amount of video. Never is there less than 48 hours before writing over data on hard drive. Hard drive spares are kept at all service centers for replacement when hard drives are pulled. Data can be retrieved by using a LocoCam retrieval box (Figure 5). This box will give you an opportunity to pull all data off the storage module and load it on to a DVD or CD. Remote monitoring is provided by GE in Erie, PA. The 24/7 center is alerted if a Digital Video Recorder has a problem.

The Wabtec Digital Video Recorder is being installed on Class 1 Railroads that include the KCS, UPRR,, BNSF and CN. An install will take up to 8 man hours to complete.







During an install, Wabtec will work to make sure the customer is happy with the camera placement. The camera is placed inside the cab as shown in Figure 6. Wabtec Railway Electronics and March Networks teamed together to create VideoTrax. VideoTrax LDVR is equipped with a Health and Diagnostic display that indicates the status of the LDVR, Camera, and Microphones. VideoTrax is a rugged Digital Video Recorder created specifically for the railway industry (Figure 7). A special key is used to pull the hard drive. When an accident occurs, a Mechanical supervisor will pull the hard drive and take it to an investigation station (Figure 8). Once data is pulled from the hard drive, the hard drive is put back in service. Data can be stored up to 11 days depending on the amount of data stored. No less than 48 hours will write to the hard drive without writing over it. Railroads that are equipped with the VideoTrax have them wired to record continuously as long as the locomotive is powered up.

The Rail Head Digital Video Recorder (Figure 9) has been installed on 26 locomotives on regional railroads. Time spent on locomotive install averages out to 16-24 man hours, depending on locomotive model. The hard drive is protected by a key that only a select number of mechanical and management individuals have. The only maintenance required by Railhead is that the hard drives be replaced every two years. The Railhead video box can be mounted in several locations depending on space availability on specific road types. The system has a test button to verify function of system. This monitor assures you that the video is recording to the hard drive. Audio is checked during FRA Inspection. LED's are used to verify that system is operational. Spare hard drives are kept in the Locomotive Department. The camera is located in the external part of the locomotive (Figure 10). Hard drive data is written over between 48 hours and 7 days depending on the amount of data recorded. Never less than 48 hours. Data is pulled and read by a Locomotive supervisor.

Electro-Motive Diesel (EMD) is offering locomotive Digital Video Recorder (LDVR) video and audio surveillance system that integrates directly with the EMD FIRE Locomotive Control System - synchronizing event recorder data in real time rather than post playback. The EMD LDVR can record up to four video and four audio sources simultaneously. Installation takes 8-10 man hours. Data can be offloaded in three ways: via the removable hard drive (key-locked to prevent unauthorized access); through a wired Ethernet Connection; or by a wireless 802.11 download. Hard drive capacity is optional, with the standard unit storing 8-10 days before overwriting data. THE EMD LDVR system is durable and secure and meets all AAR shock and vibration specifications.

SAIC Video Camera (Rail View) is installed on about 1600 NS locomotives. It takes an average of 8 hours to install this system. Each RailView install goes through an operational inspection with all supporting documentation prior to the locomotive being released. This test and verification process is a key piece to a successful install. RailView DVR management is handled by the NS Transportation Data Center (TDC). The TDC is responsible for insuring data preservation for all captured incidents in accordance with NS policy guidelines. The RailView camera (Figure 11) is internal in the cab located on the engineer's side. DVR downloads are captured by one of two methods; either in the field on board the locomotive or remote at the RDC lab. The RailView box (Figure 12) is located in the nose of the locomotive. Spare hard drives are kept at each service center if there is a need to replace one after an incident.

In conclusion LDVR systems are now being installed across the rails every day. The impact of having DVR's on the locomotives is having a positive financial effect in court rooms. If a crossing accident occurs with a locomotive equipped with a video camera, it is now easier to see which party was at fault by simply viewing the video. This is only the beginning of the evolvement with cameras. In the next 5 years most of the Class 1 Railroads will be using cameras.

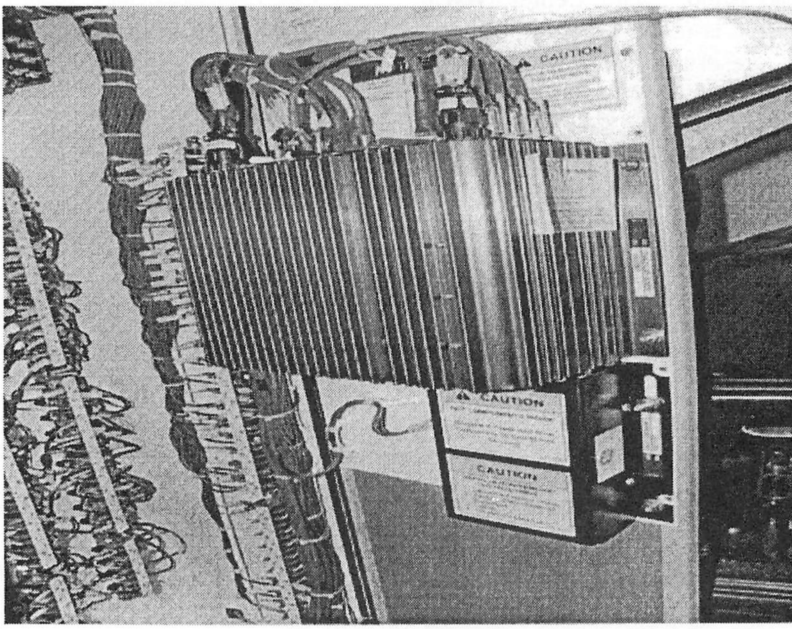


Figure 1

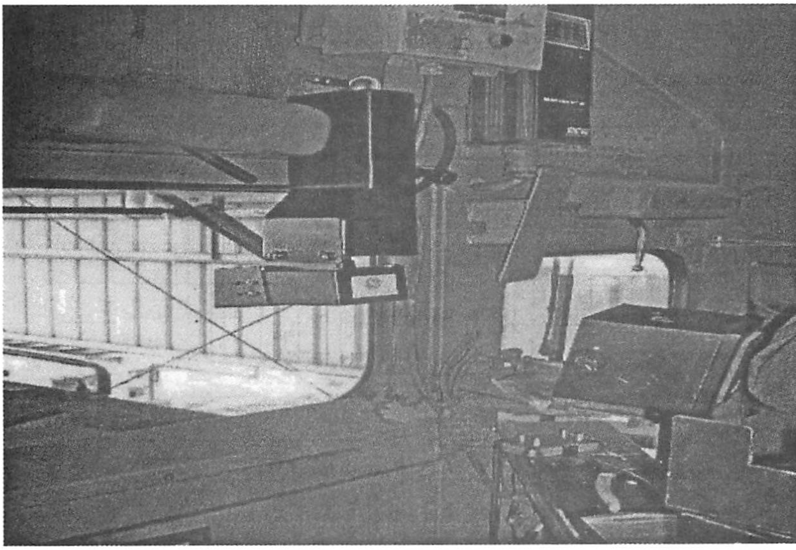


Figure 2

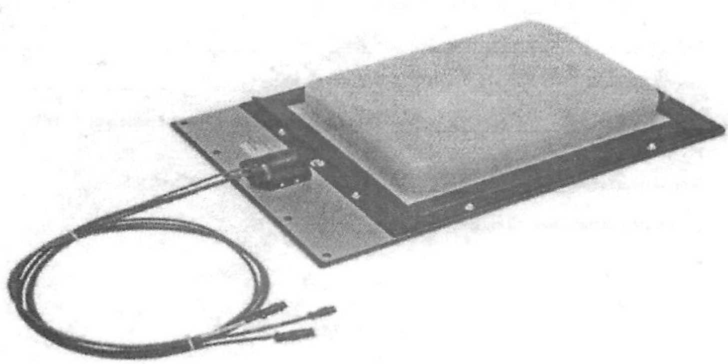


Figure 3

DVR Removal/Chain of Custody Form
Jacksonville DVR Custodian 904-359-3737

HARD DRIVE REMOVAL

1 Name:________________ Title:________________ ID No.:________________

2 Event Date:________________ Reported Time:________________ AM / PM

3 Location of Event:

City:________________ State:________________

Milepost (with prefix):________________ Street/Road Name:________________

4 DOT Crossing Number:________________ 5 Train Symbol:________________ 6 Locomotive Number:________________

7 Date of Removal:________________ GPS Time of Removal:________________ AM / PM

8 Location of Removal: ☐ Check if same as location of event

City:________________ State:________________

Milepost (with prefix):________________ Street/Road Name:________________

9 Removal Instructions Followed (circle one): YES NO 10 Confirm Seal in Place (circle one): YES NO

11 Serial Number of Seal:________________ 12 Serial Number of Hard Drive Unit Removed:________________

HARD DRIVE REPLACEMENT

13 Hard Drive Replaced (circle one): YES NO

14 Name:________________ Title:________________

15 Date:________________ GPS Time of Replacement:________________ AM / PM

16 Location of Replacement: ☐ Check if same as location of removal

City:________________ State:________________

Milepost (with prefix):________________ Street/Road Name:________________

17 Locomotive Number:________________ 18 Installation Instructions Followed (circle one): YES NO

19 Serial Number of Seal:________________ 20 Confirm Seal in Place (circle one): YES NO

21 Serial Number of Hard Drive Unit Installed:________________

Figure 4

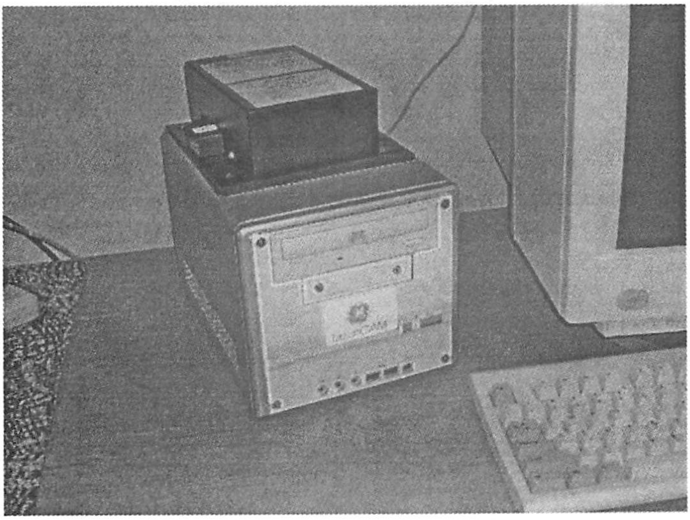


Figure 5

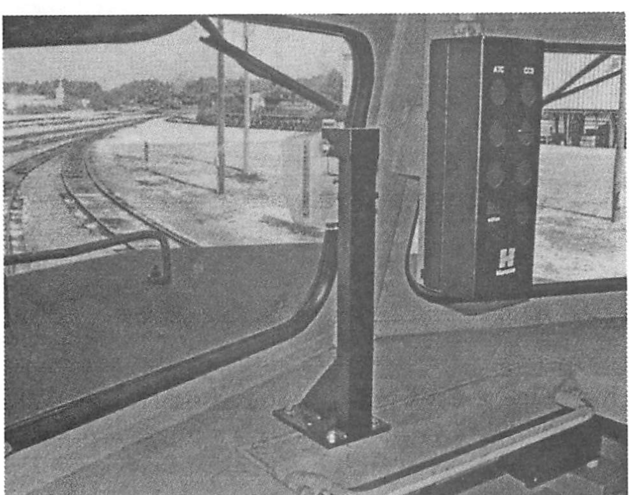


Figure 6

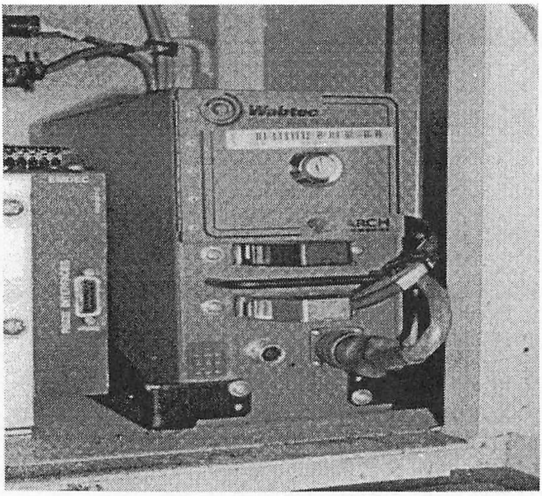


Figure 7

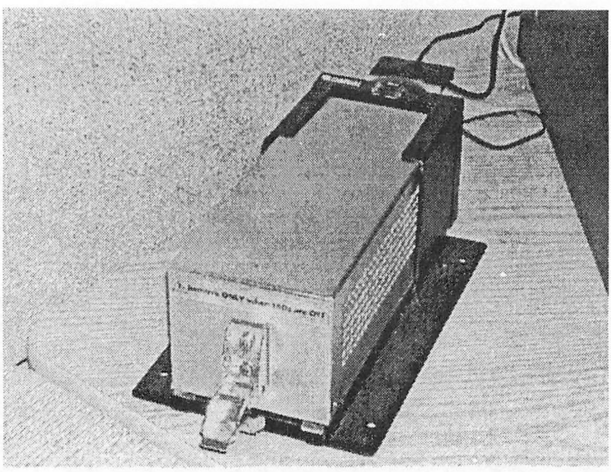


Figure 8

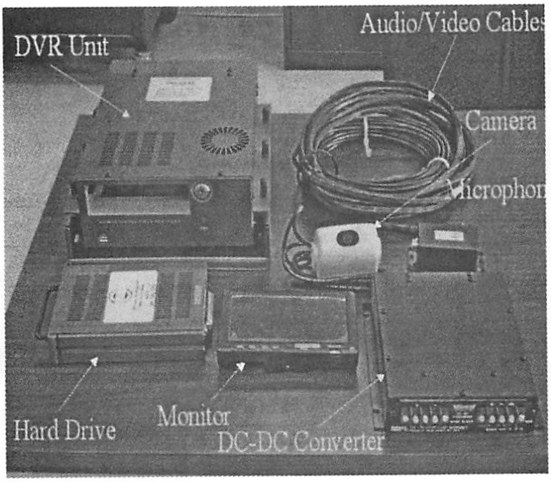


Figure 9

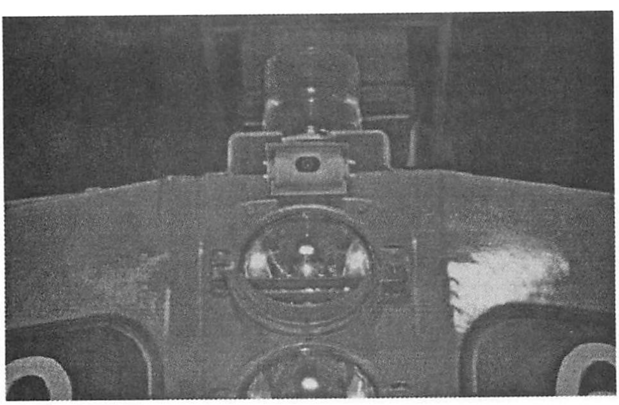


Figure 10

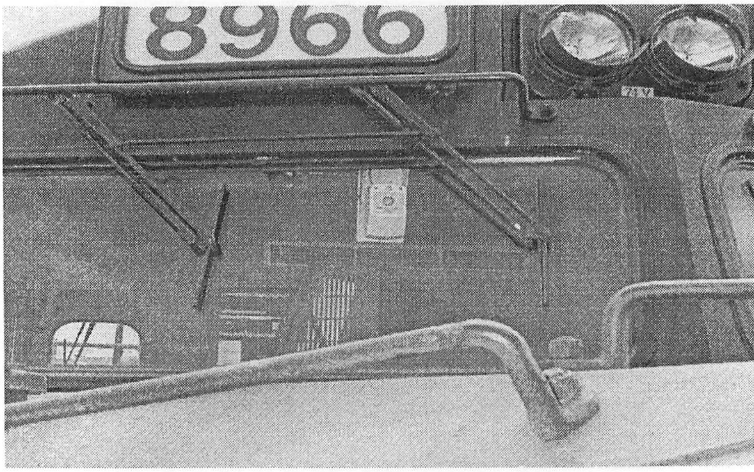


Figure 11

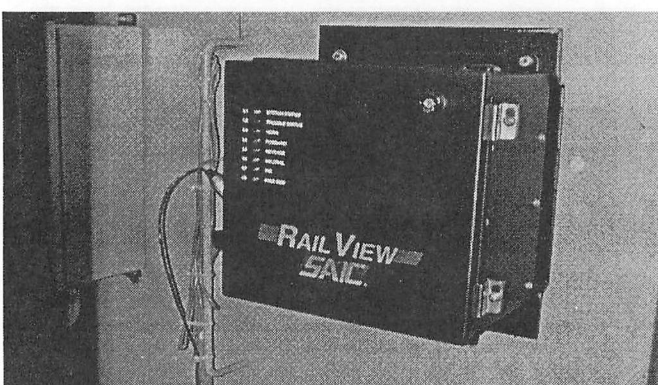


Figure 12

3. CN Distributed Braking Car

Prepared by
Joe Whitmer
Loco Reliability Specialists
Canadian National Railroad

History

The Distributed Braking Car concept continues building on the original Trainlink ES system, which CN has been applying to its fleet. The Trainlink ES system was instituted to allow the operation of longer trains consisting of 10,000 ft plus. Application of ES allowed for faster braking response, and reduced train forces. Trainlink ES did not, however, provide for release of the brakes or make up for brake pipe leakage.

The Distributed Braking car is currently being introduced into operations to assist in cold weather operations. In cold weather environments, brake pipe leakage increases and can be problematic on longer trains. Often, trains cannot be charged properly at the originating location. Also, breaking the train line enroute can create operational problems. Because of this, maximum train length is typically restricted in the winter months, requiring the running of extra trains. Because the DBC provides a second source of trainline air, full-length trains can run all year-round.

What is it?

An auxiliary locomotive braking system located in a boxcar coupled at the rear of the train. This concept is similar to having a DP equipped locomotive running at the rear of the train.

The concept

This Distributed Braking Car duplicates commands given by the engineer causing brake application and releases to occur from both ends of the train providing for better train handling due to reduced train forces.

Benefits provided by the DBC

- Better cold weather operation
- Reduced brake pipe charging time
- Faster brake applications
- Faster and more uniform brake cylinder pressure build up
- Reduced brake pipe gradient
- Simultaneous emergency braking from head-end and tail-end
- More responsive train deceleration
- Train stopping time is reduced (approximately 20% or greater)
- Stopping distance is reduced (approximately 30% or greater)
- Improved control of slack action
- Reduced train slack action (buff and draft forces) and longitudinal forces
- Potential reduction in frequency of train separations

Theory

The basic functionality of the car is that the locomotive is equipped with a Trainlink ES type head end device that constantly communicates the brake pipe and equalizing reservoir pressures to the car. The car using DP equipment monitors these signals and acts to apply and release the brakes from the rear of the train simultaneously with the front end.

The car itself consists of the electrical system and the air system. In the center of the system is an Ingersol-Rand XP-185 air compressor. This is a diesel driven air compressor that supplies not only the constant 140-psi main reservoir pressure, but also delivers 120-volt, 6-kW AC power source. From this AC source we drive directly the rooftop strobe lights, blowdown heaters, and battery charging for the 72-volt DC system. The DC system is required to operate the locomotive EPIC II air brake equipment on the car.

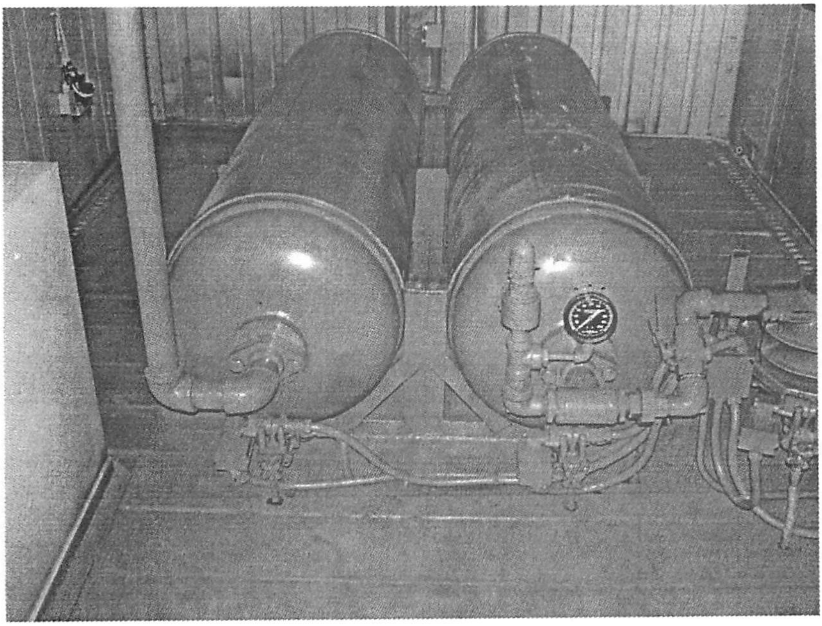
The actual control system consists of the RRM (data radios), NIU (Network Interface Unit), CCU (Computer Control Unit), BCU (Brake Control Unit), and LIU (Locomotive Interface Unit). Data is received by the RRM and communicated to the BCU through the NIU and CCU. This information controls the increase and decrease of brake pipe pressure as transmitted by the LCU (Locomotive Cab Unit). Fail-safe control is built-in to the system and operates similar to Distributed Power. For example, if communication is lost, the DBC will still continue to maintain brake pipe pressure until a reduction in brake pipe is seen, i.e., the engineer makes a set. At that time the DBC will cutout its brake equipment until communication is reestablished and the engineer reenables the system. Emergency applications are enacted both by reaction to the emergency rate of reduction and radio signal. The DBC also acts as the EOT in the fact that it transmits information back to the LCU, such as Brake Pipe pressure, EOT Moving, and Marker On. To perform the actual EOT Moving input, we chose to use a Doppler radar assembly; this option seemed to be cost effective and did not require any mechanical hardware to be applied to the trucks. This could be a real problem as freight car trucks are not normally equipped with axle generators.

Construction

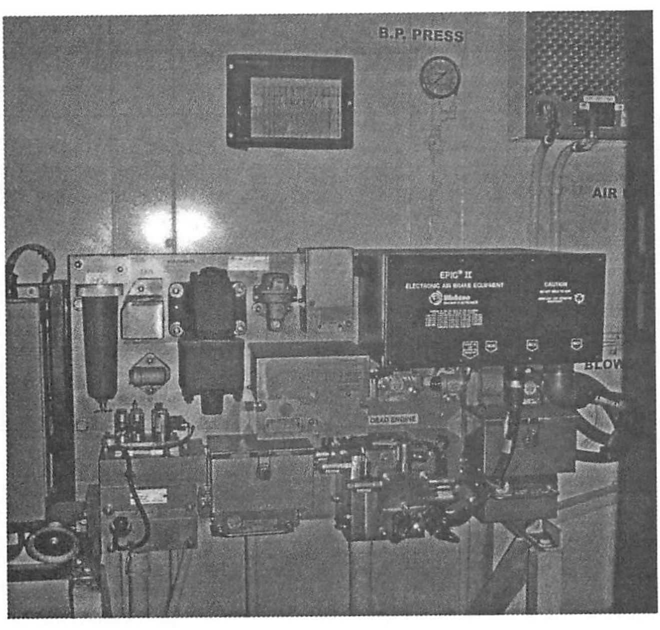
In fall of 2005, CN Mechanical built a prototype of the DBC, CN 15201. The donor car was originally a BN air repeater car. Although the original concept was that it also provided air to the train, it was a mid-train design vs. the end of train design proposed at CN. The original pneumatic equipment was removed from the car along with the diesel driven air compressor. The Ingersoll-Rand compressor was chosen for installation since it comes in a package unit complete with generator. One major hurdle was the requirement of 72-volts DC for the locomotive type air equipment; this was met by using a Transtronic power converter built for this application. A 1000-gallon fuel tank was applied in the 'B' end of the car with fillers on both sides of the car to allow for filling from either side. Finally, EPIC II electronic air brake equipment was applied utilizing radio equipment similar to Distributed Power applications. Once the car has been completed electrically and mechanically, all equipment is tested during a complete commissioning session.

Where are we now?

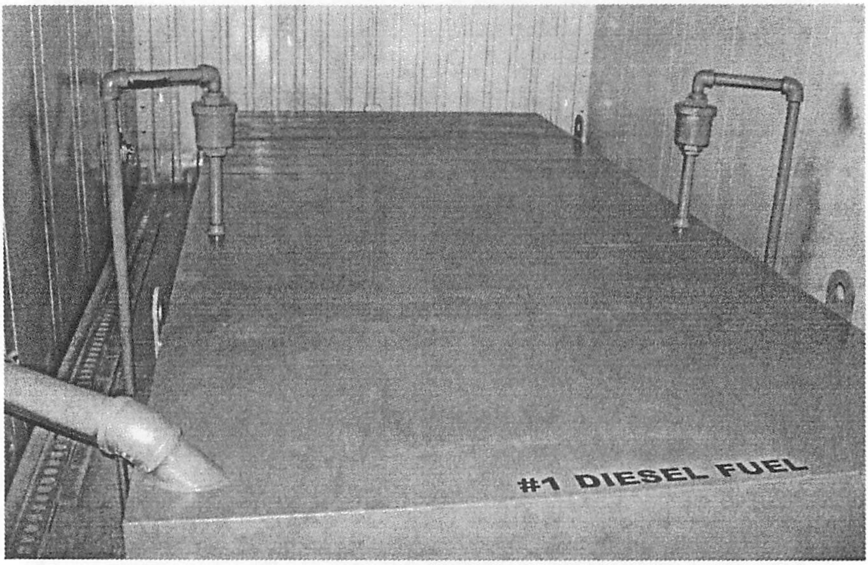
The prototype and two other cars have been in service for some time with positive reports. By the end of 2007 CN plans to have a total of 10 of these cars in regular service. A couple of improvements are in the works to make the cars even better than they are now.



DBC main reservoir tanks

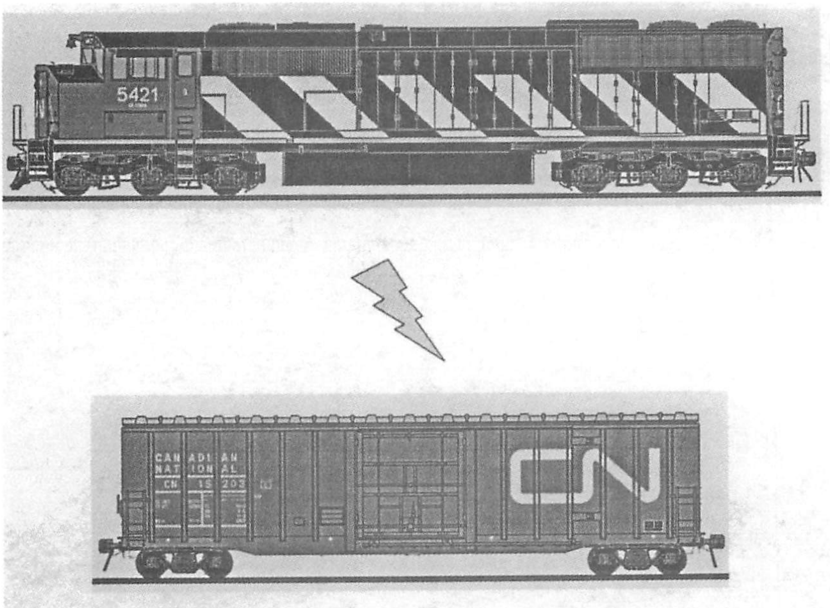


EPIC II air brake rack

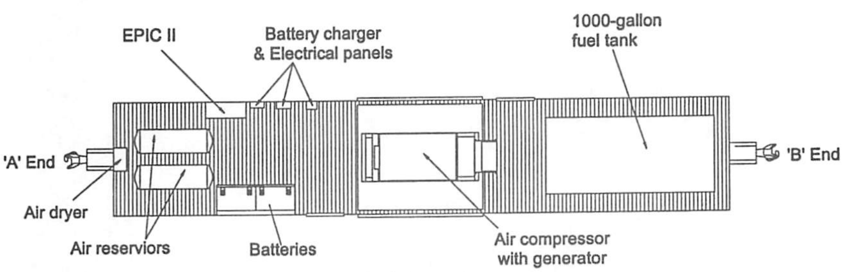


1000-gallon fuel tank in 'B' end

Completed car 15204 ready for service

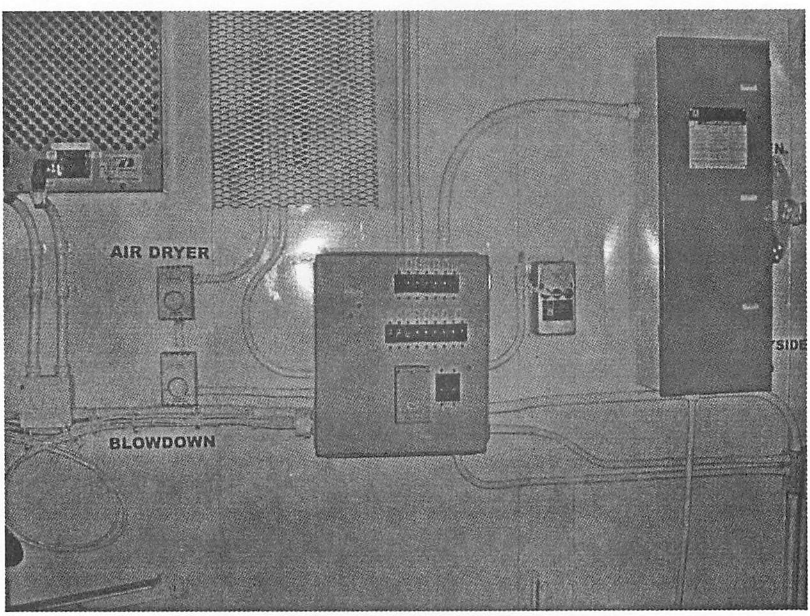


Locomotive to DBC communication using Trainlink ES

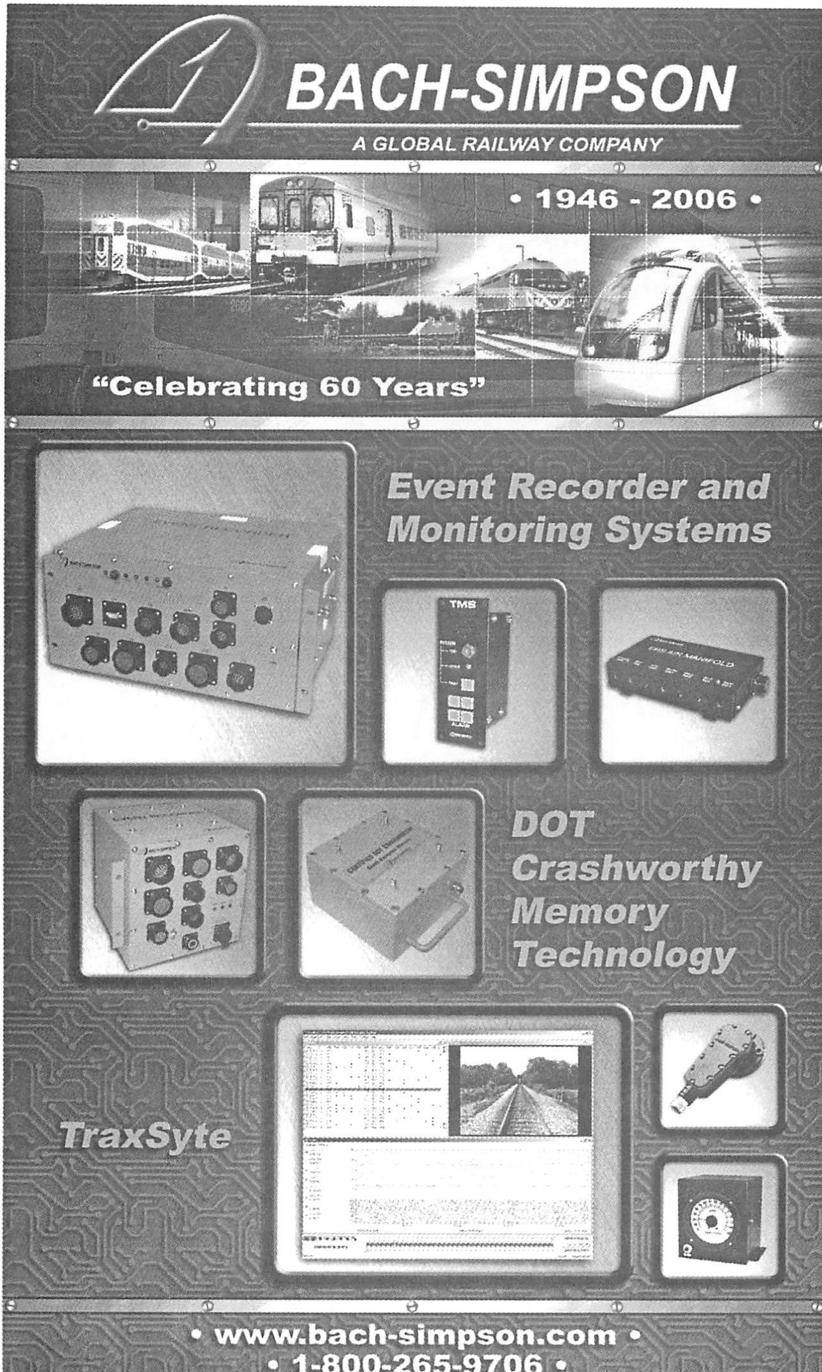


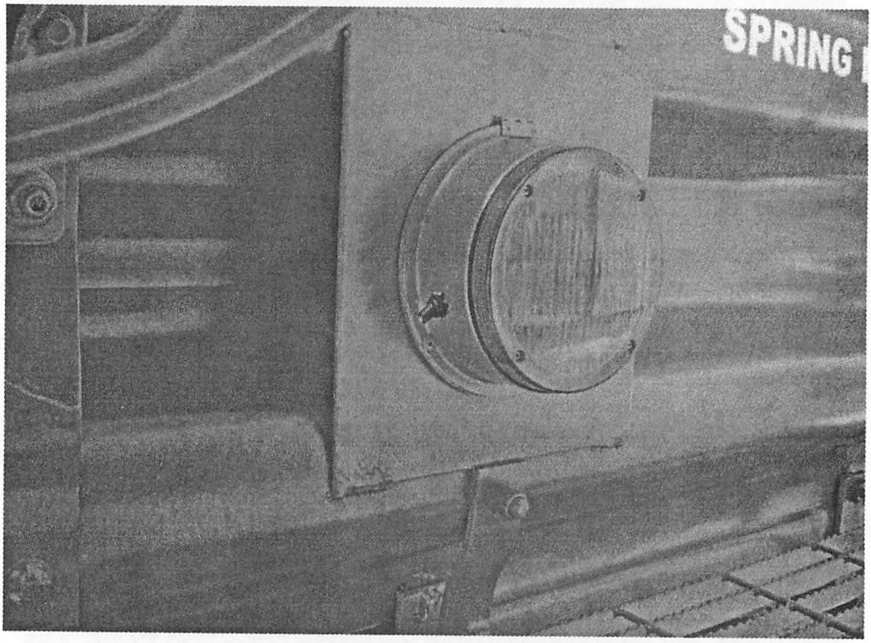
DBC Layout

Ingersoll Rand air compressor w/6kW generator



Battery charger, main breaker panel, and change over switch





EOT flasher on end of DBC

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

FRIDAY, SEPTEMBER 14, 2007
2:00 P.M.

Chairman
STUART OLSON
Regional Sales Manager
Wabtec Corporation
Alpharetta, GA

Vice Chairman
MIKE DRYLIE
Electrical Systems Engineer
CSX Transportation
Jacksonville, FL

COMMITTEE MEMBERS

D. Becker	Design Engineer	Electro Motive Diesels	LaGrange, IL
J. Boggess	Sr. Mgr.-Motive Pwr.	Alaska RR	Anchorage, AK
D. Bruss	Engr. New Cap. Equip.	Amtrak	Philadelphia, PA
F. Fraga	Electrical-Special Proj.	FEC Rwy.	Orange City, FL
B. Hathaway	Consultant		Port Orange, FL
B. Kirdeikis	Sr. Rel. Specialist-Elec.	CN RR	Edmonton, Alberta
G. Lozowksi	Tech. Mgr-RR Prod.	Natl. Elect. Carbon	Greenville, SC
B. McCaffrey	Consultant	Transsuply, Inc.	Wilmington, DE
D. Maryott	Mgr.-Locos.	BNSF Railway	Fort Worth, TX
S. Mueting	Field Service Engineer	Siemens Transp.	North Platte, NE
T. Nudds	Cust. Service Manager	ZTR Control Syst.	London, Ontario
D. Perkins	Consultant	Union Pacific RR	Omaha, NE
R. Price	Mgr.-Field Opns.	Montana Rail Link	Livingston, MT
R. Slomski	Sr. Prog. Engr.	RailPower Hybrid	Erie, PA
C. Taylor	Appl. Specialist	Bach-Simpson	London, Ontario
V. Trout	Mgr.-Mech. Engrg.	Union Pacific RR	Omaha, NE
L. White	Tech. Sales Rep.	Bach-Simpson	St. Hubert, Quebec

Note: Keith Melling of Peaker Services will be joining the committee. Brian Hathaway is a Past President of LMOA-Les White is the current President of LMOA

PERSONAL HISTORY

T. Stuart Olson

Stuart was born in Jacksonville, FL and received a Bachelor of Science degree from the University of Central Florida. In 1974, following a six-year tour of duty as a US Navy nuclear submariner, he began his railroad career with a relatively new company, Auto-Train in Sanford, FL. While at Auto-Train he advanced from locomotive junior machinist to Draftsman, Project Engineer, Director of Facility Maintenance, and finally Director of Operations.

In 1979 he began serving the industry from the other side of the track as Field Representative for New York Air Brake. In 1983 he took the position of Sales Engineer for Aeroquip Corporation in Chicago, IL, where he advanced to Account Executive. In 1987 he was promoted and transferred to Wytheville, VA as Aeroquip Railroad Products Manager.

After a brief stint with Republic Locomotive Works as Director of Sales, and Bach-Simpson as Regional Sales Manager he continued to broaden his knowledge by accepting a position at Q-Tron as Manager of Business Development.

The railroad industry was changing at a fast pace. Railroad supply companies were merging and in acquisition mode. Q-Tron was purchased by Motive Power Inc., where Stuart transitioned to the position of Regional Sales Manager.

A short time later Westinghouse Air Brake Co. merged with Motive Power forming Wabtec Corporation. He is the Regional Sales Manager for Wabtec servicing Class 1, Short Line and regional railroads in the Southestern US.

Stuart is a long time member of the LMOA Diesel Electrical Maintenance Committee serving as committee member and vice chair, as well as presenting technical papers. He is a past recipient of the Committee MVP.

Currently living in Atlanta, GA with his wife Winky, they have two children and five grandchildren.

THE DIESEL ELECTRICAL MAINTENANCE COMMITTEE WOULD LIKE TO EXPRESS THEIR SINCERE APPRECIATION TO SOUTHWEST RESEARCH INSTITUTE FOR HOSTING THEIR WINTER MEETING IN SAN ANTONIO, TX ON FEBRUARY 19 & 20, 2007

THE COMMITTEE WOULD ALSO LIKE TO THANK SIEMENS TRANSPORTATION FOR HOSTING THEIR SUMMER COMMITTEE MEETING IN ATLANTA, GA ON JULY 23, 2007 AND FOR PROVIDING TOURS OF THEIR FACILITIES

1. Finding Open & Short Circuits On AC Traction Motors

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The advent of three-phase traction on diesel locomotives has not eliminated electrical troubles associated with traction motors. Instead, it has just redirected them. Our father's DC series-wound traction motor had a commutator, carbon brushes, a stationary field and an insulated rotating armature winding. While the AC induction traction motor has done away with brushes, the comm and the insulated rotating winding, we still have a stationary winding - a winding more complicated than the field of a DC motor and a winding subject to two problems not significantly affecting the DC motors - open and short circuits.

EMD AC locomotives are configured so that three traction motors of one truck are connected in parallel to one GTO inverter (Figure 1). A short between phases of an AC traction motor can cause a failure of TWO inverter phase modules, an open causes single-phasing of a motor, resulting in very rough operation and vibration. Thus, in the scheme of things, shorts obviously can be worse than opens.

SHORT CIRCUITS

Detecting shorts in AC traction motors may sound like a relatively simple procedure, but this is true for only one type of short-the hard or fused short. The other type of short is one caused by an air gap or weakening dielectric strength in the insulation of the motor windings. This is more of an elusive short but without detecting either type of short, more damage to the electrical components will occur.

A resistance measurement of each of the traction motor phase winding with a low resistance ohmmeter (described in detail later in finding OPEN CIRCUITS section) is capable of detecting hard, fused shorts in the windings. When using a low resistance ohmmeter to measure the resistance of each of the phase windings, the procedure is to compare the resistance measurements of all three phases. A good traction motor will show an equal balance of all three resistance measurements. A defective, hard-shorted traction motor will show one of these resistance measurements different than the other two.

However, a motor with shorts due to an air gap or weakened insulation may appear to be a good traction motor based on the results of a low resistance ohmmeter test. A surge test is the most effective means of finding this type of short over any other method, including Hy-Pot and meggering.

The value of understanding the importance of each of these two types of tests has to do with preventing further damage to the Traction Control (TC) components and further cost of repair to the loco-

motive. The first step is to perform a low resistance ohmmeter test. If this test does not reveal a defect, the next stop is to perform a surge test.

How does one know when to test for shorts in a traction motor? The indications of when and how to test and how to accurately analyze the test results will now be covered. We will use a locomotive failure scenario to illustrate these conditions that begins with the end result of a shorted traction motor; alarm bells going off in the locomotive cab alerting the crew to take action.

Failure Scenario

The engine drops its load, a Hard Crowbar is fired, the alarm bells go off, and the control screen requests the related truck to be "cutout." A short has occurred and any damage to the connected electrical components has already happened. This scenario is similar on all EMD SD70MACs, 80MACs, and 90MACs.

When this unit arrives at a service facility, it is unknown as to what exactly caused the truck to be cutout. Standard service procedure is to review the fault archive of the EM2000 and identify the failure connection, or the fault recorded at the time of the failure, which will more than likely be "GTO Monitoring". This is the start of properly identifying a shorted traction motor.

Analyzing Failure Information

The EM2000 fault archive contains general information about the fault. But more detailed information closer to the source of the failed equipment is needed. That information is in the fault archive of the Siemens inverter computer, a.k.a. ASG or TCC. Once the Siemens fault archive is downloaded and reviewed, the related fault will identify the area of damage, specifically, which of the 3 phase AC outputs were affected.

There are two fault codes in the Siemens computer that contain this information, Diagnostic Code 15H, GTO Monitoring Inverter, and Diagnostic Code 18H, Inverter Output Overcurrent. (The 'H' in the code stands for the Hexidecimal format of the codes.) More likely, Code 18H will have occurred with the Fault Consequence of GTO Monitoring for two of the three phases.

The first telltale sign of shorted traction motor is the presence of GTO Monitoring for two of the three phases. The fault information shown in Figure 2 is from a Norfolk Southern SD80MAC, NS7200, with Code 18H and Fault Consequence of GTO Monitoring on phase S- and T+.

There are three indications on this fault record (labeled in Figure 2 as A, B, & C), that leads to the implication that this fault occurred as a result of a shorted traction motor. The first - Indicator A - has the Diagnostic Code of 18H, Inverter Output Overcurrent. This part of the fault record is the first indicator of a possible shorted traction motor. The second - Indicator B - shows Fault Consequence: GTO Monitoring Phase S- & T+. This identifies Phase S & T affected by the failure condition and is the second indicator of a possible shorted traction motor. The third - Indicator C - shows the AC output currents of each phase. The output currents for Phase S & T are at 2500 A, the maximum current for the system, with one phase having a negative value and the other phase with a positive value. This shows an uncontrolled, maximum current flowing from Phase T to Phase S, and being the third indicator that this was the result of a short most likely in the traction motor.

Inverter Component Damage as an Indicator for a Shorted Traction Motor

The fault information from Figure 2 indicates that both Phase S & Phase T encountered GTO Monitoring and maximum current. The primary electrical component for each of the three phases is called Phase Module. It has been noted by experience that when two Phase Modules in one inverter have been damaged beyond continued operation, "blown" or "shorted", it has been caused by a short across the inverter output. While this could happen as a result of weak insulation between the phase leads from the Phase Modules to the traction motor, the short is more than likely inside the traction motor.

With two blown Phase Modules in one inverter, the locomotive cannot continue to run without finding the shorted traction motor. Worse yet, replacing only the two Phase Modules will cause the same two Phase Modules to fail again within a short time. Replacing all three traction motors in one truck without identifying the shorted traction motor will only cycle the defective motor through the motor pool until it is installed in another locomotive, causing the same exact damage.

A Brief Description of Inverter Operation and Terms

The term "Hard Crowbar" describes an electrical device in the inverter. The device acts like a metal crowbar that is placed across the positive and negative sides of the DC Link circuit in the inverter coming from the main alternator. A "Hard Crowbar" is triggered or fired in the event of a system failure or a system shutdown. GTO Monitoring is the most critical fault for the inverter system. At the heart of the traction Control (TC) system is a Gate Turn Off Thyristor, a.k.a. GTO Thyristor or simply GTO. Combinations of GTOs are encased in three individual Phase Modules (PM). See Figure 3 for GTO block diagram.

These Phase Modules are controlled by pulse-width modulation (PWM), pulsing the GTOs off and on for the required load demand, creating the three-phase AC output. When there is a short in the motor windings, the electrical specifications of the motor are greatly altered causing changes to the AC current and frequency. This creates an erratic situation too fast for the inverter control system to protect the inverter components. The controlled ebb and flow of the TC system has been drastically disrupted.

Two Tests to Shorts - Two Shorts to Test

The next challenge is to properly

test and identify the short. Two types of shorts, hard and air gap, require two types of tests, low resistance ohmmeter test and surge test. The quick and easy test is the low resistance ohmmeter test, identifying the easily spotted, hard-shorted traction motor. If the low resistance ohmmeter test does not reveal a short, it may appear that the traction motor is not defective...unless the traction motor has an air gap or weak insulation short not detectable by a low resistance ohmmeter. Then a surge test is required.

The surge test is not as quick and easy as the low resistance ohmmeter. However, this shouldn't be a deterrent to performing this test. Avoiding the surge test could lead to a never mentioned third test, the R2MPM & STA test. Or, "Replace 2 More Phase Modules & Surge Test Anyway". This third test is not so quickly and not so easy, and it's an expensive test that should be avoided. See Table 1.

Back to Failure Scenario

In the earlier mentioned failure scenario, the faults were analyzed and two Phase Modules confirmed as defective. The next step is to disconnect all of the traction motor leads in the specific truck. Inverter 1 or TCC1 operates truck 1, on traction motors 1, 2, & 3. And for Inverter2 or TCC2 operates truck 2, on traction motors 4, 5, & 6. After the leads are disconnected, the traction motors can be tested.

Low Resistance Ohmmeter Test

The principle of the low resistance ohmmeter test *is to measure* the resistance of the phase-to-phase windings in the traction motor and to compare the measurements to each other for balance. See Figure 4 and Table 2. The conclusion of this example shows traction motor #3 to have unbalanced phase-to-phase resistance measurements. Traction motors #1 & #2 have good balanced resistance measurements. Traction motor #3 was replaced.

The example in Table 3 had two defective Phase Modules, yet the low resistance ohmmeter measurements did not reveal a shorted traction motor. There is a phase-to-phase short somewhere in the circuit. How can it be detected? The surge test is the answer to that question.

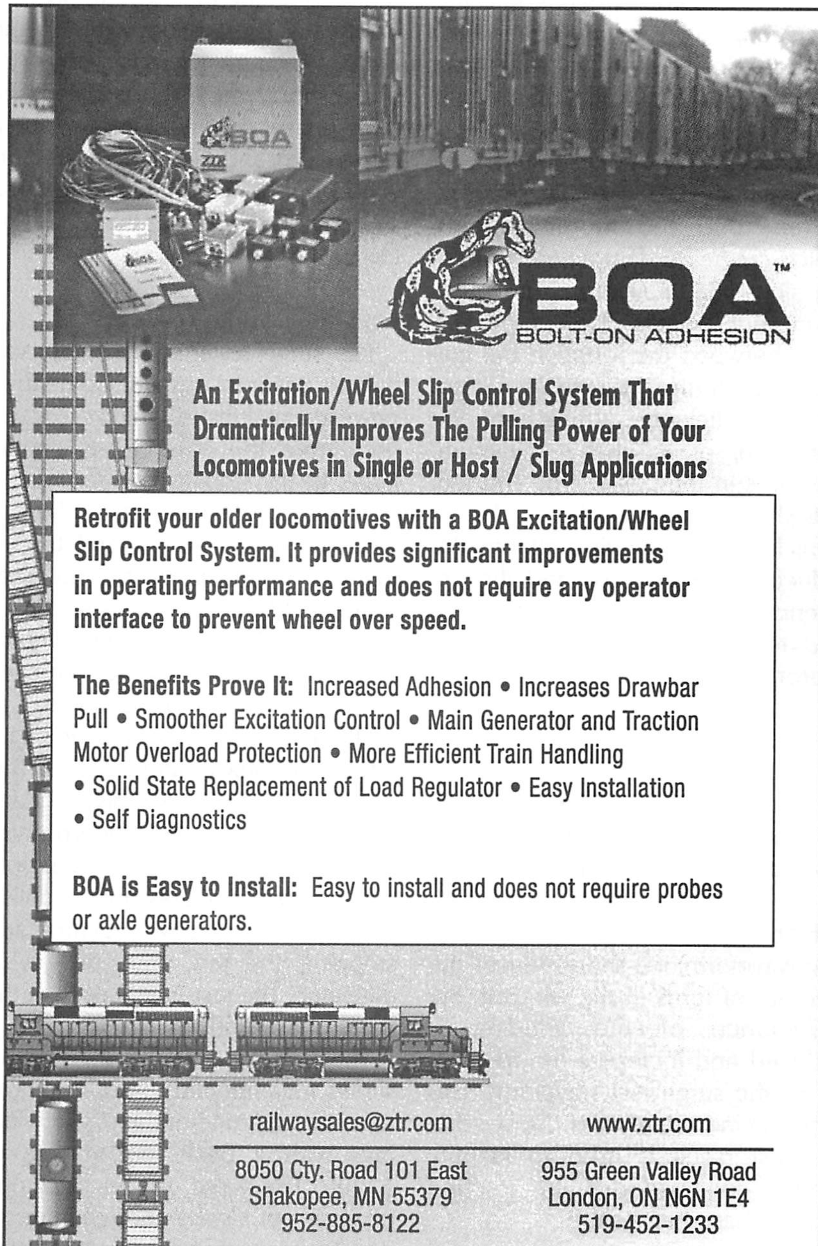
Surge Testing

There are two shorting conditions that are not easily detected; an air gap between phase windings and a weakened dielectric strength of the winding insulation. Concerning the properties of the air gap, Paschen's Law states the breakdown voltage of a gap is a non-linear function of gas pressure and gap distance.

$$V = f(pd) \quad p=\text{pressure},\ d = \text{distance}$$

Or more simply stated, two parallel, un-insulated wires separated by about the thickness of a hair (approx. 0.0032") require a minimum of 350V to jump the gap. This voltage is also known as Paschen's minimum.

Concerning the dielectric strength of winding insulation, there are a variety of conditions that can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degrade the insulation strength, including thermal cycling, vibration, movement of coils wearing into the insulation, high voltage transients, and chemical effects. The only way to test turn-to-turn insulation strength is with a surge test.

The principle of surge testing is to send a high, fast rise-time pulse of current into the motor winding which creates a dampened, or ringing sinusoidal waveform. The pulse of current creates a voltage difference between the loops in the coil windings. If this voltage is greater than the dielectric strength of the insulation, or Paschen's minimum, the turns in the coil will be shorted. This short will reduce the number of turns in the coil winding, altering the inductance of the coil and the frequency of the surge test waveform, and revealing the shorted traction motor.

$$\text{Frequency} = \frac{1}{2n\,LC}$$

n = number of turns in winding
L = Inductance of windings
C = Capacitance of surge tester

From this equation for the surge test waveform, if a short reduces the number of turns in the winding, the inductance of the winding is reduced and increases the frequency of the surge test waveform. This increase in frequency is displayed in the test result is used to identify which coil winding, or traction motor phase has a short.

Phase-to-Phase and Turn-to-Turn shorts

There are two more types of shorts to define that have to do with where the short is occurring in the motor windings. There is a phase-to-phase short, which shorts two of the three phases within the motor, and a turn-to-turn short, which is a short within one phase of the motor but shorting the turns in the coil. See Figure 4.

Surge Testing

The surge tester used in this scenario is Baker Instrument Company's newest digital tester, which separates itself from the past by eliminating large, heavy step-up transformers. It is a portable device that can be carried to the locomotive and test all traction motors in place, but does require 110V power. The Baker surge tester is shown in Figure 5 connected to a traction motor removed from a locomotive and connected to all three phase leads. It is not your father's ordinary surge tester. This device uses solid-state high voltage power supplies and incorporates high-speed electronic evaluation, which processes previously applied pulses to detect any weakness and stopping the test, thus preserving dielectric. The tester tests each of the three phases individually.

The surge test results in Figure 6 shows a dampened sinusoidal waveform through one of the phase windings with a peak test voltage of 5120V. The surge test result of one phase is not always enough information to correctly analyze the motor without a reference - just like one measurement of the low resistance

ohmmeter test cannot correctly analyze the motor. All three-phase measurement results need to be compared to each other to properly identify the defect. Figure 7 is an overlay of the surge test results of all three phase windings for a good traction motor. These properties are nearly the same. Note the Peak Surge table in the upper left corner, labeling the peak test voltage for each of the phases.

The surge test results of a defective traction motor are shown in Figure 8. The guideline for detecting defects is to compare the same test results of each of the three-phase windings. The surge test results for Figure 8 shows two of the phase test results nearly identical and one that is not. The one that is not identical is the phase winding that is shorting. As described earlier, the principle of surge testing is if there is a short, the number of turns in the winding is reduced thereby increasing the frequency of the surge test waveform. And this test result has one waveform that looks over dampened and with an increased frequency, or waveform shifted to the left. This result also indicates a turn-to-turn short within the winding as it is only affecting one phase.

Now what about the failure scenario that was started at the beginning of all of this? It has the GTO monitoring faults, the two defective Phase Modules, but passed the low resistance ohmmeter test. Let's see the results of this traction motor with the surge test.

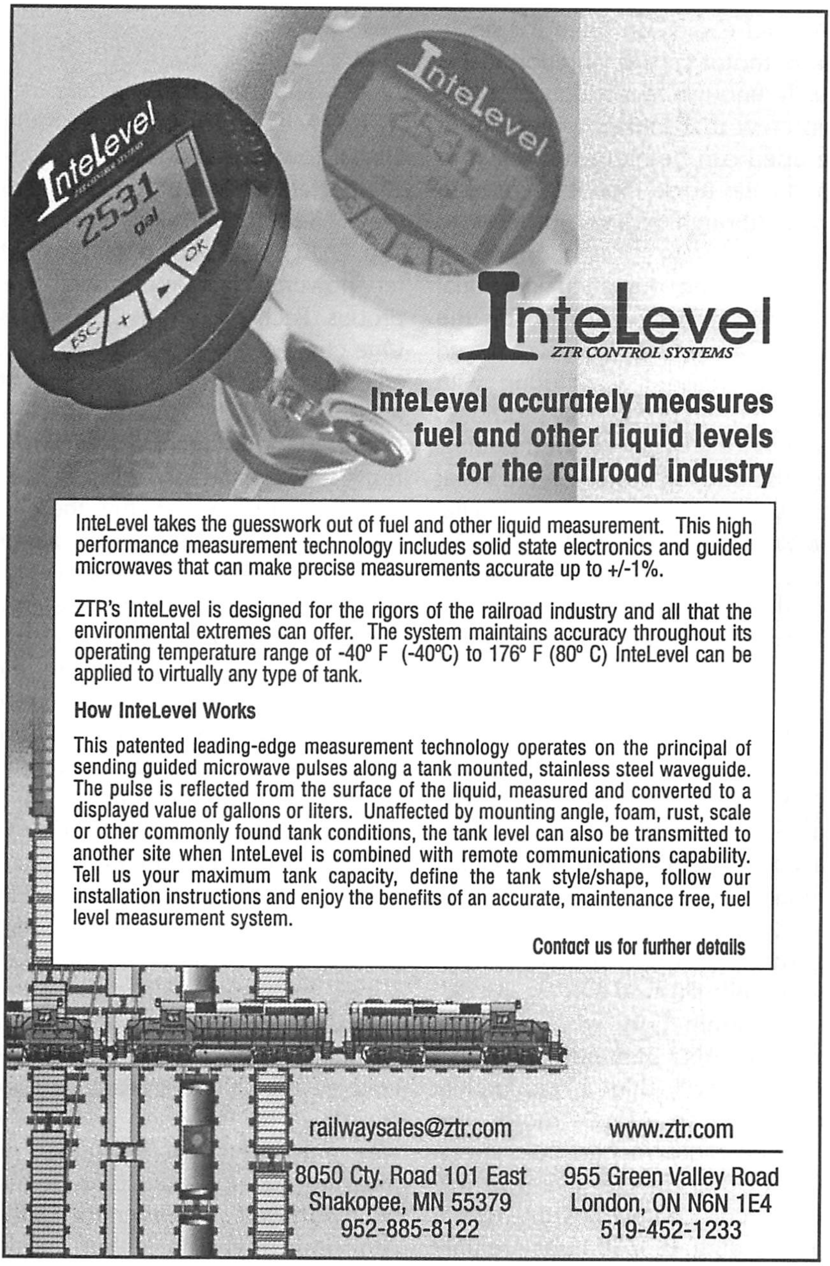
Surge Test of Failure Scenario

All three *traction motors operated* by this inverter did not reveal a defect from the low resistance ohmmeter test. In fact, those test results indicate all three traction motors looked good. But the damage to the two Phase Modules strongly supports the presence of a short.

Figure 9, 10, and 11 are the surge test results of locomotive NS7200 for traction motors #1, #2, & #3 respectively. Just by looking at the surge test results of the three traction motors one could conclude the test results in Figure 10 or traction motor #2, look more erratic than the test results of the other two motors in Figures 9 and 11, or traction motors #1 & #3. Concluding, the results indicate a defect with traction motor #2, and test results of traction motors #1 & #3 are identical and are not defective.

Remembering the low resistance ohmmeter test results for the NS7200 in Table 4 shows the results did not identify the defective traction motor. Final analysis of the surge test results shows a phase-to-phase short in traction motor #2 as two of the phase test results had similar defect properties.

One final item to make note of when performing the surge test on a defective traction motor. When ramping up to the maximum test voltage during a surge test, a winding with an air gap or weak dielectric insulation will begin "arcing" across the defect. The "arcing" can be heard by the operator as a ticking or clicking sound coming from the motor under test. This sound is another indicator in properly detect-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ing a defective traction motor.

OPEN CIRCUITS

As said earlier, an open (or single phase) motor causes vibration that is usually enough to announce to the train crew that there's a problem. If the open can be narrowed down to a particular truck, then it becomes a simple (though tedious) process to drop three sets of traction motor leads and ring out each individual motor. In at least one case on the Alaska Railroad, a motor removed for other reasons was found with HALF an open phase. This prompted a search for a better method to diagnose the traction motor circuit. What we found is Megger Group's Digital Low Resistance Ohmmeter (DLRO).

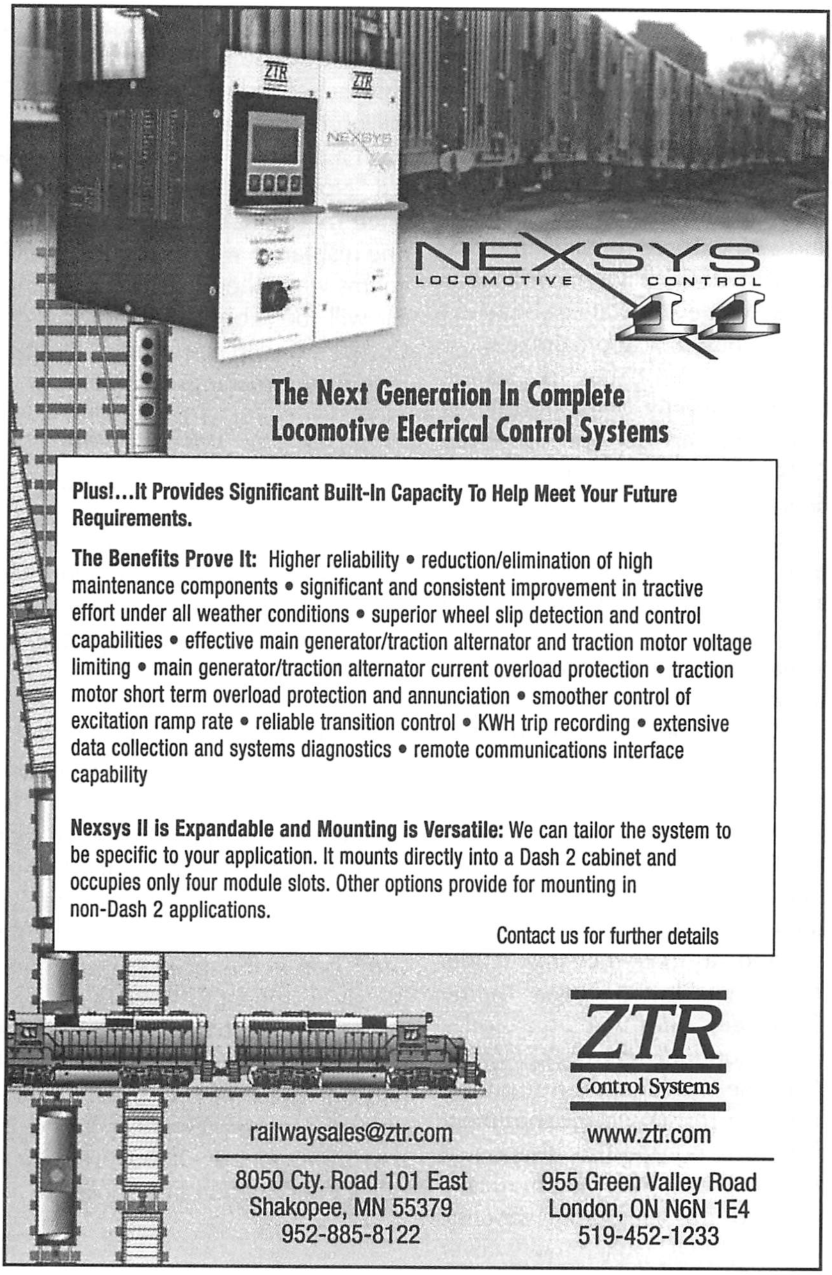
The EMD AC traction motor (whether the TB2630 motor in SD70MACs or the TB2830 in the SD90MAC) has two parallel wye winding that are brazed to each of the phase cables. Figure 12 shows a schematic of the motor, Figure 13 shows the cable connections. The "half-open" motor had one of these brazed connections burned open , so that all the current was flowing through the remaining parallel winding. This caused the distressed, overheated coils illustrated in Figure 14.

An examination of Figure 12 shows that ANY ohmmeter or even a bell-ringer will find a completely open phase on a single motor. The half open motor necessitates measuring a 50% change in a 150 milliohm circuit - barely possible with a typical digital VOM but readily achievable with the DLRO. The fine resolution of the DLRO suggested it might be possible to find open motors without disconnecting every individual motors.

The DLRO

The Megger (formerly Biddle) Digital Low resistance Ohmmeter 10 is a portable, "4-wire" low-resistance meter. See Table 5 and Figure 15. The DLRO is a self-contained, battery-powered instrument with two probes. Each probe has 2 contacts. One contact on each probe supplies a constant current thru the test resistance. The other contact measures the resultant voltage drop across the test resistance. The resistive autoranging feature will change the constant current source to maximize the resolution from tens of micro-ohms to 2000 ohms in very quick fashion.

We run headlong into one quirk of the DLRO when we measure the line-to-line resistance - the inductive nature of the AC traction motor. When the resistive auto-ranging is turned on, the resistance of a TB2630 motor measures 241 milliohms. When the inductive circuit feature is enabled, it measures 156 milliohms. If, however the rotor happens to be removed, then the resistance measures 156 milliohms regardless of DLRO settings. It actually took some time before we discovered the different readings from "resistive" to "inductive". In fact it was only after we happened to measure a stator after its rotor had been removed[1]. However, the DLRO can find opens in either mode. Because much of our experimental data was done in the "resistive"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mode, we will present resistance numbers in that mode - that is 230 milliohms, line to line per motor.

[1]When the DLRO is set for "resistive" mode, the meter determines the resistance in about 2 seconds. In "inductive" mode, the meter enters into constant scanning as it changes current source values. A final reading takes nearly 20 seconds until the inductive effects dampen away.

Measuring Parallel Motors

Let us look now at the simplified power circuit for the entire truck (Figure 16). Three parallel motors, each with 250 milliohms will have the line-to-line resistance between any two phases of approximately 77 milliohms. The cable resistance between inverter and motor is insignificant, as 50 feet of EMD 325/24 cable will add only 4 milliohms per motor. The absolute value will vary with the ambient temperature of the motor widings, but each line-to-line reading (u-v, v-w, w-u) will be very nearly the same.

At first, we would disconnect the three phase cables at the bus bars of the TCC. But then, one of our electrician apprentices (growing tired of breaking and bolting connections) asked if it was really necessary. This prompted us to look at the power circuit of the inverter, seen in Figure 3. Each phase module is a turned-off GTO and a free-wheeling diode. Since the maximum output of the DLRO is only 200mV and the diodes will not conduct below 0.7 V, the GTO phase modules do not participate in the resistance measurement and there is no need to disconnect phase cables. This dramatically speeds up the diagnostic process; discharge the DC Link, remove cover for the TCC terminals, check for residual voltage and start measuring resistances.

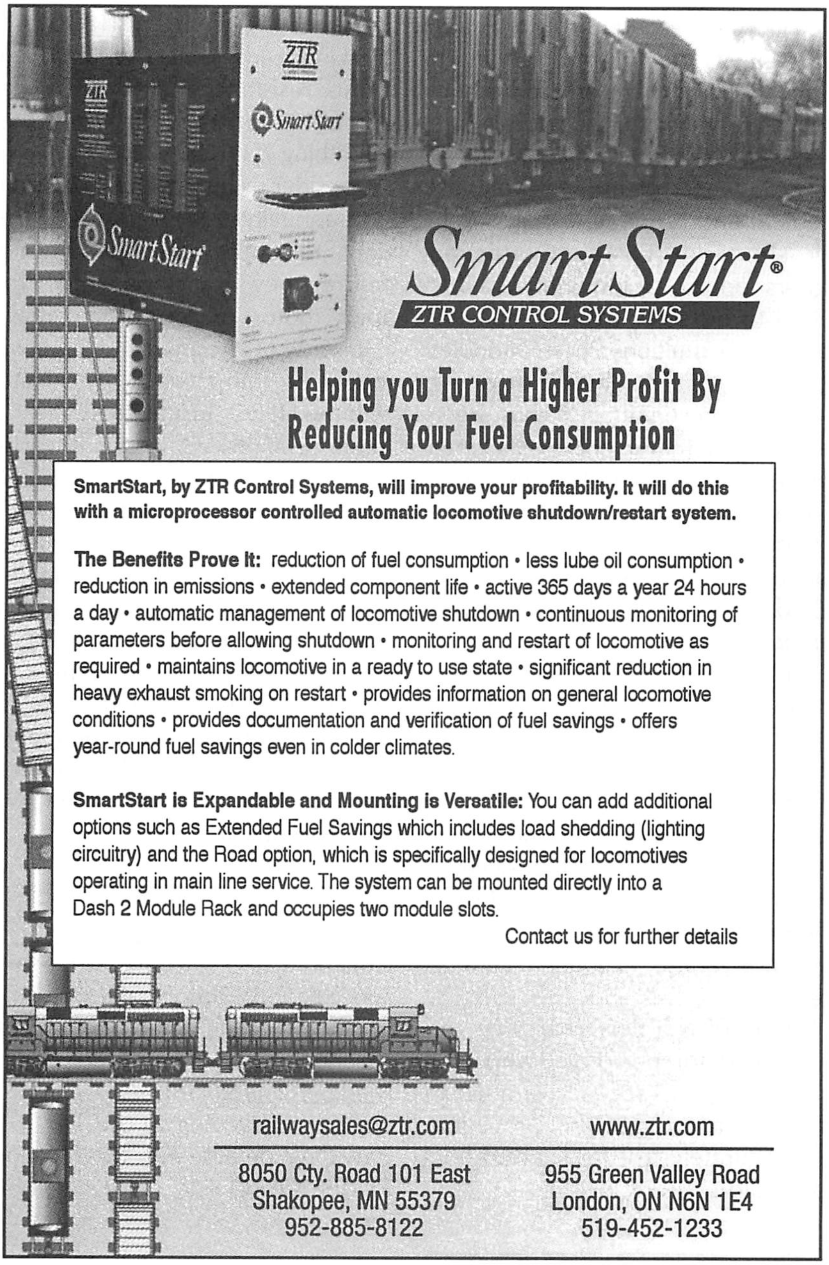
Assume that one traction motor has an open in phase W. Actual measurements of an open-motor SD70MAC had the "normal" 77 milliohms between U and V, but 107 milliohms between U-W and V-W. Such a difference can be easily spotted. Now assume we have a half-open motor in a truck. In that case, one resistance will be about 231 milliohms while the other two resistances will be about 348 milliohms. Combined with the other 2 normal motors, the readings will be:

U-V	U-W	V-W
77 mΩ	87 mΩ	87mΩ

Thus, the half-open motor in a truck can be spotted by a difference of 10 mΩ between line-to-line resistances, a full open motor spotted by a 30 mΩ difference.

Canvassing The Fleet

Once we had a diagnostic tool, we at The Alaska Railroad applied it to our fleet of 24 SD70MAC's (16 that are 7 years old, the last 8 are 3 years old), worried that there might be half-open motors that we could catch before the motors would completely overheat. All were in fine shape, all with balanced resistances from 77 to 80 milliohms. We've still had our share of "full open" single-phased motors[2] (Figure 17) and in that situation the DLRO provides a quick confirmation of a problem.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In Conclusion

For Short Circuits

While the procedure of detecting shorts in AC traction motors sounds relatively easy, there are some conditions in which that is not so. The focus on this presentation was to show how to identify a potential problem and properly test and identify shorts in EMD AC traction motors on MAC locomotives. The failure to do so will cause repeated damage to multiple Phase Modules in EMD MAC series locomotives.

In this presentation it has been emphasized that if there has been two defective Phase Modules in one inverter, this is pretty much a sure sign of a shorted traction motor. The traction motors need to be properly tested for shorts by the means presented here.

While two defective Phase Modules is an excellent indicator, it is possible if there is one defective Phase Module there could still be a shorted traction motor. There has not been enough of this type of incident to collect data and develop guidelines. However, the guidelines developed here would be accurate for singe Phase Module failure as well.

Figure 18 is a flow chart that can be copied for personnel who deal with this type of scenario in order to assist them through this procedure and accurately test for shorted traction motors.

[2] The phase cables pass thru the stator and are secured with a plastic. The 470 miles of jointed ARR rail (now dramatically reduced through our rail welding program) has had to be a factor in the broken connections.

For Open Circuits

The DLRO provides a quick method to evaluate an entire truck for opens in one test WITHOUT breaking leads. Unless all three line-to-line resistances at the TCC are within 1-2 mΩ of each other, then something is amiss.

Consider using the DLRO on quarterly, annually or semi-annually if you want to find "half-open" motors before they transition into "full-open" motors or to winding damage.

Reports of "hopping" locomotives should be immediately investigated with the DLRO. Just at press time, an AkRR SD70MAC crew reported "Unit bucks under load of B5 dynamic brake about 25 MPH downhill w/56 loads." The electrician checked both trucks with the DLRO, found 82 mΩ all around on the rear truck, but got 89/89/82 mΩ on the front truck. When the motor was removed and disassembled, sure enough, a half-open motor was found. No coil overheat damage resulted, as the open motor was found so quickly.

References

Baker Instruments Company, Ft. Collins, CO: Providing surge test specifications, theory and principles of surge testing, and reference to Paschen's Law.

Megger Limited
website (www.megger.com)
Providing details and specifications for the DLRO low resistance ohm-meter.

Contributions

I'd like to thank the electricians of the Alaska Railroad who did all the work gathering data using the DLRO on our fleet of SD70MAC's.

-Jay Boggess

I'd like to thank the Union Pacific for their cooperation in acquiring shorted traction motor information. And to Siemens personnel on other SD70MAC, 80MAC, & 90MAC projects contributing to this presentation.

-Steve Mueting

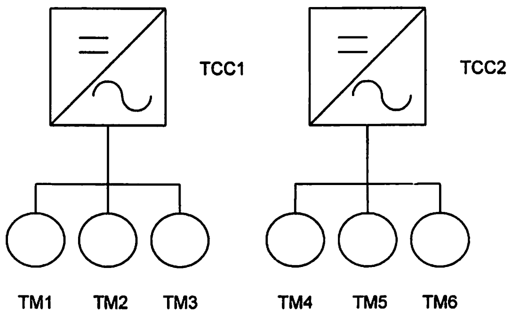


Figure 1 – EMD Locomotive Basic Power Circuit

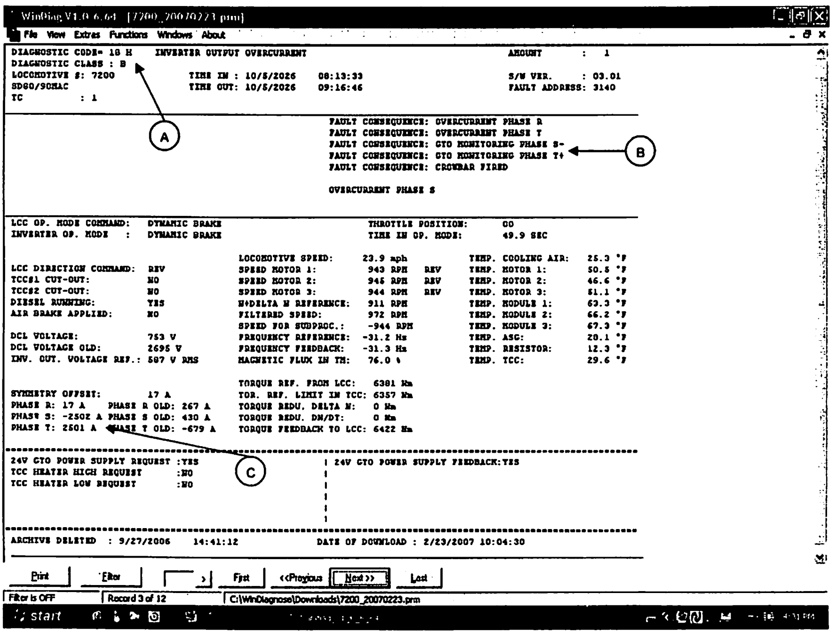


Figure 2 - Siemens Fault Information with Indicators A, B, & C

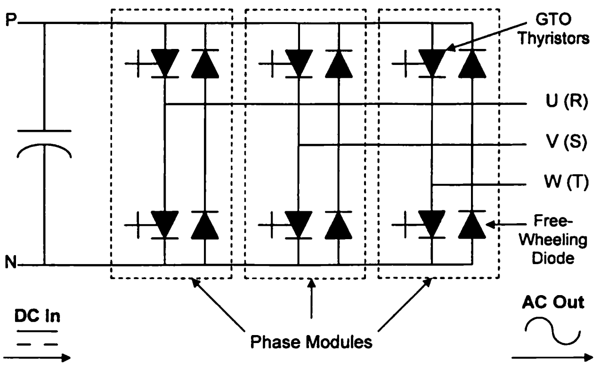


Figure 3 – GTO Inverter Simplified Schematic

Two Shorts / Two Tests	**Hard Short**	**Air Gap Short**
Low Resistance Ohmmeter Test	Effective	Not Effective
Surge Test	Effective	Effective

Table 1 – Short Circuit Test Effectiveness

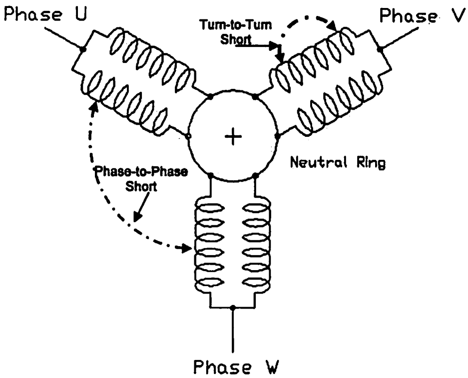


Figure 4 – AC Traction Motor Schematic with Shorts

UP 8051	Phase Resistance Measurement (milliohms)			
Traction Motor	**U-V**	**V-W**	**W-U**	**Difference**
#1	98.0	98.0	98.0	0.0
#2	99.4	99.1	99.4	0.3
#3	148.1	148.0	98.8	49.3

Table 2 – UP 8051 Resistance Test

NS 7200	Phase Resistance Measurement (milliohms)			
Traction Motor	**U-V**	**V-W**	**W-U**	**Difference**
#1	101.2	101.4	101.3	0.0
#2	100.3	100.0	100.2	0.0
#3	102.1	102.2	102.2	0.0

Table 3 – NS 7200 Resistance Test

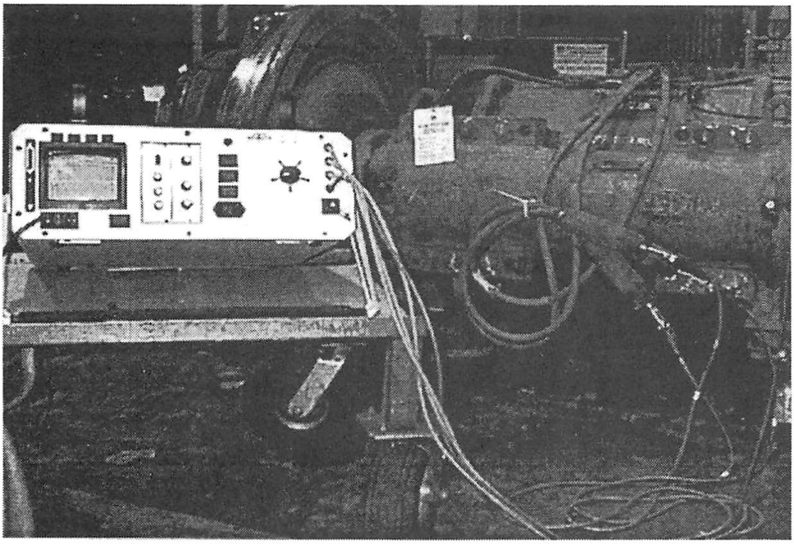


Figure 5 - Surge Tester connected to traction motor

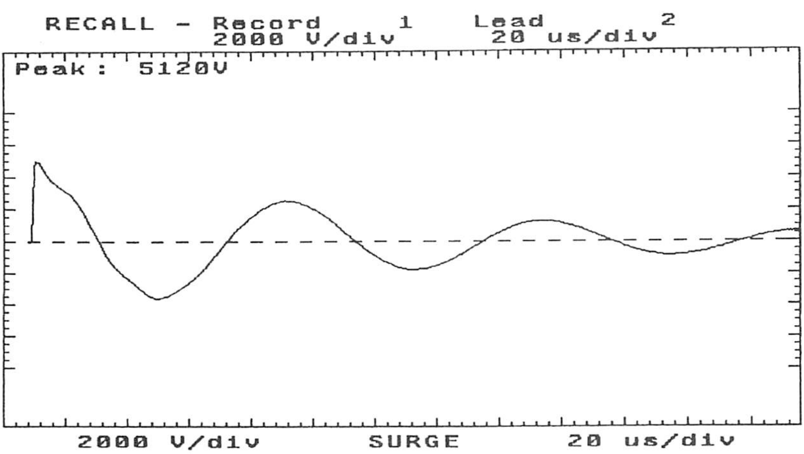


Figure 6 – Surge test results of one phase winding

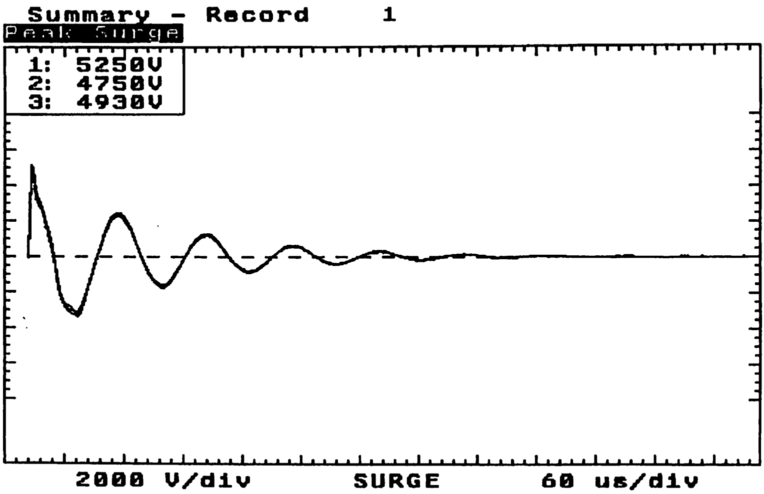


Figure 7 – Surge test results of all three phase windings

Good motor

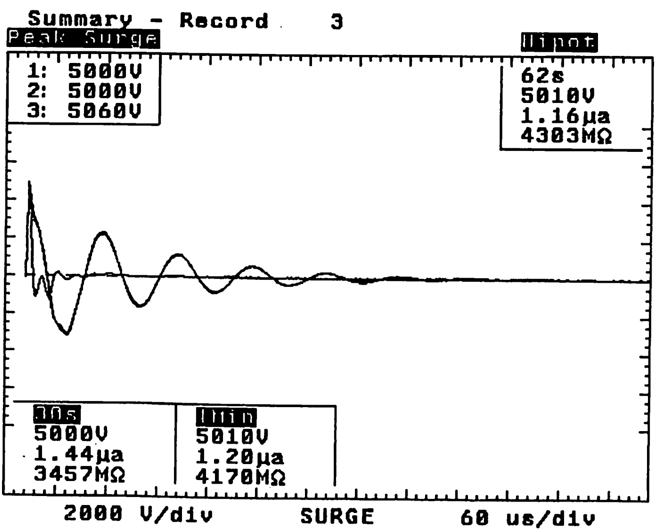


Figure 8 – Surge test results of all three phase windings – Defective motor

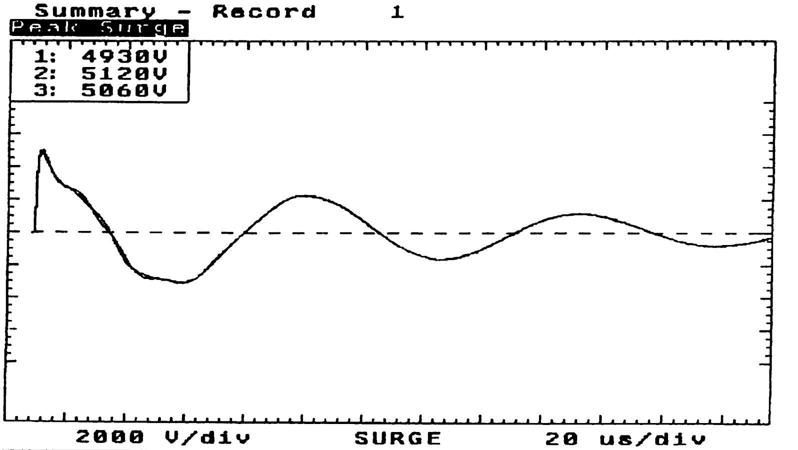


Figure 9 – Surge test results of NS7200 TM#1

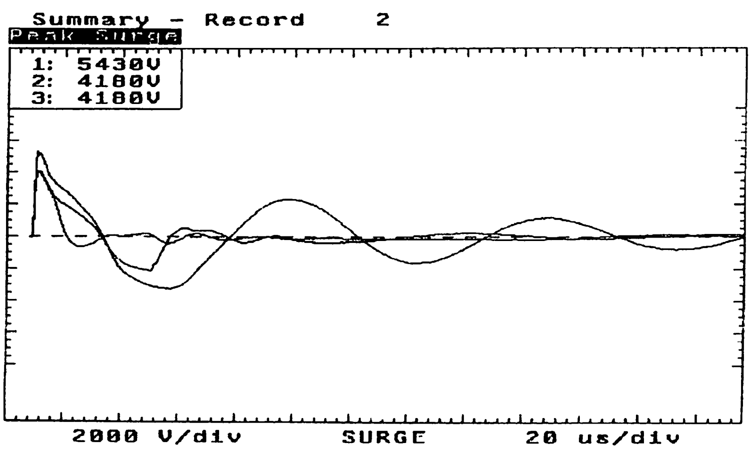


Figure 10 – Surge test results of NS7200 TM#2

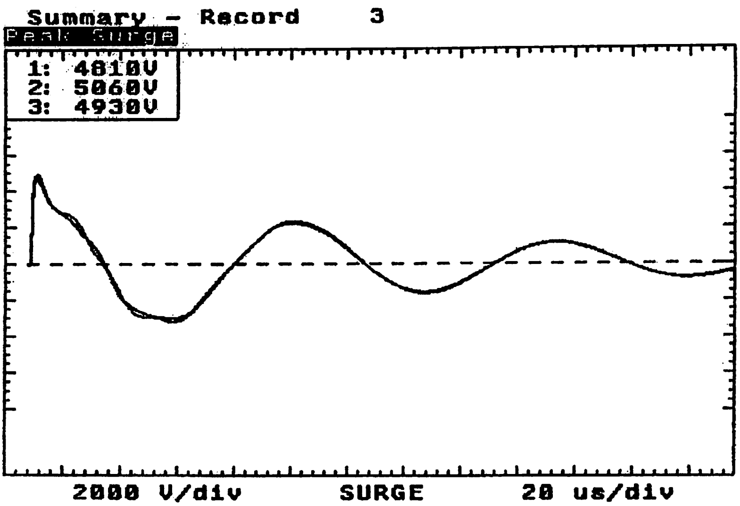


Figure 11 – Surge test results NS7200 TM#3

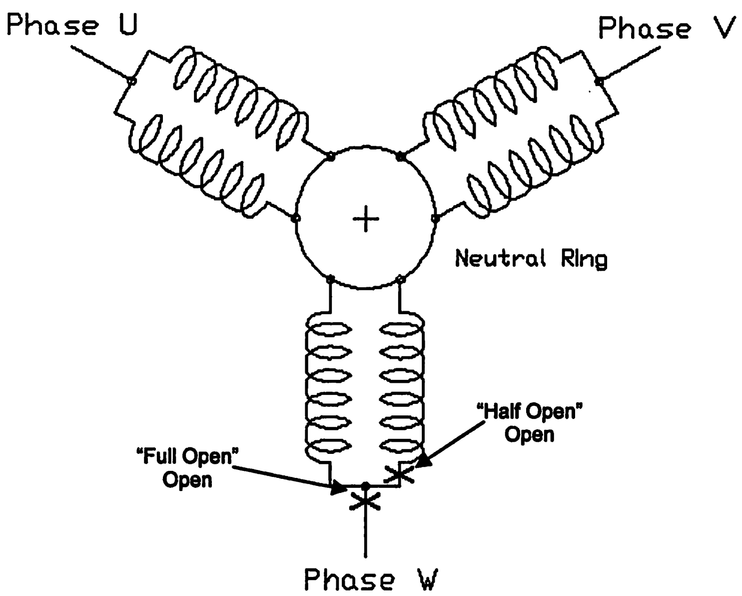


Figure 12 – Motor Schematic For Open Circuits

Figure 13 - Repaired Motor Cable Connections of Half Open Motor

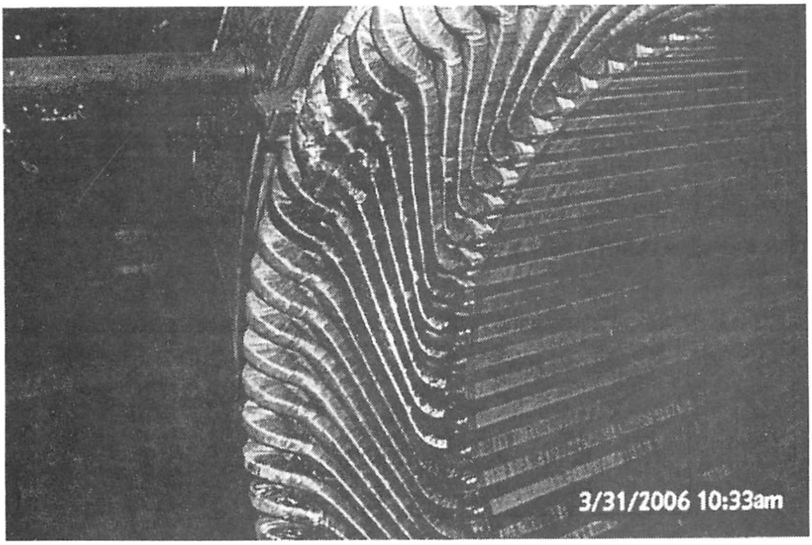


Figure 14 - Winding Damage Due to Half-Open Motor

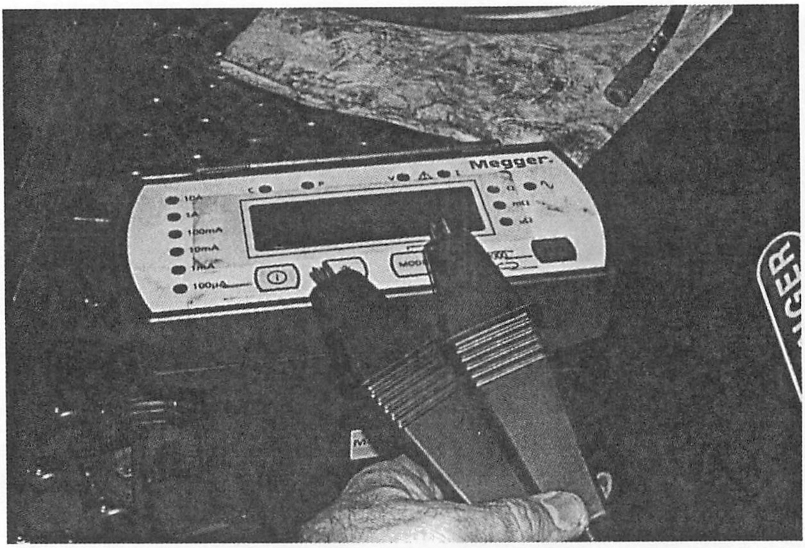


Figure 15 - Megger DLRO Low Resistance Ohmmeter

Full Scale	Resolution	Full Scale Volts - Resistive	Full Scale Volts - Inductive	Test Current Resistive	Test Current Inductive
1.9999 m Ω	0.1 µΩ	20mV	n/a	10A	n/a
19.999 m Ω	1 µΩ	20mV	20mV	1A	1A
199.99 m Ω	10 µΩ	20mV	200mV	100mA	1A
1.9999 Ω	100 µΩ	20mV	200mV	10mA	100mA
19.999 Ω	1 mΩ	20mV	200mV	1mA	10mA
199.99 Ω	10 mΩ	20mV	200mV	100uA	1mA
1999.9 Ω	100 mΩ	200mV	200mV	100uA	100uA

Table 5 – Megger DLRO10 Characteristics

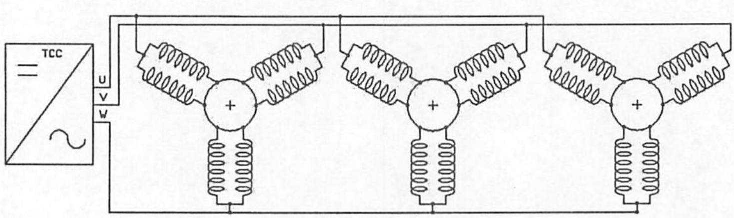


Figure 16 - TCC and Three Traction Motors

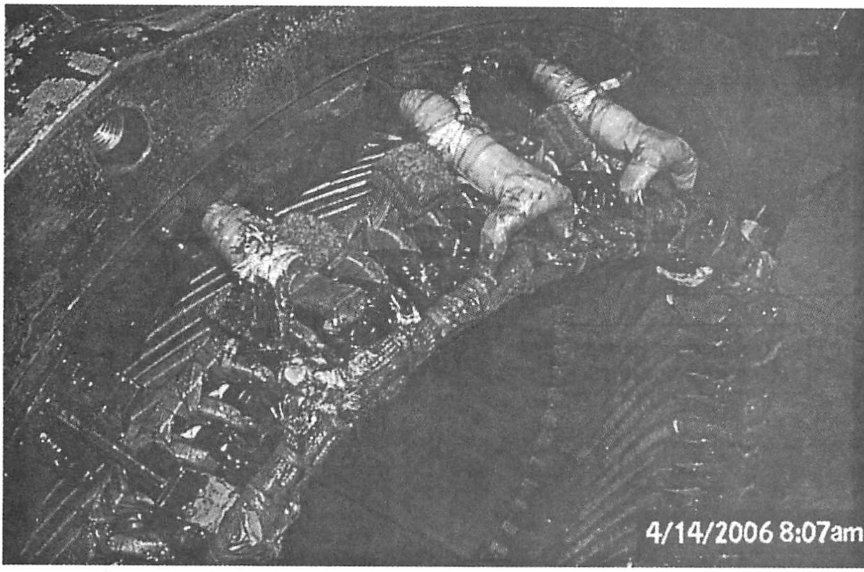


Figure 17 - "Full Open" Motor Lead Connections

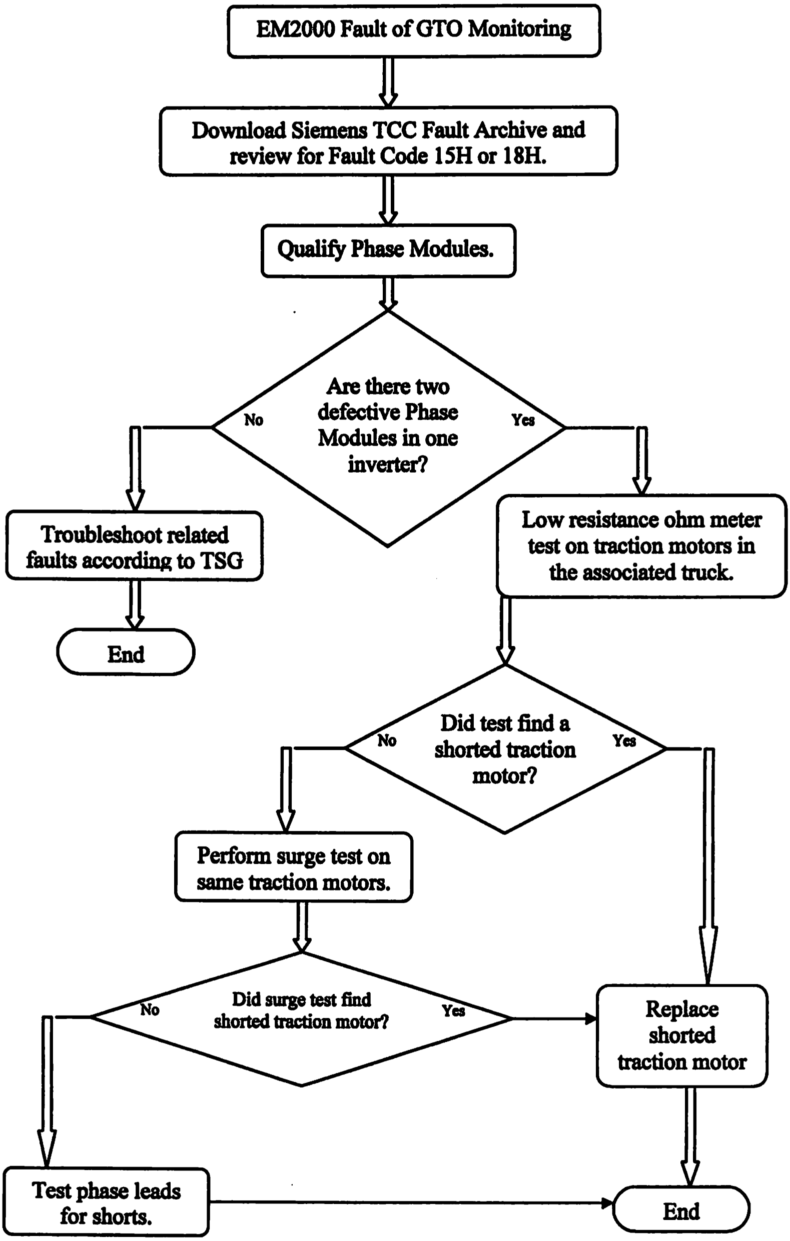


Figure 18 – Flowchart of properly testing for shorted traction motors

2. LOCOMOTIVE CAB SIGNAL FAILURES AND TROUBLESHOOTING

Prepared by
Felix Fraga,
New Smyrna Beach
Locomotive Shop

Ultra Cab I Operation

Ultra Cab I automatic train control at Florida East Coast Railway was originally designed by Harmon Industries (now part of GE Transportation Global Signaling). Its primary functions are indicating maximum allowable track speed, and avoiding an overspeed condition through a penalty brake application. Block layout determines where the cab signal aspect will change as the train moves. The ATC system receives aspect codes (CCO thru CC9) from a wayside generator through the rails, decodes the signals, displays the aspect in the cab (ADU), and enforces the associated speed. Principal components include the Logic Control Cab Rack; CSR (Cab Signal Receiver); LSL (Locomotive Speed Limiter); Power Supply; ADU (Aspect Display Unit); CDU (Conductor Display Unit); EDU (Engineer Display Unit); Lead/Trail Cutout Switch; Air Cutout Valve (needs to be sealed per FRA); Axle Drive Alternators (60ppr-on the #2 axle); Optical Box (Links Ultra Cab to Event Recorder); Pickup Coils and Bars; Magnet Valve; ATS Acknowledge Foot Pedal Switch (110-115 PSI, brake pipe). FRA Title 49 CFR Part 236 requires a daily or after trip test (236.586), a departure test (236.587), and a periodic test (236.588). These requirements are satisfied at service tracks, locomotive shops, interchange points, and/or initial terminals

The majority of malfunctions or defects are due to:

- CSR out of calibration or failed - 18%
- Axle drives and speed probe defects - 46%
- LSL out of calibration or failed - 17%
- Power supply problems - 10%
- Pickup coil defects - 5%
- ATS Acknowledge Pedal switch not working

Locomotive cab signal flips occur when the aspect indications intermittently change for a short period of time (less than 5 seconds) and then return to the original aspect indication. Cab signal failures are an intrinsic part of ATC operation and are expected to happen. Based on a survey of 19 FEC trains operating between 2/16/06 and 2/23/06, there were 103 cab signal flips. Engineers set the brakes only 9% of the time. The average train speed was 46 mph. The cab signal flips occurred 76 times on the main line and 38 on curved track.

Cab Signal Flip Causes

- Track anomalies in curves, grade crossings, crossovers, and interlockings.
- Highly magnetized rails
- Traction motor interference with pickup coils, receiver bars, and windings.
- Truck components with mechanical defects (abnormal vibrations, truck hunting).

- Incorrect receiver bar alignment
- CSR out of calibration, LSL defects, and pickup coil defects stemming from mechanical, energy, winding, and hysteresis (slow reaction time) losses.

Cab Signal Flip Remedies

- The engineer should wait at least 5 seconds. If after this period of time, the cab signal won't return to its original aspect, the engineer should take action and apply good train handling procedures complying with the aspect displayed
- Slow the train by setting the brakes. After the indication changes to a more favorable aspect, the speed may be increased.
- When the train has been slowed down, or stopped, because of continuous flips the engineer needs to contact the dispatcher to ask permission to cut the ATC out.

Cab Signal Flip Economic Losses

- Fuel is wasted by resuming train speed (diesel engine RPMs increase) and having the locomotive main air compressor working longer to recharge the air in the train line.
- Setting the brakes to slow the train down cuts back on kinetic energy, wearing out brake shoes and wheels.
- Lost revenue due to an inability to adhere to the timetable (operating plan) and late deliveries to the customer.
- Crew expenses increased by overtime.
- Increased locomotive maintenance costs. After the locomotive arrives at its destination, the ATC has to be (readjusted), or some components need to be changed to have the locomotive return to service as a lead locomotive. Repairs frequently involve replacement of the CSR, LSL, or Power Supply.

The table shows the $ cost of some component replacements which is a factor when faced with making these ATC repairs.

Summary

This paper provided a brief overview of the operational theory of the Ultra Cab I Automatic Train Control system used on the FEC to include its principal components, and some of the types of defects encountered with the system. This paper also addressed cab signal flips and some of its causes and remedies along with the economic lossses as a result of these cab signal flips.

3. MAINTAINING MAIN GENERATORS - SOME SAFER METHODS

Prepared by
Bill Kirdeikis,
Senior Reliability Specialist
Electrical-CN

At CN we still have fairly large fleet of locomotives in yard service that use D12 main generators and in fact even have some units with D15 generators. As anyone knows a main generator is a much higher maintenance item than an alternator.

With this paper I will not be dealing with all aspects of main generator maintenance but rather two specific items that can be done safer than we have done in the past. These tasks would be.

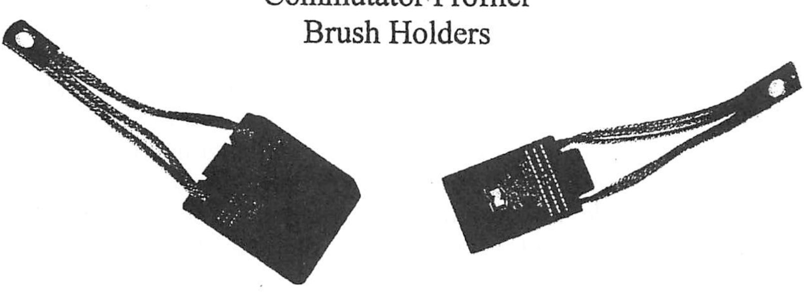
1. Cleaning of the main generator commutator.
2. Seating of the main generator brushes.

Cleaning Main Generator Commutators

Most people who maintain main generators have had the need to clean the commutator due to oil or dirt ingress or even flashover. We like many other railroads in most cases resort to using a standard rubber stone (Fig. 1), which in effect is nothing more than a somewhat coarse giant eraser. The unit is started and with the generator covers open the stone held by hand is pressed against the commutator and maneuvered across the entire surface to clean the commutator (Fig. 2). This would include angling the stone in an attempt to get to those areas of the commutator, which cannot be easily reached e.g. the area of the commutator under the generator frame area (Fig. 3). We have done this for many years and every person doing it may have felt leery about having their hand that close to a commutator moving at some 49.8 ft/second or roughly 34 mph but the job was still done with a lot of care and attention.

This method was used successfully for a long time until one of our electricians had the stone grab and forced his hand into the rotating commutator. He was actually very fortunate in that his injuries were limited to severe abrasions to his fingers. The first thought was that the employee was at fault for not taking proper care while doing this job but further thought on this matter made it pretty clear that the job should be able to be done in a safer manner withouth the inherent danger of getting people's hands that close to the moving commutator.

The first idea conveived was an extension for the commutator cleaning stone (Fig. 4), which would allow the extension to sit on the web of the main generator frame (Fig. 5). This idea was discarded for two reasons, the inherent drag of the moving commutator on the stone with tendency to try and flip the stone up is almost magnified by the extenstion and there is very little chance to get the stone into the hard to reach areas of the commutator (Fig. 6). What this did is define the rules of what the alternative methods had to do and these rules were we could not depend on hand held stones and the cleaning method had to have the



ability to clean the entire surface of the commutator. With the help and ideas of a supervisor at one of our shops an entirely different method was thought of which encompasses both of these critical points.

The new concept is in fact a very simple one. Remove one of the brush holders and apply a specially cut cleaning stone to the brush holder which is solid on the base which contacts the commutator and actually extends to the outside of the commutator outside of the brush paths as well as cleaning the area in between the brush paths. A prototype was cut out of the two existing commutator-cleaning stones (Fig. 7 and Fig. 8). This was made in two pieces, as the length of the stones is insufficient to make it out of one piece. We are still working with an outside firm to find commutator cleaning stone stock in sufficient size to build this stone in a one-piece design. Once the stone is applied to the brush holder, the holder is reapplied to the generator with the height of the holder set so that the cleaning stone tip is just resting on the commutator (Fig. 9) (Unfortunately unable to get detail between brush holder body and commutator showing cleaning stone). Spacer blocks are then placed in the brush pockets from the top side to apply pressure on the stone rather than having the stone preloaded with spring pressure which would make the proper application of the brush holder a lot tougher while keeping the stone square in the pockets. In addition the spacer blocks can be used over again rather than being discarded as a wear item. The end of the stone is cut at the same angle as a standard main generator brush but not contoured like a brush to allow the stone to conform to the commutator as it cleans with the commutator rotation into the open area under the stone. This will make for an easier break in on the cleaning stone effectively giving the same advantage a bevelled leading edge would give us.

Overall this new cleaning stone application will add a total of about 10-15 minutes to the job of cleaning a commutator but will ensure a complete cleaning of the commutator but first and foremost will ensure that no one will have to try and extract somebody's hand or fingers that have been jammed into a commutator. Ten to fifteen minutes seems a pretty fair trade off for the added safety.

Seating Of The Main Generator Brushes

One of the main methods used for seating main generator brushes after a complete brush change out is the use of an abrasive stone, that is basically a chalk stone which breaks up and rides under the brushes grinding them down on the commutator contact surface to seat the brushes (Fig. 10). With this stone you need to use the stone in front of about every 3-4 brush holders with the generator turning to get enough of the seating compound travelling under the brushes in the trailing holders. While there is much less friction on the seating stone as compared to a cleaning stone it still does involve getting your hands in very close proximity to the rotating commutator once the stone starts to wear down. In addition to this a large amount of residue of the stone is left in the generator which needs to be blown out.

A much cleaner and safer method is to use a spray bottle loaded with hydrogen peroxide which has been proven to aid in brush seating and is used by many motor and generator rebuilders. Following is the actual step in the air curing procedures used by our Symington shop in Winnipeg.

(2). Seat Brushes: Start unit and spray hydrogen peroxide at commutator in three or four spots to seat brushes and reduce brush noise.

Overall there are many items done on a locomotive that do carry some inherent danger and locomotive maintainers must be ever vigilant when doing these tasks especially. If we can take out some of the inherent dangers of these tasks we are duty bound to examine and try new procedures that might just do that.

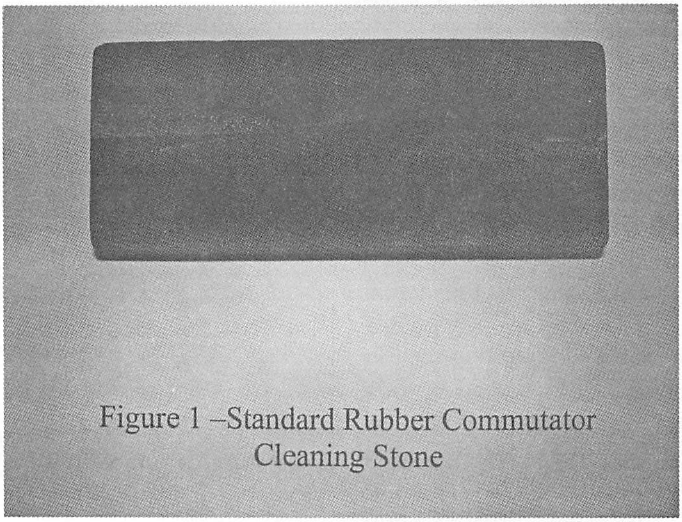


Figure 1 –Standard Rubber Commutator Cleaning Stone

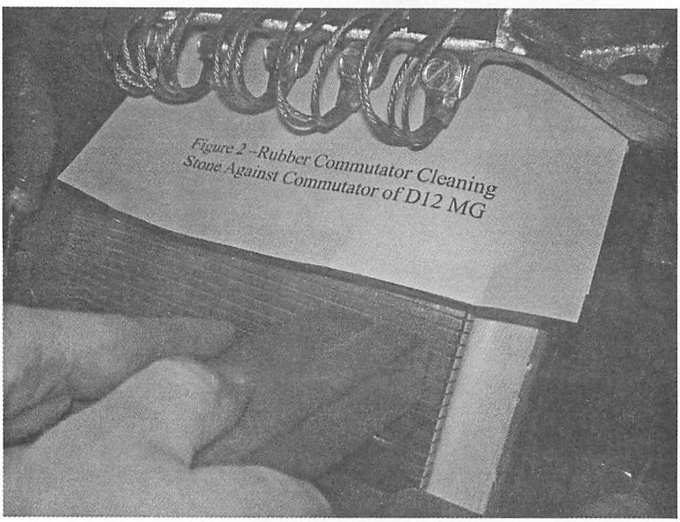


Figure 2 –Rubber Commutator Cleaning Stone Against Commutator of D12 MG

Figure 3 - Hard To Reach Commutator Area For Cleaning

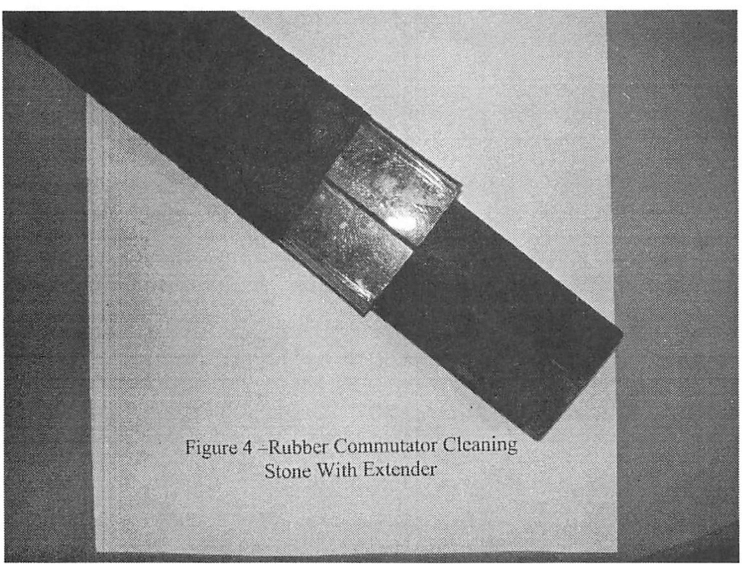


Figure 4 –Rubber Commutator Cleaning Stone With Extender

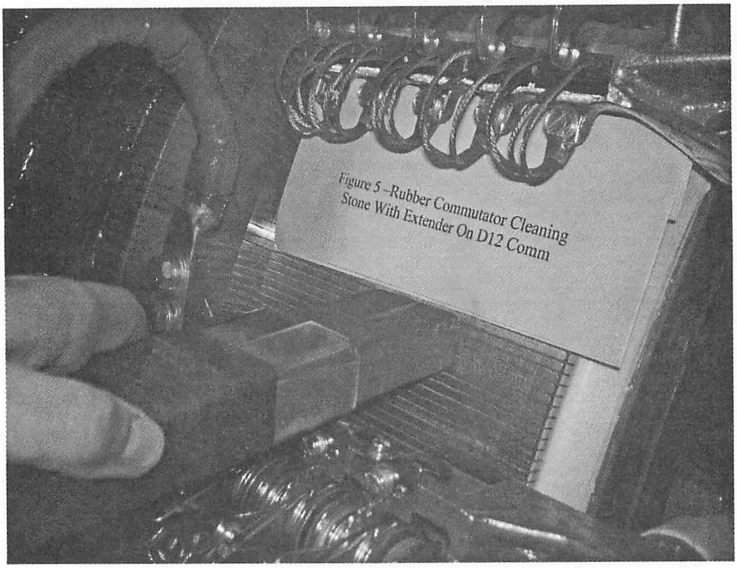


Figure 5 –Rubber Commutator Cleaning
Stone With Extender On D12 Comm

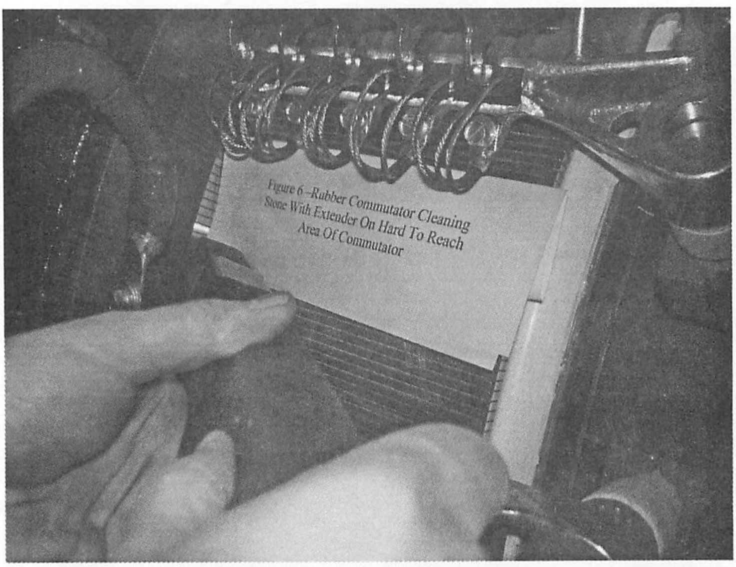


Figure 6 –Rubber Commutator Cleaning
Stone With Extender On Hard To Reach
Area Of Commutator

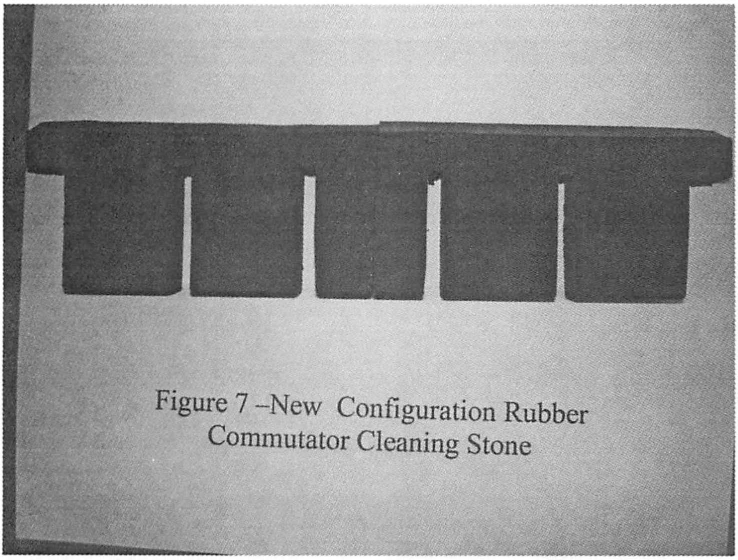


Figure 7 –New Configuration Rubber Commutator Cleaning Stone

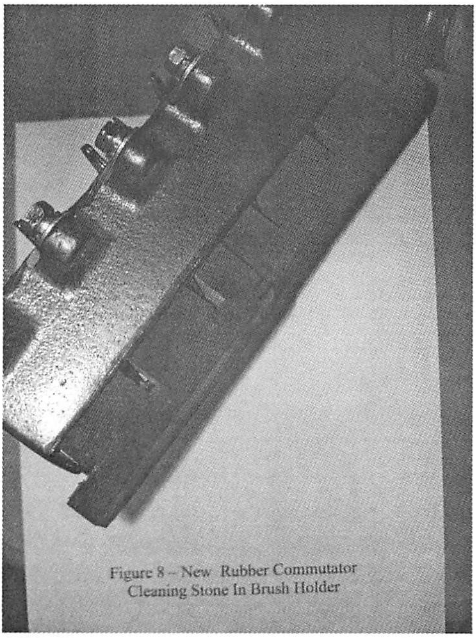


Figure 8 – New Rubber Commutator Cleaning Stone In Brush Holder

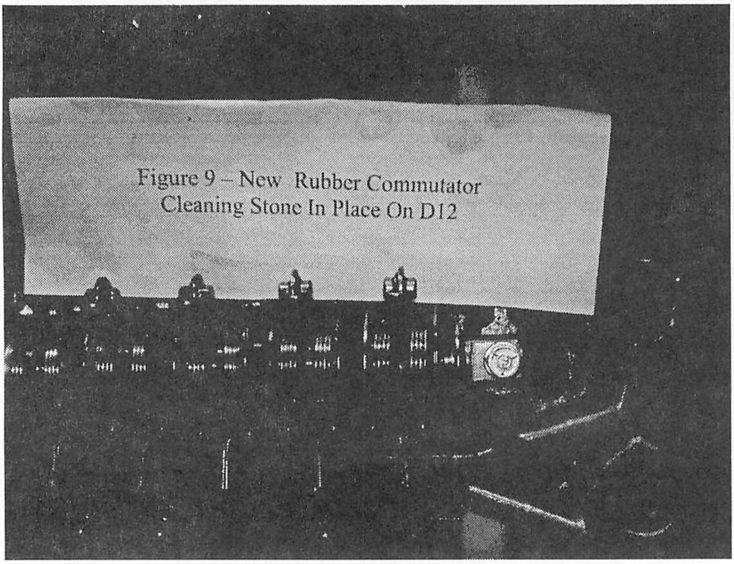


Figure 9 – New Rubber Commutator Cleaning Stone In Place On D12

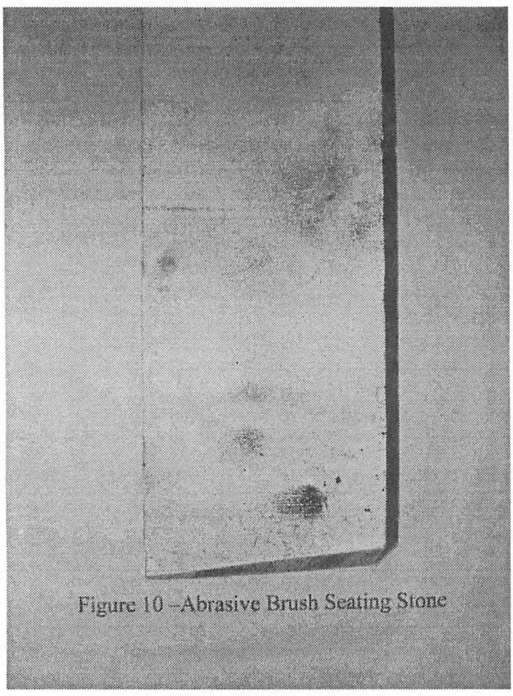


Figure 10 –Abrasive Brush Seating Stone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4. LOCOMOTIVE SOFTWARE MANAGEMENT

Prepared by
Victor Trout,
Manager Mechanical Engineering
Union Pacific

The fast paced world of electronics and computers has led companies from various industries to take a proactive approach to software management. The railroad industry is no exception and needs to consider the consequences of ignoring some of the more modern technology found on their fleet, especially, the software that runs the computers in key systems on their locomotives. As the railroad industry is beginning to become more wireless friendly, it's important to consider software upgrades on locomotives in the same way you would for your home computer or workstation. This paper will cover why upgrades are needed, why it's important to maintain software, and some beneficial techniques behind software management.

Consider your home computer or workstation. How often do you upgrade your computer at home? It's a safe bet that the answer is less than 30 years. How long do railroads keep their locomotives? Many keep their locomotives in service for more than 30 years! That's amazing considering other industries keep their similar duty-cycle products in service for a decade or two at best. It's no surprise why railroads keep locomotives in service for so long: they are built to last and expensive to replace.

Let's consider a locomotive model which has surpassed the 30 year mark: EMD SD40-2. The electronics were made of simpler components and the hardware logic network made from these components is now handled by software. With the introduction of complex computer systems in newer locomotives, hardware is rapidly being replaced by software and additional functionality that enhances the performance of the locomotive can be achieved. Picture computers from the 1960's & 1970's and how they evolved into what they are today: faster, smaller, and cheaper.

With the introduction of modern electronics on locomotives, the longevity of hardware as compared to the useful life of software is a big problem because the continuous improvements and upgrades make software systems obsolete long before a locomotive is scheduled for replacement. In fact, the hardware which houses software will most likely become obsolete during the life span of the locomotive. Although the manufacturers will state a typical locomotive lifespan is 20 years, the locomotive computer hardware and software was never designed to last 20+ years without upgrades. Often times, when a hardware component becomes obsolete, the external computer software that controls it will need to be upgraded for a number of reasons like new communication protocols.

Locomotive maintenance is considered a large expense for the railroad but after factoring in all the expenses incurred by not performing maintenance, it really isn't an expense. How many road failures and/or recrew events are prevented thanks to maintenance? For example, on DC locomotives it's critical to change out traction motor brushes once a certain wear line mark is reached or it will fail and cause a road failure. There are also key maintenance tasks which address components that have a certain wear out period such as a fuel filter. It's only a matter of time before neglecting maintenance on locomotives will cause serious road failures and delays in train operation. I don't need to spend too much time convincing anyone that maintenance is important, however it's apparent railroads don't focus their efforts on all parts of the locomotive that need to be maintained.

As you may already know, certain locomotive models are utilizing technology that's found common to a PC (e.g. Windows XP). How many software patches has Microsoft released since Windows XP was introduced in 2001? Dozens if not hundreds, and most likely if you're running a computer with Windows XP it will automatically update in the background or if you're a little more computer savvy, you may manage when and how the upgrades are installed. I'm sure the applications you run on your home computer are very important, but is your computer responsible for operating applications that could adversely affect safety? How about applications that are responsible for ensuring critical deliveries make it to their destination on time? A locomotive is responsible for such tasks, and the software that controls the locomotive systems are critical and need to be maintained either on-site or remotely. Let's consider another industry where maintenance is critical to safety and timely deliveries: aerospace. Airplanes are periodically maintained and much like locomotives, there are certain government regulations that force the airline companies to perform a certain level of maintenance on their fleet. The aerospace industry also has certain standards and certifications regarding software which help minimize the risk of catastrophic events. The RTCA DO-178B: Software Considerations in Airborne Systems and Equipment Certification is a standard developed by the Radio Technical Commission for Aeronautics, Inc. to certify software in the aerospace industry. One of the key principles is the software criticality level which is used to assess the effects of failure ranging from No Effect through Catastrophic. A concept like this seems futuristic to our industry but it's been a common practice in other safety critical industries for years.

One of the basic elements of software management is documentation. This can be as simple as creating spreadsheets with fleet information and software versions, to something more sophisticated that includes software differences and perhaps current software versions for each locomotive in your fleet in a complex database. Why is documentation so important?

Consider an AC locomotive fleet that's in a specific type of service (high speed intermodal for example), and so far this locomotive model has been running reliably and safely for years. Because of shifts in the economy, transportation operations wants to change the service these locomotives run to slower, heavier train service like coal. While these locomotives are designed to handle any type of service, let's just say hypothetically something about the consistency of slower speeds in coal service causes the speedometer to momentarily go haywire at a variety of speeds. What if this problem is only caused by a handful of locomotives at the beginning of the order? Reason? They have a different version of control software than others in the fleet but you didn't know there was any difference.

Seems like a simple problem to correct, right? Well, what if you have to take hundreds of locomotives out of service because you didn't document your software versions and weren't aware this problem was confined to only five locomotives? That's just one example, but in any industry, it's common and good practice to document all software versions and maintain a certain level of configuration control on critical systems. There are a multitude of techniques that can be utilized in order to effectively obtain software versions on locomotives. With a large fleet of locomotives, the challenge is not necessarily how to document the software versions; rather, it's collecting the software information off your locomotives. This may sound simple but it's no easy task when you've got thousands of locomotives traversing across a large portion of the country, not to mention the out of service time needed for manually gathering this information. Until wireless technology becomes more widespread in the industry, most information gathering must be done by either inspecting or obtaining a log file with a laptop from the locomotive manually by a craftsman. Typically, a fault log or event log file off a given locomotive computer system will contain a version number in the header or footer of this log. Currently at UP, we use two methods for obtaining software version information off our locomotives. One method is wireless transfer which is accomplished by means of traditional radio communications, satellite, or 802.11 and it's by far the most accurate means of information transfer. The other more widespread method at UP is the practice of obtaining software information by taking a manual log file download from the locomotive itself when it comes in for servicing, unscheduled, or planned maintenance. Although this is more time consuming, once the information is transferred into the UP system, it's there for the taking and any sort of fleet analysis can be done instantaneously. In addition, we have certain methods in place to add tasks automatically through our CMMS (computerized maintenance management system) when the software version is incorrect or obsolete.

Another key element to software management is ensuring proper testing is conducted by the manufacturer before installation is applied fleet wide. Often times, the manufacturer will utilize railroads for field testing

purposes by installing a newly released software package on a small number of locomotives for a given period of time. I cannot stress the importance of this testing from personal experience especially when the changes could potentially affect other systems (distributive power, cab signals, electronic air brakes, etc.). It's also important to keep in mind that the field testing should have a defined beginning and end. Field tests often begin with a time-frame documented for the release of the final version of software but many times upon completion of the test, the field test units don't get upgraded because they are lost in the shuffle and/or forgotten. This might work if the test software and the final release software are identical, but this is a rare occurrence.

The future of the railroad industry depends upon how well we maintain all parts of our locomotives; this includes software and electronics. The good thing about having a limited number of OEMs is that there is commonality in fleets between railroads and through collaborative efforts, we can help each other with shaping the way software is maintained for the future.

CONSTITUTION AND BY-LAWS LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

Revised September 22, 2003

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 - Railroad Membership shall be composed of persons currently or formerly employed by a railroad company and interested in locomotive maintenance. Membership is subject to approval by the General Executive Committee.

Section 2 - Associate Membership shall be composed of persons currently or formerly employed by a manufacturer of equipment or devices used in connection with the maintenance and repair of motive power, subject to approval of the General Executive Committee.

Associate members shall have equal rights with railroad members in discussing all questions properly brought before the association at the Annual Meeting, and shall have the privilege of voting or holding elective office.

Section 3 - Life membership shall be conferred on all Past Presidents. Life membership may also be conferred on others for meritorious service to the Association, subject to approval by the General Executive Committee.

Section 4 - Membership dues for individual railroad and associate membership shall be set by the General Executive Committee and shall be payable on or before September 30th of each year. The membership year will begin on October 1 and end September 30. 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. Life members will not be required to pay dues, but 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. Each officer will hold office for one year or until successors are elected. In the event an officer leaves active service, he may continue to serve until the end of his term, and, if he chooses, continue to serve as an executive officer and be allowed to elevate through the ranks as naturally occurs, to include the office of President.

Section 2 - There shall be one Regional Executive officer assigned to oversee each technical committee. Regional Executives shall be appointed from the membership by the General Executive Committee for an indefinite term, with preference given to those having served as a Technical Committee Chairperson. A Regional Executive who leaves active service may continue to serve as such, and shall be eligible for nomination and election to higher office.

Section 3 - There shall be a General Executive Committee, composed of the President, Vice Presidents, Regional Executives, Technical Committee Chairpersons, and all Past Presidents remaining active in the Association.

Section 4 - There shall be a Secretary-Treasurer, appointed by, and holding office at the pleasure of the General Executive Committee, who will contract for his or her services with appropriate compensation.

Section 5 - All elective officers and Regional Executives must be LMOA members in good standing. (See Article III, Section 4.)

Article V - Officer, Nomination and Election of

Section 1 - Elective officers shall be chosen from the active membership. A Nominating Committee, composed of current elective officers and the active Past Presidents, 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 - Vacancies in any elective office may be filled by presidential appointment, subject to approval of the General Executive Committee.

Section 4 - The immediate Past President shall serve as Chairman of the Nominating Committee. In his absence, this duty shall fall to the current President.

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 additionally 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.

The Vice Presidents shall perform such other duties as are assigned them by the President.

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 General Executive Committee.

C. Perform the duties of the Secretary of the 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 Regional Executive officers shall:

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. Attend and represent LMOA at meetings of their assigned technical committees.

D. Promote Association activities and monitor membership levels within their assigned areas of responsibility.

E. Promote and solicit support for LMOA by helping to obtain advertisers.

Section 5 - Duties of General Executive Committee:

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 Auditing and Finance Committee.

D. Determine the number and name of the Technical Committees.

E. Exercise general supervision over all Association activities.

F. Monitor technical papers for material considered unworthy or inaccurate for publication.

G. Approve topics for the Annual Proceedings and Annual Meeting program.

H. Approve the schedule for the Annual program.

I. Handle all matters of Association business not specifically herein assigned.

Section 6 - The General Executive Committee is entrusted to handle all public relations 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 General Executive Committee.

Section 2 - A vice chairperson, selected by the chairperson and approved by the President.

Section 3 - Committee members, selected as follows:

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 direction of the General Executive Committee, non-railroad personnel may be allowed to participate in committee activities.

Section 4 - All individuals who are on technical committees must be LMOA members in good standing. (See Article III, Section 4).

Section 5 - Subjects for technical papers will be selected and approved by the General Executive Committee.

Article VIII - Proceedings

Section 1 - 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.

Section 2 - Those present at any meeting called on not less than thirty days advance written notice shall constitute a quorum.

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 and By-Laws may be amended by a two-thirds vote of the active members present at the Annual Meeting.

DIESEL MECHANICAL MAINTENANCE COMMITTEE TWENTY-FIVE YEAR INDEX

2006

1. Lost Opportunities of Rebuilding Trucks
2. GP/SD38-2S Locomotive-A New Class of Power
3. Heavy Diesel Engine Field Repair
4. Benefits of Mobile Maintenance

2005

1. Crankcase Overpressure Today - Concentrating on EMD and GE Locomotives
2. Cold Weather Locomotive Operations
3. Importance of Cooling System Health, EPA Compliance Impact
4. Overhaul Extension

2004

1. GE Evolution Series-Maintenance and Reliability
2. EMD 70ACe and SD70DC-Tier 2 Locomotive Models-Mechanical Maintenance Enhancements
3. Best Practices Series-For Regional and Shortline Railroads-Managing Locomotive Wheel Wear
4. Maintenance Savings - Mother/Daughter Units

2003

1. Training 60/30 Impact Now & Beyond
2. Condition Based Maintenance, Practical Approaches and Techniques

2002

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

2001

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

2000

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

1999

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

1998

1. LMOA Best Practices Series: GM Engine Crankcase Pressure Troubleshooting
2. Union Pacific's New EMD Diesel Engine Rebuild Line At

Downing B. Jenks Locomotive Facility-No. Little Rock, Arkansas
3. GE Turbo Rebuild Procedures
4. Mechanical Impact of Locomotive Emissions Regulations
5. Locomotive Engine Bearing Developments

1997

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

1996

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

1995

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

1994

1. Electronic Fuel Injection.
2. ICAV - The Physical Affects on Instantaneous Crank Shaft Angular Velocity Technology
3. Maintenance Practices Com-parison Between Regionals and Class I Railroads
4. Amtrak Document Manage-ment.

1993

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

1992

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

1991

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

1990

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

1989

1. Wheel Axle Gear Wear/Impact on Traction Motor Life
2. 710 Engine - Operational and Overhaul Update
3. GE Power Assembly Improve-ments 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 Lubricator
3. Gear Case, Bull Gear and Pinion

Gear Longevity in the 1980's - Gear Cases - Canadian National Experience.
4. Maintenance of Locomotive Fueling Systems for a Spill Free Operation

1986

1. Rebuild of Valve Bridge Assemblies
2. Update of New Locomotive Service Problems, EMD and GE Effecting Quality Performance
3. Chromium Plating and Its Uses
4. Development of a New Diesel Engine for Heavy-Duty Locomotive Service

1985

1. Procedures for Storing Serviceable Locomotives for Quality Performance
2. New Locomotive Service Problems, EMD and GE
3. 92 Day Service Requirements: EMD, GE and Bombardier

1984

1. Mechanical Aspects of New Locomotive Designs
2. Maintenance of Locomotive Components

1983

1. Leaks: Cooling Water, Lube Oil, Fuel Oil and Air
2. Torquing Recommendations.
3. Update on Fuel Efficient Locomotives
4. Radiator Screens
5. Alternate Starter Systems

1982

1. Fuel Conservation - Effects on Maintenance
2. Fuel Conservation - What It Costs.
3. Diesel Fuel Receipt and Disbursement
4. Turbochargers

1981

1. Running Gear
2. Filtration
3. FRA Rules
4. Follow-up on Previous Topics

DIESEL MATERIAL CONTROL COMMITTEE
TWENTY-FIVE YEAR INDEX

2006

1. PDAs for Inventory Control
2. Inventory Management System

2005

1. Centralized Materials Management
2. Centralized Component Core Management-Centralized Warehouse-Locomotive Comonents - Part A: BNSF Rwy. Centralized Component Core Management-Rotable Warehouse - Part B: Norfolk Southern Corp.

2004

1. Milk Run: Norfolk Southern's Dedicated Locomotive Parts Shipping System

2003

1. Just in Time Delivery - The Juniata - Shop Material Control Program
2. The Continuous Improvement Approach

2002

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

2001

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

2000

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

1999

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

1998

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

1997

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

1996

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

1995

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

1994

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

1993

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

1992

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

1991

1. The World of Recycling
2. Problems with Solution
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 Feed-back
3. Paperless Requisitions
4. A Practical Application of Bar Coding in the Railroad Industry

1987

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

1986

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

1985

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

1984

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

1983

1. Improved Locomotive Produc-tivity Through Computerized Dat
2. Inbound Material Inspection
3. Minimize Maintenance Cost Through Material Management Systems
4. New Ideas In Material Storage Containers

1982

1. Use of kits in locomotive maintenance
2. Cost effective methods of shipping material from vendors.
3. Union Pacific's Component Inventory Maintenance System (CIMS).
4. Advantages of using shipping containers

1981

1. Disposal of Unserviceable Component Parts: What is the Most Profitable Method?
2. Innovations in Stores Material Handling, Via Computer Technology
3. Locomotive Held for Material: an Update for the 80's
4. The Best Approach to Procuring

Material; New, UTEX, Repair and
Return or Shop Repair

SHOP EQUIPMENT AND PROCESSES COMMITTEE TWENTY-FIVE YEAR INDEX

2006
1. Wheel Gauge Technology
2. Train Washing
3. EnvironmentalRailroad Containment Products

2005
1. Mobiturn Wheel Truing Services

2004
1. Under the Hook Lifting Devices
2. Sanding in the Railroad Industry-Part III - A Gentle Answer for an Abrasive Situation

2003
1. Locomotive Shop Support Systems and Equipment
2. Hand Tools - An Ergonomic Update
3. Locomotive Lifting Systems

2002
1. NOTE: PAPER ON LIFTING SYSTEMS WAS PRESENTED BY RON BEGIER OF PORTEC AT THE 2002 CONVENTION; HOWEVER IT DID NOT APPEAR IN PUBLICATION - WILL APPEAR IN THE 2003 PROCEEDINGS PUBLICATION

2001
1. Standing in Railroad Industries - Part II - How to Specify Reliable and Safe Sanding Systems

2000
1. The Tandem Wheel Truing Machine at Amtrak's Ivy Shop
2. Shop Talk 2000: Fall Protection Technology
3. Sanding in the Railroad Industry

1999
1. Increasing Diesel Shop Capacity
2. Conrail-Cold Asphalt Processing of Environmental Waste Sand and Sludge
3. Dry Ice Cleaning of GE Intake Ports
4. AAR-LFIS No Spill Fueling System

1998
1. Smoke Opacity Testing-Emission Detection Equipment and its Use
2. Hydraulic Tensioning Tools and its Use
3. High Speed Portable Align Boring Series
4. Locomotive Mobile Servicing

1997
1. Wheel Truing as Preventive Maintenance
2. Conrail-Selkirk Diesel Terminal Wastewater Treatment Facility Recent 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 Pre-paration

with Sodium Bicar-bonate 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 Replace-ment Equipment and Pro-cedure.
3. Locomotive Component Re-placement Forklift Attachment.
4. Locomotive Sanding, Fueling and Drop Tables.
5. Hazardous Waste Disposal

1989

1. Automated Locomotive Wheel Shop
2. Laser Guided Material Handling Vehicles
3. Bulk Rail Lubrication Storage & Fill Systems
4. Pilot Plate Straightening Equip-ment

1988

1. Fuel Management Control Systems
2. Locomotive Mounted Rail Lubrication Fill Systems.
3. Comparison of Shop Air Compressors
4. Locomotive Toilet Servicing Equipment
5. Innovations in Blue Flag and Derail Protection

1987

1. Modern Servicing Facility for Improved Reliability and Availability
2. New Developments in GE Tools.
3. Implementation of a Quality Process
4. A Quality Traction Motor Shop.
5. Wheel Truing Machine Tech-nolo-gy

1986

1. Robotics Update 1986 - Now What?
2. CNC Machine Tools
3. A New GE Power Assembly Area
4. Locomotive Wash System - 1986

1985

1. Computer-Assisted Preventative Maintenance
2. New Tools for Material Handling and Overview of Balancing Technology
3. Effect of Governmental Re-gula-tions on Locomotive Finishing

1984

1. Shop Tools.
   A. New Tools
   B. Shop-Made Tools
2. Traction Motor Shop Equipment Up-Date
3. Hazardous Waste Handling and Disposal

1983

1. Locomotive Maintenance Using a Production Line Process
2. Shop Tools to Increase Productivity and Improve Quality.
3. Dynamic On-Line Performance of Locomotives Without On-Board Tele-Metering
4. Management in Action
5. New GE Training Cente
6. Welding Qualifications

1982

1. Tools
2. Rebuild line for EMD turbocharg-ers
3. Air brake equipment line
4. Industrial robots
5. Automated machines
6. Safety related items and equip-ment

1981

1. Training Aids.
2. Testing Devices Inspired by New FRA Laws
3. Tools and Training for Pro-ductivity
4. Changes to Shop Facilities Required by Newly Adopted EPA & OSHA Regulations
5. Tour through Conrail Altoona Shop
6. Supply/Service Facilities
7. GE Assembly Shop

DIESEL ELECTRICAL MAINTENANCE COMMITTEE
TWENTY-FIVE YEAR INDEX

3. Electromagnetic Interference (EMI on AC Locomotives)
4. QTRAC 1000 Adhesion Control System
5. Locomotive Health Monitoring-The Key to Improved Main-tenance

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 Elec-trical Equipment
2. Locomotive Batteries
   a. Storage Handling Proced-ures
   b. *Recommended Maintenance* Procedures
   c. Recommended Repair Procedures
3. Amtrak's AC Traction Locomotives
4. Modern Tooling for Electricians Recorders
3. Why Can't We Have One Central Computer?
4. EPA and Regulation Driven Cleaning

1990

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

1989

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

1988

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

1987

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

1986

1. Cleaning, Handling & Storage of Electrical Equipment
   A. Solid State Components
   B. Rotating Equipment
2. Qualification of Locomotive Power plants through self load

1985

1. Locomotive Microprocessor Technology in Retrospect
2. Dynamic Brake Protective devices and Troubleshooting EMD-2 and GE-7 Locomotives
3. Indicators and Recorders for Locomotive Retrofit Application - Fuel, Speed, Power and Selected Events

1984

1. On-Board Diagnostics
2. GE's **CATS** (Computer Aided Troubleshooting System)
3. Fuel Conservation Through
4. Electrical Modifications
5. Performance of Locomotives After Storage

1983

1. Ground Relay Trouble Shooting
2. Specification for remanu-factured D87 Traction Motor Frames (Using D-77 Armature Coils)
3. Locomotive Storage (Electrical)
4. Water Cooling and Refrigerating Methods for Locomotive Cab Application

1982

1. Tests on Traction Motors
2. Transition Trouble-Shooting
3. Onboard Diagnostic Systems
4. Starting Systems

1981

1. Evaluation of Improved Test Methods
2. Teflon Bands
3. New Generation Locomotives
4. Electrical Troubleshooting
5. Batteries and Charging Systems
6. Troubleshooting EMD AC Auxiliary Generator System
7. Selection of Locomotives for Major Locomotive Overhauls

NEW TECHNOLOGIES COMMITTEE
TWENTY-THREE YEAR INDEX

3. Advanced Traction Motor Testing

1994

1. Electronic Fuel Injection Sys-tems.
2. Status of Distributed Power in Freight Trains.
3. Advances in Distributed Power-Iron Highway.

1993

1. New Technology to Solve Old Problems
2. Developments in Off-Shore Technology
3. Updates on AC Traction Developments

1992

1. Talking to the "Smart' Locomotive
2. Cab Noise Abatement
3. Electronic Management of Locomotive Drawings
4. Update on High Productivity Integral trains
5. AC Traction - A New Development

1991

1. Locomotive Cab Integration and Accessory Management
2. Improvements in Locomotive Adhesion Performance
3. The Role of Duty cycles in Locomotive Fuel Consumption.
4. What's New in Gadgets and Black Boxes: What do our Locomotives Really Need?
5. Failure Analysis

1990

1. Motor Driven Air Compressors for Diesel-Electric Locomotives
2. Locomotive Cab (HVAC) Heating, Ventilation and Air Conditioning Systems
3. Effect of Technology on Standardization of Cab Control Equipment
4. Locomotive Durability, Relia-bility and Availability - Understanding Your Abilities

1989

1. A Rational Approach to Testing Locomotive Components
2. New Developments in Loco-motive Cab Design

1988

1. Amtrak F69 PH AC Passenger Locomotives
2. New Component Develop-ments Retrofittable to Older Model Locomotives
3. Locomotive Applications of Catepillar Engines
4. Wheelslip Control for Individual Axles

1987

1. Electronic Fuel Injection Sys-tems
2. Update on Electronic Gover-nors
3. Recent Advances in Steerable Locomotive Trucks - the E.M.D. 4 Axle, 4 Motor HT-BB Articulated Truck
4. Converting an F40 Locomotive to A.C. Traction

1986

1. Future Train Control Systems
2. Bringing Future Train Control Systems Back to Earth
3. Low Maintenance Locomotive Batteries
4. Electronic Engine Control Systems

1985

1. The Sprague Clutch for E.M.D. Turbocharged Engines
2. A.C. Traction Locomotives Update
3. Natural Gas Locomotive Update
4. Ceramic Coated Engine Com-ponents
4. Locomotive Cab Develop-ments

1984

1. G.E. Dash 8 Locomotives
2. E.M.D. 50A Series Locomotives
3. Natural Gas Locomotives
4. Appraisal of the A.C. Traction Locomotive

1983

1. Microprocessors for Locomotive Control and Self Diagnosis.
2. Locomotive Fuel Tank Gauges
3. Locomotive Aerodynamics
4. Bombardier HR 616 Locomotive
5. Missouri Pacific - Phase III Locomotive Heavy Repair Facility, N. Little Rock, Arkansas

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE TWENTY-FIVE YEAR INDEX

2006

1. Fuel Additives-A Possible Method to Reduce Fuel Consumption in Railroad Diesel Locomotives

2005

1. Engine Oil 202 - Refined Base Oils and their Importance in Lubrication
2. Biodiesel - A Potential Fuel Source for Locomotives

2004

1. Discussion of the LMOA Fuels, Lubricants and Environmental Committee Pentane Insolubles Procedures Revision 4
2. Engine Oil 101 - Viscosity and Additives
3. Used Oil Analytical Results, What do they Mean, How to Interpret the Results and How do you Respond?

2003

1. Laboratory Results May Put Your Locomotive at Risk
2. Top of Rail Friction Modification Studies on the BNSF

2002

1. Improved Generation 5 Lubricant Provides Potential for Extended Lube Oil Filter Life
2. Corrosion Protection of Locomotive Cooling Systems

2001

1. On-Board Oil Management System
2. Evaluation of Locomotive Engine Oil Analytical Laboratories
3. Fuel Additives - Friend or Foe

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4. Field Experiences with Multigrade Railroad Locomotive Oils.
5. Conrail Wheel/Rail Lubrication Update

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1. Field Test Data Follow-Up and Description of "Generation 5" Locomotive Crankcase Oil
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1. Used Oil Analysis and Condemning Limits
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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

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1. Common Fuel Additives and their Effectiveness
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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
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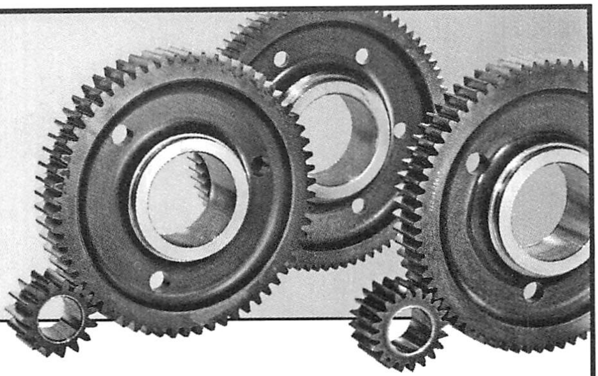

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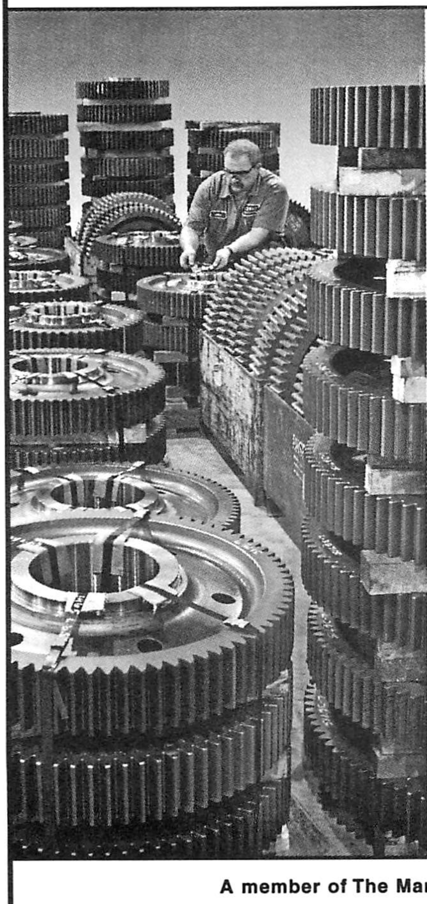

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