LMOA

Locomotive Maintenance Officers Association

Proceedings of the 73rd Annual Meeting

SEPTEMBER 19-20, 2011

Minneapolis, Minnesota

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2010 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 2010.

NAME	**COMMITTEE**
Ryan Stege	Diesel Electrical Maintenance
Jim Christoff	New Technologies
Roger Collen	Shop Equipment and Processes
Tom Kennedy	Diesel Mechanical Maintenance
Dennis McAndrew Chuck Kunkel Glenn Bowen	Fuel, Lubricants and Environmental
Eric Fonville	Diesel Material Control

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

LMOA EXECUTIVE COMMITTEE

NOTE: The FL&E committee selected Co-MVPs – Dennis McAndrew, Chuck Kunkel and Glenn Bowen

The Executive Board of the LMOA would like to express their sincere gratitude to the Union Pacific Railroad for hosting their Joint Technical Committee meeting at the UP Headquarters in Omaha, Nebraska on June 2 and 3, 2011 and for providing a tour of the Harriman Dispatch Center. Special thanks goes to John Estes, General Manager of the Union Pacific and Tad Volkmann who is an LMOA Past President.

The Executive Board would also like to thank Magnus-Farley and John Macklin for giving the committee members an opportunity to tour their facility in Fremont, NE.

The luncheon on Thursday, June 2nd was hosted by Tom Gallagher of Chevron Oronite—Tom is a member of the Fuel Lubricants and Environmental Committee— Thank you Tom for your generosity.

The luncheon on Friday, June 3rd was hosted by Mike Fritzel of Link Up International— Thank you Mike for supporting the LMOA.

We also wish to thank 1st VP Glenn Bowen for making all of the necessary arrangements for the meeting and the hotel (Great job, Glenn) and to Amy Colling of the UP for all her efforts in ensuring that our meetings went off without a hitch.

LMOA Executive Board wishes to express their sincere appreciation and gratitude to Dwight Beebe of Temple Engineering who is chairman of the FL&E Committee for sponsoring the working luncheon during the LMOA Executive Board meeting held on Tuesday, October 19, 2010 at the Hilton Bonaventure in Montreal, Quebec.

Thank you for your continued support of our organization, Dwight.

PAST PRESIDENTS

1939 & 1949	F.B. DOWLEY (Deceased) Shop Supt., C. & O. Ry.
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1947	S.O. RENTSCHILLER (Deceased) Chief Mechanical Officer, Bessemer and Lake Erie R.R.
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1949	J. W. HAWTHORNE (Deceased) Vice-Pres.- Equipment, Seabord 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, Seabord 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, Southen 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.
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1964	H.N. CHASTAIN (Deceased) General Manager-Mechanical, A.T. & S.F. Ry.
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1966	F.A. UPTON II (Deceased) Asst. Vice-President-Mechanical, C.M. St. P. & P. R.R.
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1968	T.W. BELLHOUSE (Deceased) Supt. Mechanical Dept., S. P. Co., - St. L. S.W. Ry.
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1972	K.Y. PRUCHNICKI (Deceased) General Supervisor Locomotive Maintenance, Southern Pacific Transportation Company
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1976	J.D. SCHROEDER, Retired Assistant C.M.O.-Locomotive, Burlinton Northern Railroad, 244 Carrie Drive, Grass Valley, CA 95942
1977	T.A. TENNYSON (Deceased) Asst, Manager Engineering-Technical, Southern Pacific Transportation Co.
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1980	J.H.LONG (Deceased) Manager-Locomotive Department, Chessie Systems
1981	R.G.CLEVENGER, Retired, General Electrical Foreman, Atchison, Topeka & Santa Fe Rwy

1982	N.A. BUSKEY (Deceased), Asst. General manager-Locomotive, Chessie Systems
1983	F.D. BRUNER (Deceased), Asst. Chief Mechanical Officer, R&D, Union Pacific RR
1984	R.R.HOLMES, Retired Director Chemical Labs & Environment, 600 Brookestone Meadows Place, Omaha, NE 68022
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, 8913 West 161st St, Overland Park, KS 66085
1987	D.L.WARD (Deceased), Coordinated-Quality Safety & Tech Trng, Burlington Northern RR
1988	D.G. GOEHRING, Retired, Supt. Locomotive Maintenance, National RR Passenger Corp, 1408 Monroe, Lewisburg, PA 17837
1989	W.A.BROWN, Retired, I&M Rail Link, 9047 NE 109th St. Kansas City, MO 64157
1990	P.F.HOERATH, Retired, Sr. Mech. Engr. Shop, Conrail 1534 Frankstown Rd, Hollidaysburg, PA 16648
1991	D.D.HUDGENS, Retired, Sr Mgr R&D, Union Pacific, 16711 Pine St., Omaha, NE 68130
1992	K.A.KELLER, Retired, Supt. Locomotive Maint, Reading RR, 241 E. Chestnut, Cleona, PA 17042
1993	W.R.DOYLE, Project Manager, Sound Transit, Seattle, WA 98104
1994	M.A.COLES, Sr. Mgr-Loco. Engineering & Quality, Union Pacific RR, 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, Retired-Genl Supt.-Fuel Opns, NJT Rail Opns, 2005 Acadia Greens Drive, Sun City Center, FL 33573
1998	H.H.PENNELL, Retired-Ellcon National, 1016 Williamsburg, Lanne, Keller, TX 76248
1999	JAKE VASQUEZ, Retired, Asst. Supt.-Terminal Services, Amtrak 1130 Walnut Ave, Osawatomie, KS 66067
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2003	BRIAN HATHAWAY, Consultant, Port Orange, FL 32129
2004	BILL LECHNER, Retired, Sr Genl Foreman-Insourcing-Air Brakes, Governors & Injectors, Norfolk Southern Corp, Altoona, PA 16601
2005	TAD VOLKMANN, Director-Mech. Engrg., Union Pacific RR, Omaha, NE 68179
2006	BRUCE KEHE, Supervisor-Maintenance, Gary Rwys, Gary, IN 46401
2007	LES WHITE, Applications Specialist, Bach-Simpson, London, Ontario N6A 4L6
2008	MIKE SCARINGE, Director-Locomotives, Amtrak, Beech Grove, IN 46109
2009	DENNIS NOTT, Northwestern Consulting, Boise, ID 83703
2010	BOB REYNOLDS, Sales Manager, Amglo Kemlite Laboratories, Calgary, Alberta T24 2V8

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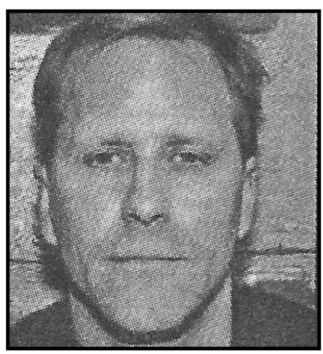

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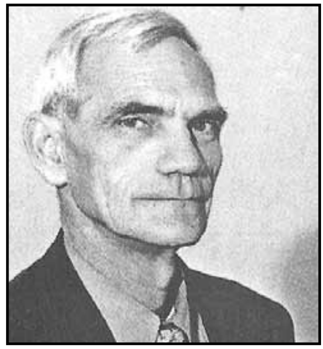

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Palatine, IL

DAVE RUTKOWSKI
Chief Mechanical Officer
Providence & Worcester RR
Worcester, MA

Tom Kennedy, Union Pacific, making a presentation on the affects of long term storage of locomotives from a Mechanical Committee perspective. Sub-committee members Dave Cannon and Glenn Bowen both of the BNSF seated at the head table. Presentation was made on Tuesday, October 19, 2010 during the annual convention in Montreal, Quebec

Bill Kirdeikis, Canadian National, presenting an Electrical Committee perspective on the affects of long term storage of locomotives


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Keith Mellin, Peaker Services, presenting another portion of the Electrical Committee perspective on long term storage

Ron Bartels, Via Rail-Canada, presenting a portion of the Electrical Committee perspective on long term storage

Chuck Kunkel, Glenn Bowen and Dennis McAndrew being honored for their outstanding contributions and service to the LMOA Fuel, Lubricants and Environmental Committee during the convention in Montreal, Quebec on October 2010.

Chairman Bob Dittmeier, Afton Chemical, presenting plaques to Messrs. Kunkel, Bowen and McAndrew.

Past President Les White, Bach Simpson (right) presenting Past President's LMOA watch to outgoing President, Bob Reynolds of Amglo Kemlite. The ceremony was witnessed by newly installed President, Jack Kuhns of Graham White.

Past President Bob Runyon (right) presenting Past President's Pin to outgoing President, Bob Reynolds. Newly elected 2nd VP Ron Bartels attended the presentation

LMOA executive officers - seated left to right – Newly elected President Jack Kuhns, Graham White, newly elected 1st VP Glenn Bowen, BNSF, newly elected 2nd VP, Ron Bartels, Via Rail-Canada, newly elected 3rd VP Brad Queen, BNSF. Standing left to right – Past President, Bob Runyon, Consultant, outgoing President Bob Reynolds, Amglo Kemlite, Past President, Les White, Bach Simpson and Past President, Dennis Nott, Northwestern Consulting

Jack Kuhns calling the meeting to order
as the newly installed President of LMOA

Newly installed 1st VP Glenn Bowen, BNSF, (right) greeting newly installed
3rd VP Brad Queen, BNSF, as newly installed President Kuhns, Graham White,
admires Brad's new LMOA blazer.

2010 State of the Union Address

President Bob Reynolds

Good afternoon ladies and gentlemen, fellow LMOA Committee Members and LMOA Executive Committee members. Thank you for attending the 2010 Locomotive Maintenance Officers Association Technical Sessions.

I would like to review the past year of LMOA. The economy, which greatly affects attendance at out technical sessions, has improved in the past year. A good barometer of the economy is rail traffic, which according to the AAR, is up compared to last year. Good news! Despite a fragile economy, participation by the committees remained strong with good attendance at committee meetings. The slowly improving business environment kept all six of our LMOA Committees busier than ever. There are always special opportunities for improving processes, saving fuel, reducing costs, etc. Our technical committees took up the challenge.

The LMOA held its annual Joint Committee Sessions in Roanoke, Virginia in May. We had a good turnout of members. Much appreciation goes out to the Norfolk Southern and Graham White Manufacturing for co-hosting the event. The Norfolk Southern provided the meeting rooms, a luncheon and a great tour of their Roanoke Facility. Thank you to Jeff Cutright at Norfolk Southern for taking care of the arrangements. Graham White Manufacturing hosted the auditorium for the joint session presentations and the lunch that followed. Thanks goes out to 1st Vice President Jack Kuhns of Graham White Manufacturing for doing an excellent job of organizing this year's Annual Joint Session. The LMOA relies greatly on and appreciates our rail and supplier sponsors for providing facilities and arrangements for our various meetings.

The attendance at the Joint Session was good. There were about 60 Committee Members in attendance. The meetings were very productive and all of the preliminary presentations were excellent.

Coming out of the annual convention last year we made a commitment to the Chief Mechanical Officers to provide them with research, analysis and solutions on issues that impede maintenance and reliability of locomotives. One such issue was the storage of locomotives and their reinstatement back into service. If you recall over a year ago there were thousands of stored surplus locomotives. Committee members reviewed various policies that were available from various roads and developed a new all encompassing document. We are here to continue to support the Chief Mechanical Officers.

In August 2009, the Railway Supply Institute informed the Four Combined Mechanical Associations that the 2010 session in Chicago was cancelled because of the economy. The LMOA formed an internal Committee to address this issue and quickly decided that the work of LMOA must continue. We got together with the other three Combined Mechanical Associations to develop an alternate site. And here we are in Montreal. It was a long hard road because it was something we had never done before. The Railway Association of Canada and the Canadian Association of Railway Suppliers are to be congratulated for stepping up to the plate and arranging this convention. I also congratulate our LMOA organizing committee for their hard work on the project.

As far as 2011 is concerned, the RSI is still planning to support the four combined Associations at the 2011 indoor and outdoor show in Minneapolis. As previously reported, this event will be conducted in conjunction with REMSA and AREMA. It will be a huge industry event—book your hotel in early January! More details will be issued as soon as known.

In 2010 we resumed a link with the American Short Line Railroad Association. A few years ago we made contact with the ASLRRA to share technical information and gained some new members. This year, although we did not make a presentation at their annual meeting, we did contribute a paper on air compressor maintenance. The paper will be included in their monthly newsletter.

As we go into 2011 the LMOA is still a strong organization, in good financial shape and we are ready to face challenges as they appear.

I would like to thank all the employers who sponsor our committee members. Allowing your employees to join and participate on committees is the ultimate contribution to the success of the industry, the LMOA and to members. I also would like to thank all the vendors and railroads that support our organization with meeting rooms, lunches and the opportunity to tour their facilities.

I would also like to thank the sponsors of the annual book of presentations. This book is a gold mine of technical information that is an important reference for all locomotive technical people. Please patronize the sponsors of the book so we can continue to publish it. There is a list of sponsors in the front of the book. I would like to thank Amglo Kemlite Laboratories for sponsoring my activities with the LMOA.

Last, but not least, I would like to thank everyone in the LMOA for the support I have received this year. We have some very dedicated members who take our industry and the LMOA very seriously. A big thank you goes out to my executives; 1st VP, Jack Kuhns; 2nd VP, Glen Bowen; 3rd VP, Ron Bartels; and the man that keeps this whole association together and organized, Mr. Ron Pondel, our Secretary-Treasurer.

Acceptance speech

Jack Kuhns

I would like to start by recognizing the heart and soul of the LMOA, Ron Pondel, for his tireless efforts to keep all the organizational details handled and information distribution done like clockwork. He is a true professional and we are very fortunate to have Ron's guidance and selfless service.

As well we should recognize and thank each other and our companies who support us, for attending and supporting our attendance at this meeting. For the LMOA members, those present and those that could not attend, as well as those who wish to, I remind you that being a part of this organization is something to be proud of. We would like to thank the C.A.R.S.(Canadian Association of Railroad Suppliers) and R.A.C. (Railway Association of Canada) for extending the invitation to join their venues and hosting these meetings.

Let's see, where do I begin . . . Without a doubt I am honored to be standing here. My journey started two generations ago . . . My grandfather was chairman of the Diesel Mechanical Committee, the year I was born. He worked for the Monon RR and was a mechanical supervisor. My father, who many of you knew, was also Chairman of the Diesel Mechanical Committee. He progressed through Regional Executive, then on through three stages of Vice President. Dad retired from CSX in 1985 as the 1st VP of the LMOA and joined the supply side of the industry as a consultant. At that time only active railroads were allowed to become president. So, I had to take a more circuitous route but managed to get the bylaws changed in advance of my time to ascend to the Throne! I do believe I can proudly say that I am the first, but hopefully not the last, Third Generation LMOA'er. I understand it is considered bad form to talk too much about myself, bear with me . . . these are my 15 minutes! I have been reminded that I have another first to claim . . . I joined the LMOA Diesel Mechanical Committee as a guest speaker/presenter in 1993. The following year I was invited to join the committee as a member . . . I was the first-ever non-OE Supplier invited to join. I thank Tad Volkmann for giving me the opportunity and for trusting that I would respect the LMOA code of ethics. From that beginning I have followed their lead and did whatever possible to respect the organization and those who have come before me. These accomplishments I am proud of.

Please keep an eye on the clock but I do want to say a few things about the LMOA and what it should mean to all of us. As I mentioned the Supply side of the industry is now an important part of the LMOA, roughly 50%. I would like to remind my fellow LMOA suppliers that as members of LMOA you have certain responsibilities to uphold. These responsibilities are not any different than those for the railroad members, however, it should be understood that also like railroads it is an honor to be asked to join . . . and herein lies your challenge . . . This is where you must hold yourselves to an arguably higher standard. What is true of all organizations, you will get out what you put in. We do not want anyone to think that the LMOA is a club where supply members have exclusive access to the decision makers of the industry. Therefore to be a member you must keep yourself out of situations where this type of opinion could be formed. It is also not a place where you can drop in for personal gain then drop out once you have achieved whatever you were after. It is up to the Vice Chairman, Chairman and Regional Executives to screen all members for their sincerity and contribution. All committee members should be expected to write papers and assist others on paper development. Simply showing up is not enough, however this is also very important! Participation in the LMOA has always been in addition to your regular job. Personal development and learning is the cornerstone of the LMOA. We have few professional speakers in our organization but we have lots of professional students of the industry. All papers written on topics, where numerous options are available within the supply community, should be generic in nature. It is the author's responsibility to do the research necessary to offer all options and present a paper that is neutral and offers the audience as much of a learning experience on a topic as possible. Infomercials are not allowed and again, it is up to each committee and their Regional Exec to properly vet the papers prior to giving presentations. We should continuously ask ourselves what belonging to the LMOA brings to our respective employers. I can honestly say that I have never attended an LMOA function that I didn't come away with newfound knowledge and further respect for those that have willingly given their time and enthusiasm to share and learn together. This is most important and we should always keep this in mind as everyone is a resource, and must be spent wisely. . .

I must say again, it is an honor to be standing here and to be given the chance to serve as President of this organization . . .one that has helped me learn from the finest Industry in North America and then allowed me to share what I have learned. Thank you!

Report on the Committee on Diesel Mechanical Maintenance

Monday, September 19, 2011

9:00 A.M.

Chairman

Jeff Cutright
Assistant Manager
Norfolk Southern Corp
Roanoke, VA

Vice Chairman

George King II
Chief Mechanical Officer
New York Susquehanna & Western RR
Cooperstown, NY

Commitee Members

R. Aranda	Genl Foremann-Locos.	Belt Rwy of Chicago	Bedford Park, IL
I. Bradbury	CEO	Peaker Services	Brighton, MI
S. Bumra	Assistant Manager	Amtrak	Chicago, IL
D. Cannon	Mgr-System Loco Mgr	BNSF Rwy	Ft. Worth, TX
M. Daoust	CMO	Tshiuetin Rail Transp.	Clarke City, PQ
T. Frederick	Mech. Engineer	CSX Transportation	Jacksonville, FL
D. Freestone	Mgr-Loco Opns	Alaska RR	Anchorage, AK
J. Hedrick	Principal Engineer	SW Research Institute	San Antonio, TX
T. Kennedy	Mgr-Mech Engrg.	Union Pacific RR	Omaha, NE
A. Mallette	Sr. Rolling Stock Mgr.	RailPros Inc	Los Angeles, CA
D. Nott	President	Northwestern Consulting	Boise, ID
C. Shepherd	CMO	Arkansas & Missouri RR	Springdale, AR
J. Sherbrook	VP & GM	Loco Docs, Inc	Trussville, AL
B. Singleton	VP-Sales	Transpar Corp.	Niskayuna, NY
T. Standish	Quality Mgr	Electro Motive Diesels, Inc	LaGrange, IL
G. Sumpter	SE Regional CMO	Rail America	Jacksonville, FL
*R. Svoboda	Mech Compliance	Metrolink	Los Angeles, CA
* G. Winsel	Supervisor	Canadian National	Edmonton, AB
K. Wollschlager	Reliability Technician	Trico Predict	Pewaukee, WI

* Standby

Note: Dennis Nott is a Past President of LMOA

PERSONAL HISTORY

Jeff Cutright

Jeff was born in West Virginia and attended WVU earning a BSME in 1979. He joined Norfolk Southern (NS) in 1980 as a management trainee after a year and a half with Weirton Steel. Jeff has held many positions in the NS Mechanical Department, including staff and shop supervision. His work experience includes production monitoring and scheduling, as well as locomotive maintenance, repair, overhaul and emissions compliance. The majority of Jeff's career has been in locomotive back shops that specialized in both GE and EMD engine and component overhaul. Jeff has been active with LMOA since 1994. Jeff earned an MBA from Averett University in 2004. Jeff and his wife Loenita have two daughters, Sarah and Haley, in college who play collegiate sports. Sarah is a catcher and infielder in softball. Haley is a distance runner. Leonita teaches nursing. Jeff enjoys photography, cycling, mountain biking, and being outdoors.

The Diesel Mechanical Maintenance Committee would like to extend their sincere appreciation to Wabtec/Motive Power for hosting the committee meeting on March 17, 2011 in Boise, Idaho. Special thanks to LMOA Past President Dennis Nott for handling all the arrangements.

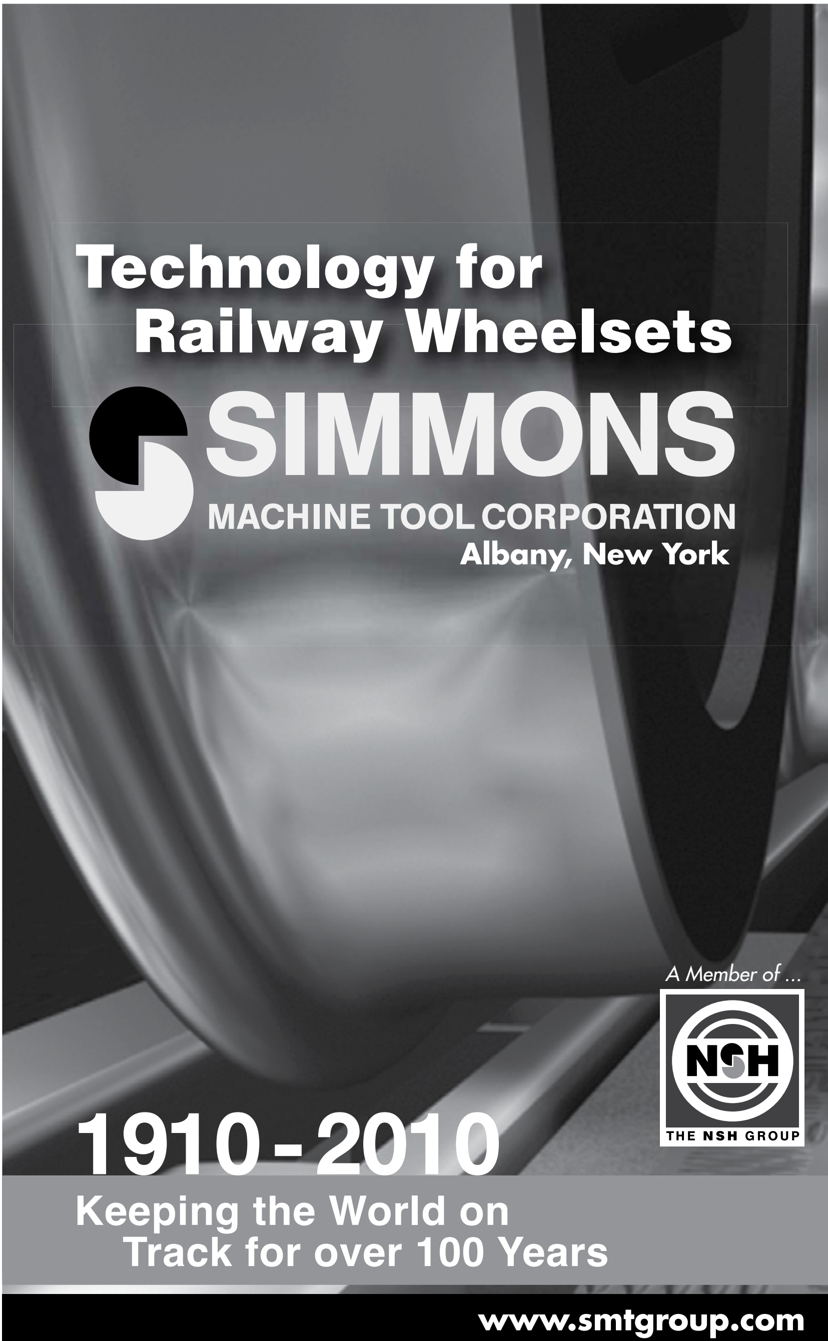
The Committee also had a conference call on December 9, 2010 and the phone lines were provided by Amtrak and committee member Sarabpreet Bumra.

Locomotive Storage and Return to Service Best Practices

Prepared by:
Tom Kennedy, Union Pacific Railroad
Dave Cannon, Burlington Northern Santa Fe Railroad
Glen Bowen, Burlington Northern Santa Fe Railroad

The weak economy has resulted in a surplus of locomotive power necessitating the storage of thousands of locomotives across all railroads in both serviceable and unserviceable conditions. As a side note, which is not addressed in this paper, there are rail cars stored too, but in much larger quantities.

As the railroads responded to the downturn in business it became evident that the locomotive storage processes used by the railroads varied and that there was no consistent and accepted standard. The OEM requirements for storage varied between the OEM's and were typically considered by the railroads to be overly complex and time consuming with little supporting rationale. The OEM's typically developed their requirements to protect new locomotives during storage prior to and during international shipping which is a different environment than the railroads experience in their storage process. Just like the storage process, the return to service processes vary between railroads, too. To minimize product degradation during storage and optimize reliability once the locomotive is returned to service, the railroads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requested the LMOA to develop a standardized set of Best Practices. This is the intent of this paper.

All locomotive systems and components are potentially degraded to varying degrees by the environmental factors, such as humidity, experienced during storage, see photos below. This paper focuses primarily on the mechanical, fuels and oil, and pneumatic systems of a locomotive. The storage impact to the electrical systems and electrical components are addressed in a separate paper from the LMOA Electrical Committee.

It should be noted that not all reliability issues are due to storage. Inherent reliability is affected by multiple factors such as historical performance, the product's inherent reliability, maintenance history, etc. A fundamental goal of any storage process is to store and return the product to service at an equal reliability that the product went into storage with. Expecting an improvement in reliability when the units come out of storage is unrealistic without some intervention such as reliability modifications and upgrades.

This paper is the product of cross functional participation between the LMOA Mechanical Committee, the LMOA Fuels, Lubricants, and Environmental (FL&E) Committee and includes participation from the railroads, the OEMs, the oil and fuel companies, and a variety of additional locomotive component and material suppliers. A balanced perspective of the storage issues and development of consistent and standardized best practices is the objective of this paper.

Storage Principles

To develop best practices the LMOA team established the following guidelines:

- Used the best recommendations from OEM's and RR's
- Only practices that promote safety will be considered
- Recommendations have to be practical (good bang for buck)
- Practices have to show a proven benefit
- Practices have to be based on sound science

Some practices are still under study or review so the railroads and OEM's are continuing their assessment of these for possible further enhancement of the best practice recommendations for continuous improvement. As units are returned to service from storage, new opportunities may be identified and the plan is to have future updates added to future "Best Practices" document.

Storage Definitions

A stored locomotive is a locomotive that is not started or moved for an extended period of time, typically greater than 30 days. Each stored locomotive should be classified with one or more of the standardized definitions shown below.

- Stored serviceable: Unit was functioning when stored
- Stored unserviceable: Unit was not functioning when stored
- Short-Term Storage: Stored less than 180 days
- Long-Term Storage: Stored greater than 180 days

- Good order - Can be returned to service with minimal effort
- Needs light repair (Wheel truing, TM change, COT&S)
- Needs heavy repair (PA, Gear train, Turbocharger)
- Bad order - Will take more than 30 days to repair
- Pending sale or evaluation

The best practices discussed in the following sections are annotated with LT or ST to show applicability to either Long Term or Short Term or both

Placement into Storage – Location

Dry and mild temperatures are preferred environments for storage since moisture is the principal cause of degradation. A common storage location enables consistent and efficient storage and by staging locomotives with a last in first out strategy this helps expedite return of the most desirable locomotives to service quickly, or the return of locomotives under lease, etc. The preferred location should also be logistically separated from main lines where vibration from passing trains may cause brinelling of wheel bearings. Note: False brinelling may be mistaken for actual brinelling but it is still a good practice to store locomotives, if possible, away from heavy vibration sources.

Best Practices: Into Storage – Fuel System

- Drain condensate from fuel tank (ST, LT)
- Remove all but 500 gallons of fuel from tank (ST, LT)
- Add an appropriate biocide/stabilizer to fuel tank (ST, LT)
  - o Obtain approval of your Environmental, Safety, and Health Department prior to the use of any biocide additives
- Include MSDS data precautions into work planning
- Conduct appropriate training
- Ensure proper personal protective equipment (PPE) is available and used
- Operate locomotive 15 min to circulate treatment (ST, LT)

Best Practices: Into Storage – Cooling System

- Add an appropriate amount of a "filming" corrosion inhibitor (ST, LT)
  - o Obtain approval of your Environmental, Safety, and Health Department prior to the use of any corrosion prevention additives
- Include MSDS data precautions into work planning
- Conduct appropriate training
- Ensure proper PPE is available and used
- Start and run the engine to ensure the coolant is fully circulated through entire cooling system, including radiators (ST, LT)
- Allow system to cool, vent, and completely drain. (ST, LT)
- Failure to drain the system will degrade EPDM seals if the "filming" corrosion inhibitor is petroleum based
- Purge trapped water to prevent freeze damage, e.g., fuel preheaters, dead headed lines, etc.
- Remove water pump drain plugs (only required on GE locomotives), bag and wire plugs to pump.

- Lubricate cooling fan shutter and louver linkage (LT)
- Close all cooling fan shutters (ST, LT)
- "Fail open" shutters must be disconnected/secured in the closed position

Best Practices: Into Storage – Engine and Engine Oil

- Test lube oil for fuel dilution with lab test or a fuel sniffer (ST, LT)
  - o If fuel dilution is detected find the source and correct
- Test lube oil for free water using a Crackle Test (ST, LT)
  - o If free water is detected find the source and correct
- Governors (non-sealed), drain oil and refill with fresh oil (LT)

Best Practices: Into Storage – Pneumatic System

- Air Compressor
  - o Take air compressor oil sample for analysis (ST, LT)
  - o Test lube oil for free water with a Crackle Test, and correct if found
  - o Drain and replace the oil and filter
  - o Remove the blanking plates on the low pressure heads
  - o Ensure all water drains out of that part of the head to prevent freezing. Some plates have freeze plugs but history shows they don't always work. Note: this may not be necessary on compressors with the newer cylinder design
- Air Dryers, if equipped (ST, LT)
  - o Inspect eye condition, if oil indicated, find source and correct
- Electronic Air Brake Type Systems (ST, LT)
  - o Drain condensate from all filters equipped with drains
  - o 26L Type Air Brake Systems (ST, LT)
  - o Remove P2A and drain condensation
  - o Blow out the airline to P2A before reinstalling
- Air Reservoirs and piping (ST, LT)
  - o Drain condensate from reservoirs and air lines
  - o Drain condensate from coalescing filters
  - o Close, drain, MU hose, and brake pipe cocks
  - o Clean dirt collectors
- Air Starters (EMD SD70ACe and SD70M-2) (ST, LT)
  - o Lubricate pinion gear drive spline and ring gear

Best Practices: Into Storage – Running Gear

- Inspect TM covers for proper sealing and securement (ST, LT)
- Inspect gear pans for proper sealing and securement (ST, LT)
- Motor support bearings (non Bearing Tapered Roller) (ST, LT)
  - o Drain water from support bearing boxes
  - o Clean wick top plate, remove wick assembly, test wick for proper function and presence of no water
  - o Inspect brass and axle for unusual conditions

- o Reapply wick with new gasket, apply fasteners and locking tabs. Wire journal support drain plug in the closed position
  - o Fill with fresh oil to proper level
- Drain water from Hyatt journal boxes, apply drain plug and wire closed, and fill with oil to proper level (ST, LT)
- Inspect traction motor lead connection boots for sealing and securement

Best Practices: into Storage – Miscellaneous

- Drain condensate from crankcase (ST, LT)
- Do not top off oil (ST, LT)
- Cover exhaust stacks using adequate covers (ST, LT)
- Clean all engine sumps and water drain holes (ST, LT)
- Clean generator aspirator ensuring proper operation (ST, LT)
- Drain retention tank and close retention tank valve (ST, LT)
  - o While in storage drain retention tank at an appropriate interval dependent on weather conditions
- Make notation “Do Not Start” tags, date stored and apply to isolation switch and to start button (ST, LT)
- Empty and clean refrigerator, block door open (ST, LT)
- Clean and drain the toilet and water supply tank (ST, LT)
- Close and lock all doors and windows (ST, LT)

Best Practices: Return to Service – Prestart

- Perform required maintenance (FRA, RR) (ST, LT)
- Inspect for and remove all debris (ST, LT)
  - o Rodents, snakes, insects, nests, leaves, trash, etc.

- Inspect and repair missing components/vandalism (ST, LT)
- Remove exhaust stack covers and inspect stack (ST, LT)
- Conduct visual truck and brake rigging inspection (ST, LT)
- Change all HVAC filters (ST, LT)

Best Practices: Return to Service – Fuel System

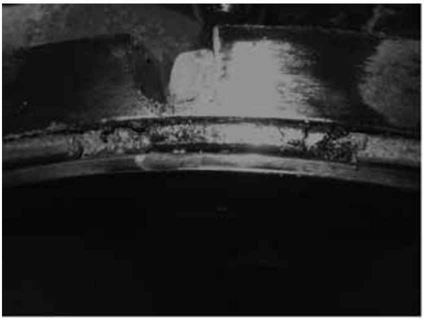
- Drain condensate from fuel tank (ST, LT)
- Change all fuel filters and clean or replace fuel suction strainer, if equipped (ST, LT)
- Fill tank with diesel fuel (ST, LT)
- Clean and inspect engine fuel sight glass (ST, LT)
  - o Replace rubber seal as required
  - o Check for proper bail ratchet operation (if equipped)
- Clean fuel tank sight glasses as required (ST, LT)
- Pressurize fuel system and inspect for leaks (ST, LT)

Best Practices: Return to Service – Cooling System

- Open all cooling fan shutters (ST, LT)
  - o Reconnect the "Fail open" shutters
- Install water pump drain plugs (GE units only) (ST, LT)
- Fill the cooling system with raw water (ST, LT)
- Flush and test auto dump valves (ST, LT)
- Add an appropriate amount of cleaner to remove the "filming" corrosion inhibitor (ST, LT)
  - o Obtain approval of your Environmental, Safety, and Health Department prior to the use of any corrosion prevention additives
  - o Include MSDS data precautions into work planning
  - o Conduct appropriate training
  - o Ensure proper PPE is available and used

Best Practices: Return to Service – Engine and Engine Oil

- Inspect engine baggy filters and change as required (ST, LT)
- Change all oil filters (LT)
- Inspect Michiana Tank Seal groove for corrosion(ST, LT)
  - o Corrosion can lead to seal failure and oil spray and fire



- Drain condensate from crankcase (ST, LT)
- Open power assembly compression relief valves (ST, LT)
- Pre-lube engine, do not overfill (ST, LT)
- Bar engine over 2 revs during pre-lube process (ST, LT)
  - o EMD: Inspect liners and pistons for rust and corrosion
  - o EMD: Spray 2 to 4 ounces of clean engine oil into each cylinder liner and piston to prevent scuffing and assist in engine starting
  - o GE: Observe free rotation and listen for unusual sounds/noise
- Conduct EMD top deck valve train inspection (ST, LT)
- Inspect GE cams and spray with clean engine oil (ST, LT)
- Conduct Air Box Inspection (EMD) (ST, LT)
- Conduct Crank Case Inspection (ST, LT)

Best Practices: Return to Service – Pneumatic System

- Air Compressor
  - o Drain and replace oil and filter (ST, LT)
  - o Flush compressor heads with clean water (ST, LT)
  - o Reinstall all blanking plates on the low pressure heads
  - o Inspect all air and water lines (if equipped) for damage and deterioration and replace as necessary
- Air Dryers, if equipped (ST, LT)
  - o Service per Railroad maintenance instructions
- Electronic Air Brake Type Systems (LT)
  - o Change MR, BP, actuating (13), and independent (20) filters
- 26L Type Air Brake Systems (LT)
  - o Change brake pipe cutout filter
- Air Reservoirs and piping (ST, LT)
  - o Inspect for and correct any degradation
  - o Ensure all MU air valves are closed
- Air Starters (EMD SD70ACe and SD70M-2) (ST, LT)
  - o Lubricate pinion gear drive spline and ring gear

Best Practices: Return to Service – Running Gear

- Inspect and correct dust guard defects (ST, LT)
- Inspect and correct TM defects (ST, LT)
- Ensure traction motor ground straps are secured ST, LT)
- Inspect traction motor lead boots for sealing and securement (ST, LT)
- Inspect and correct rigging defects (ST, LT)
- Inspect and correct journal box defects (ST, LT)
- Recheck motor support bearings (non BTR) (ST, LT)
  - o If water is found repeat process for placement into storage
- Recheck Hyatt journal boxes (ST, LT)
  - o If water is found repeat process for placement into storage

Best Practices: Return to Service – Starting Engine

- Remove all "Do Not Start" tags (ST, LT)
- Close all electrical breakers for starting locomotives (ST, LT)
- Close cylinder compression relief valves (ST, LT)
- Verify engine protection operation before starting engine (ST, LT)
- Prime fuel system and inspect for fuel leaks (ST, LT)
- Start engine and bring to normal operating temperature prior to performing any test or moving locomotive (ST, LT)
- Inspect for proper oiling and operation (ST, LT)

Best Practices: Return to Service – Engine Running

- Inspect for fuel, oil, water, air, and exhaust leaks (ST, LT)
- Run self check on applicable electrical systems (ST, LT)
- Check operation of HVAC (ST, LT)
- Verify that engine protection devices operate (ST, LT)
- Verify the MR charges (130 - 140 psi) and brakes set (ST, LT)
- Verify air compressor unloader valve is functioning (ST, LT)
- Load test for 30 minutes (ST, LT)
    - o A load box is required for non-self loaders, a 30 minute drag test is an acceptable alternative to a load box test
- Conduct air dryer inspection for proper operation (ST, LT)
- Ensure all air MR blow-downs are functioning (ST, LT)
- Verify proper compressor output with MR orifice test to (LT)
- Conduct shop release air brake test and inspection (ST, LT)
    - o Calibrate air flow meter
- Perform stall test and directional test (ST, LT)

Best Practices: Return to Service – Post Engine Running

- Shut down engine and take engine and air compressor lubrication oil samples and submit for analysis (ST, LT)
- Test lube oil for fuel dilution with a lab test or a Fuel Sniffer (ST, LT)
    - o If fuel dilution is detected find the source and correct
- Test lube oil for free water using a Crackle Test (ST, LT)
    - o If free water is detected find the source and correct
- Drain coolant/cleaner and refill system with water treated with corrosion inhibitor to proper TDS level (ST, LT)
- Take applicable downloads and review fault logs (ST, LT)
- Install radios and FOT devices (ST, LT)
- Release to Service (ST, LT)
- Place on a control run, six months preferred with no premium service for the first two months (ST, LT)

Conclusion

To ensure successful locomotive storage and return to service performance, factually assess your locomotive storage process and procedures and replace non-value added activities with processes proven by other railroads or related industries. Use the Best Practices discussed in this paper to help develop a lean and standardized storage process. For continuous improvement assess your post storage reliability performance and revise your process as appropriate. Continue to share your success stories and lessons learned with the appropriate LMOA Committees to ensure data sharing amongst the Railroads, OEMs, and component and material suppliers for future improvement of the LMOA recommended Best Practices for locomotive storage and return to service.

Design for Reliability

Prepared by:
Tom Kennedy, Union Pacific Railroad and
Ian Bradbury, Peaker Services

The concepts of Design for Reliability (DFR) are not new, but DFR has benefitted from renewed interest in reducing support costs, avoiding missed opportunities, and improving customer satisfaction through improved reliability. This paper will be a high level introduction to DFR with the possibility of future papers expanding in detail on individual DFR elements. The topical areas to be addressed in this paper are what is DFR, why DFR, the advantages of DFR, will DFR increase product cost, the role of Systems Engineering, and the DFR elements.

The Cost of DFR:

Before we get into the details of a DFR program let's answer the question that is most likely on your mind. Will DFR result in higher product cost? This really depends first on what is your definition of cost and secondly on what are your requirements. If your definition of cost is the purchase price of the product then most likely the cost will be greater, possibly significantly. If your definition of cost is a Life Cycle Cost (LCC) basis and if the DFR program is properly designed and applied then the LCC cost should be lower, possibly significantly lower. LCC is comprised of the cost of acquisition, logistics support, operational, maintenance, and end of life disposal. Of course there are more cost elements than these but they can typically be assigned to one of these buckets. Program scope will also contribute to product and life cycle cost and product content must be assessed to its benefit to reliability performance to product development and acquisition cost. Essentially when in a development program, product content and technology must buy its way onto the platform with benefit.

Reliability History:

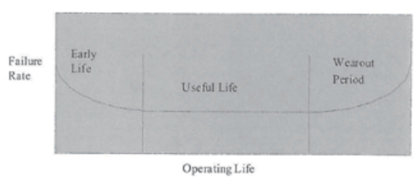
The beginnings of reliability, and ultimately DFR, can be traced back to the 1800's but its modern definition and direction were developed and matured by the US Military and Germany in the 1940's. The Science of Reliability continued to expand and be refined during the US space program under Dr. Wernher von Braun. During this time the practice of reliability was expanded in military acquisition programs and many of the techniques and tools were developed by the US government or under contract to the government. From the 1950's to present, reliability tools began seeing and continue to see increased acceptance and application in the commercial sector, especially with commercial aviation (Boeing, McDonald Douglas, Lockheed, etc.) due to their close connection with military aviation. The Japanese automotive and electronics industries, building on the work that Dr. Deming and others brought to Japan after WWII, especially embraced reliability and gained major market share through their successes.

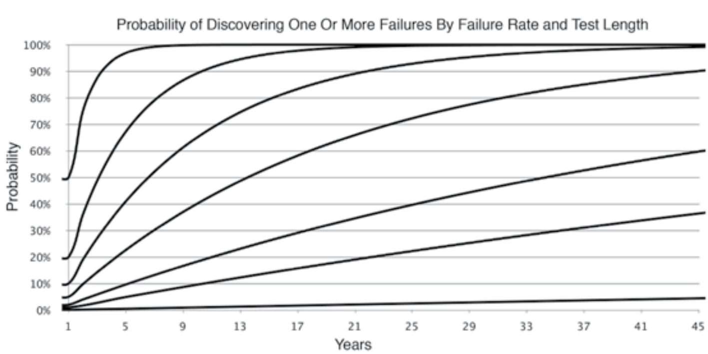
Why DFR:

To improve customer satisfaction & shareholder return. Unreliability (Q = 1 - R), directly effects the bottom line of the producer (OEM) and consumer (railroad) with missed revenue opportunities, delivery penalties, increased repair costs, additional material stocking, increased shop space, etc. Also governmental mandates typically increase product hardware and software content which degrades reliability performance. With the additional content, the reliability of the added content and the existing content must be addressed to achieve a net zero loss in reliability and preferably an increase in reliability. Additionally, in the past field testing, either at a field test site or on a railroad property has been one tool used to assess and grow reliability performance but this is expensive and time consuming with the confidence of finding deficiencies becoming less with the lower rate items or requiring extensive field test time as shown in following chart. A properly structured DFR program can successfully address these issues.

DFR - Basics:

To understand DFR we must understand the basics. Reliability is the measure of a product's ability to perform its intended function over a specified period of operating time and environmental conditions without failure. Typically reliability is expressed in terms of probability of mission success (%), Mean Time Between Failure (MTBF), Mean Miles Between Failure (MMBF), MWh's between failure, etc. Durability is often used interchangeability with Reliability but is actually a subset of Reliability, as is infant mortality and the constant failure portion of the bathtub curve. The traditional bathtub curve is shown below.

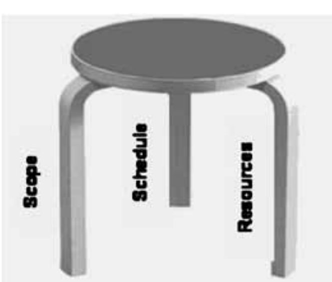




DFR – Program Elements

There are three basic program activities that when integrated together form the basis of which a DFR program is implemented. These elements are the design process, the manufacturing process, and the product operation (customer). This forms the "Triad" of DFR as shown in the following graphic.

The integration of these three program elements is accomplished through the Project Program Plan that defines the scope, schedule, and resources to achieve all key project objectives, including reliability. This integration can be pictured as a three legged stool, as shown in the following graphic, where if one of the legs is shorter than another the stool is unbalanced and subject to failure.



Another way to look at this is if your program has more scope than resources or schedule then the program is unbalanced and subject to failure. The theory of constraints dictates that the element most limited will necessitate adjustment of the others.

A fundamental tenet of reliability is that reliability performance must be designed into the product and cannot be tested or inspected in. Reliability performance is a function of the interactions between the design, manufacture, and product operation. A Reliability Program Plan is developed describing the reliability program elements of planning, design, and verification testing. These elements of the Reliability Program Plan when integrated into the Project plan through System Engineering embody the Design for Reliability Program.

DFR – Reliability Program Planning

Reliability Program Planning involves many separate but interrelated elements which, as a minimum, are:

- Design Reviews
- Reliability Requirements
- Reliability Math Modeling
- Reliability Allocations
- Carry Over Content
- Reliability Critical Items (RCI)
- Supplier Reliability Program
- Problem Solving
- Capability Maturity Model (CMM)
  - Software development

These elements are discussed further in the following sections.

Reliability Program Planning – Design Reviews

Systematic cross functional program design reviews (toll gates) are critical to ensure that the design and manufacturing elements have satisfied requirements and are ready to proceed to the next phase. If the program requirements are not satisfied then the deficiency needs to be corrected and the review repeated.

Design and manufacturing reviews included in the program schedule are:

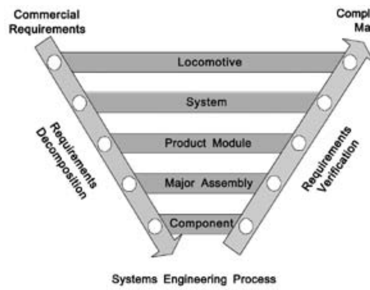
- SRR – Systems Requirements Review
- SDR – Systems Development Review
- PDR – Preliminary Design Review
- CDR – Critical Design Review
- TRR – Test Readiness Review
- PRR – Production Readiness Review
- SAR – Ship Authorization Review
- PRR – Post Production Review

Reliability Program Planning – Requirements

Reliability requirements are integrated into the Systems Engineering Management Plan (SEMP) which integrate program activities together, such as:

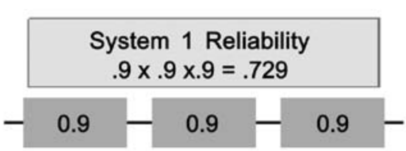
- Quality Function Deployment (QFD)
- Design Requirements
- Hardware/Software Test
- Production Planning

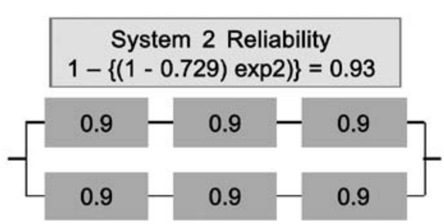
The System "V" chart, shown below, illustrates this process well.



Reliability Program Planning – Mathematical Modeling

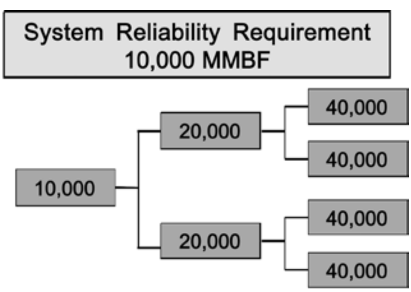
A reliability model mathematically describes the product architecture showing the dependent and independent components and paths. System interface points are included, of which many failures are interface failures, not necessarily hardware failures. Interface issues often lead to No Defect Found failure reports. Math models are essential for accurate reliability allocations, predictions, FMEA's, FTS's, etc. Two simple models, shown below, mathematically illustrate the difference in reliability performance between a series and parallel architecture.





Reliability Program Planning – Reliability Allocations

Top level Reliability requirements are allocated to the lower levels to establish design requirements. As requirements are allocated to lower levels the reliability targets increase to maintain system level performance. In a series system architecture a single point failure causes system loss. More complicated models, including non constant failure rates and redundancy, are required for more sophisticated systems and highly integrated systems. The graphic shown below illustrates the allocation concept for a series, constant failure rate architecture.



Reliability Program Planning – Carry Over Content

Reliability performance is limited by performance of the existing content carried over into new product. This performance can also be affected by a change in the operating environment or operating conditions. Existing content not changed by new design must be entered into the reliability allocations and adjusted as appropriate. Carry over content could become a Reliability Critical Item (RCI), see next section, that could require design changes.

Reliability Program Planning – Reliability Critical Items

Identification of RCI's is critical to program success since these items require additional attention. At minimum RCIs are defined by the following criteria:

- Operating or maintenance safety
- Operating success (mission reliability)
- Repair or replacement costs
- Components from new suppliers
- Components with a current performance issue
- Components developed with new/advancing technology

Reliability Program Planning – Supplier Program

Reliability Program Requirements developed by the OEM should be allocated to the sub tier suppliers. Requirements should be scaled to reflect the supplier involvement but key critical items such as the following should, as a minimum, always be included.

- Reliability Program Plan
- Parts program
- Sub tier RCI Suppliers

Additional elements such as design reviews, math models, allocations, etc. should be included based on criticality analysis and risk. Historically the root cause of many reliability problems is found at second and third tier suppliers and stem back to inadequate or ineffective supplier management from the OEM.

Reliability Program Planning – Problem Solving

All programs must have a problem solving process since it is not if, it is when problems will occur. There isn't much new "under the sun" regarding problems solving, just different packaging to improve product attractiveness and marketing opportunities. A problem solving process must include these basic steps.

- Step 1: Problem Identification
- Step 2: Action Planning
- Step 3: Short-Term Containment
- Step 4: Root Cause Analysis
- Step 5: Corrective Action & Verification
- Step 6: Implementation
- Step 7: Long-Term Evaluation

Reliability Program Planning – Capability Maturity Model

Programs that employ software for product control should employ the Capability Maturity Model (CMM) to assess the maturity of the software development process and identify process improvements. The CMM was developed by Carnegie Mellon University, reference the Software Engineering Institute (SEI), under contract to the United States Department of Defense to provide an objective method to evaluate a contractor's software development process and identify objective means for improvement. There are five levels of maturity within the CMM and these are:

- Level 1 – Chaotic
  - Starting point for new or undocumented process
- Level 2 – Repeatable
  - Minimum documentation to ensure repeatable process
- Level 3 – Defined
  - Defined and confirmed as a standard business process
- Level 4 – Managed
  - Quantitatively managed to agreed upon metrics
- Level 5 – Optimizing
  - Deliberate processes to optimize and improve

The CMM is an excellent tool for improving the reliability performance of software by eliminating undesired functions, interactions, and the generation of No Defect Found (NDF) incidents. Also with the integration of the CMM with the Systems Engineering Program miscommunication or misunderstanding of the electrical, electronic, software, and mechanical interfaces can be avoided. For example software controlled electronics can create an almost instantaneous command for a change in state that can cause problems with mechanical systems due to inertia or hysteresis. This lack of coordination of interfaces creates the opportunity for failure. CMM is worthy of a paper in and of itself but since software is embedded within the electronics of the product, further discussion and development of CMM is left to the LMOA Electrical Committee.

DFR – Reliability Design Activities

Design for Reliability involves many separate but interrelated elements which, as a minimum, are:

- Reliability Predictions
- New Content Analysis
- Failure Modes Effects Analysis (FMEA)
- Fault Tree Analysis (FTA)
- Sneak Circuit Analysis (SCA)
- Parts Stress Derating Analysis
- Parts Control Program
  - Quality Certification Requirements
- Worst Case Circuit Analysis
- Highly Accelerated Life Testing (HALT)
- Reliability Development Growth Testing (RGT)

These elements are discussed further in the following sections.

Reliability Design Activities – Reliability Predictions

A prediction of the products reliability performance is essential for the following reasons which are not all inclusive.

- Estimate reliability performance in customer environment
- Revise the reliability allocations with current information
- Accurate completion of FMEAs, FTA's, and test plans
- Identify target areas (RCI's) requiring further development
- Develop diagnostics and Built-In-Test (BIT) strategies
- Develop scheduled maintenance recommendations (RCM)
- Required for Design Reviews to show verification status

Reliability predictions are a living document updated with analysis and test results with numerous techniques available to develop them with.

- Current or similar product field performance
- Analytical tools such as MIL-HDBK-217 or NRPD
- Lab and field test results
- Customers resist conducting field tests in their environment

Reliability Design Activities – New Content Analysis

Identification and analysis of the product's new content is central to the reliability design activity. This identification separates the new content into four categories:

- Class 1: Existing technology in a proven application
- Class 2: Existing technology in a new application
- Class 3: New technology in a proven application
- Class 4: New technology in a new application

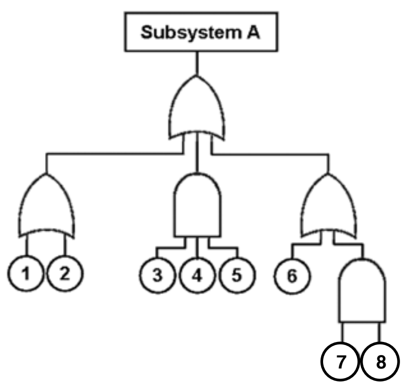
Depending on which class the new content falls into the reliability design and verification will vary with more focus and effort placed on the higher risk classes. Classes 3 and 4 are almost always categorized as RCI's. The new content analysis includes hardware, software, and systems integration elements. This process aids in identifying and managing risk. Risk can be managed but without this analysis one is left with uncertainty and this cannot be managed. A good definition of risk is that it is uncertainty defined with data.

Reliability Design Activities – Failure Modes Effects Analysis

An objective and thorough Failure Modes & Effects Analysis (FMEA) is one of the most powerful and proactive reliability design tools available. An FMEA develops the Risk Priority Number (RPN) by determining the probability, consequence, and detectability of failure modes, "bottoms up" analysis with the higher the RPN the greater the failure mode risk. Realistically not every failure mode can be addressed so RPN limits should be defined, based on program objectives, as to where mitigation is required. FMEA's can be functional or architectural based, Systems, Design, and Process. An example FMEA is shown below.

Reliability Design Activities – Fault Tree Analysis

An objective and thorough Fault Tree Analysis (FTA) is another powerful & proactive reliability design tool. Unlike an FMEA the FTA is a "tops down" analysis starting with an undesired event, identifying elements, and the path required to achieve the undesired result with design and process changes the output of an FTA. An FTA is constructed using Boolean logic, and excel for highly integrated complex systems including redundancy. Like an FMEA the FTA can be functional or architectural, Systems, Design, and Process based. A simple FTA example is shown in the following graphic.



Line No.	Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Class	Potential Cause(s) / Mechanism(s) of Failure	OCC	Current Design Controls	DET	RPN	Recommended Action (s)
4	Lamination:provide space for coils	inadequate space	short or grounds	8		Damage insulation during installation if too tight	2	Check every slot	1	16	
5	Stator frame tiebars :provide mounting for nose link and support bearing	Cracks in weld,excessive deflection	Structual motor damage, rough ride	10		Insufficient weld size,lack of understanding of environmental	4	Based on simularity of current design	2	80	FEA analysis/field testing Note CP and Alaska .

Reliability Design Activities – Sneak Circuit Analysis

Sneak Circuits are latent defects in hardware and/or software that cause uncommanded or undesired function in the absence of a hardware failure. For example on a car a sneak circuit would be when the headlights are turned on the gas gauge goes from full to half tank. Sneak Circuit Analysis (SCA) was developed in the 1960's by the US military and NASA after multiple missile and rocket failures. Sneak Circuits become increasingly probable as the product complexity and integration increases and often affect electrical and mechanical systems and software and their integration. There are tools available to identify and analyze SCA and their affect of which a few are shown below.

- Automated analytical and simulation tools
- Hot bench mockup testing (hardware in the loop)
- Software Integration Laboratory Test Facility (SILTF)

Reliability Design Activities – Stress Derating Analysis

Stress derating is the application of a component at a lower electrical and/or mechanical applied stress than the component is rated for, typically referred to as design margin or safety factor. The purpose is to derate the application to a stress level that remains in the more constant portion of the failure rate curve and to avoid exponential failure rate of wearout, Beta slope greater than 1. Derating is based on the science that with every 10 degree C increase in temperature that chemical activity doubles (Arrhenius Function). Derating is tailored to component type with some typical examples, not inclusive, listed below.

- Resistors - typically by power and < 50% of rating
- Capacitors - typically by voltage and < 60% of rating
- Semiconductors – typically by temperature

Stress derating is also dependent on component technology used such as is the component a metal can type hermetic device or plastic or epoxy encapsulated device since rate of heat transfer is effected with component technology and packaging. A derating document should be developed for each program to provide reliability design guidelines for maximum application stress allowed.

Reliability Design Activities – Components Program

A parts program establishes design, functional and quality requirements for component selection and as a minimum establishes:

- Minimum part quality levels, not all inclusive
  - Consumer
  - Commercial
  - Industrial
  - Military
  - Aerospace
- Environmental requirements, not all inclusive
  - Temperature
  - Humidity
  - Thermal conductivity
  - Radio Frequency

- Piece part acceptance testing
  - Lot sampling inspection
  - 100% inspection
  - Functional test

Reliability Design Activities – Worst Case Analysis

New product designs are typically defined for operation to the nominal operating conditions. Worst case analysis determines a products technical and reliability performance when exposed to worst case operating and environmental stresses such as the following operational and environmental factors.

- Tunnel operation
  - High temperature
  - Reduced oxygen and exhaust soot
- Weather extremes
  - Rain, Ice, Low Temp, High Temp

Worst case operating conditions result in increased part stress possibly requiring design changes. Non design change solutions may be available and should be coordinated with the customer in design reviews prior to implementation into the product design. A few, not inclusive, non design change solutions follow.

- Operating restrictions
- Infrastructure changes/additions
- Product derating - software initiated

Reliability Design Activities – Highly Accelerated Life Test

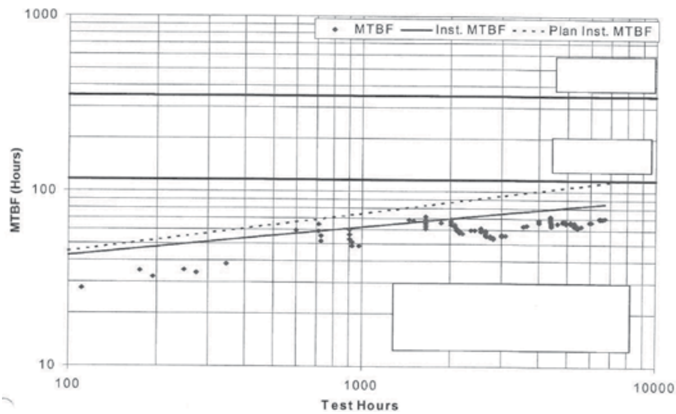
Highly Accelerated Life Test (HALT) is an accelerated test process designed to "break" the product, precipitating failure modes for analysis. Typically HALT uses the environmental stresses of temperature, vibration, shock, voltage cycling, etc. to stress the product to and beyond its design limits. These extremes are applied in a rigorous and stepped process until the product fails. The failure modes are then analyzed to determine if they are sensical or non-sensical failure modes with sensical failure modes being those that are determined could occur during the operational life of the product and non-sensical failure modes being those that would never be expected in the worst case customer application. Each sensical failure mode is assessed independently as to whether a design change should be implemented and coordinated with the customer at design reviews.

Reliability Design Activities – Reliability Growth Test

RGT is a process designed to grow reliability under the nominal operating of temperatures and vibration experienced in the customer application. Failure modes are analyzed with the problem solving process and corrective actions implemented into the test articles and the articles returned to test. Product reliability performance is plotted on log-log paper using models such as the Duane RGT model to provide an estimate of product performance and effectiveness of the implemented corrective actions and design changes. A sample RGT plot is shown on next page.

DFR – Reliability Verification

Verification of reliability performance follows the same System Engineering process for requirements verification and is separated into four groups



with the cost of verification increasing with each grouping. Some examples of specific verification techniques, although not inclusive, is shown below under each group.

- Analysis
  - Stress Analysis/FEA
  - CAD Clash
- Inspection
  - First Article – nonoperational
- Demonstration
  - First Article – operational
- Test
  - Design of Experiments DOE
    - e.g., Parameter Optimization (Taguchi Technique)
  - Highly Accelerated Life Test (HALT)
  - Reliability Growth Testing (RGT)
  - Customer Field Test (CFT)
  - Environmental Stress Screening (ESS)
  - Product Reliability Acceptance Test (PRAT)

DFR – Summary

Today's products are complex and highly integrated and their development requires that reliability be a central element of the design – hence DFR. To successfully design, implement, and achieve a DFR program the OEM's must enhance their knowledge and expertise with reliability design tools and rigorously apply them and change the paradigm that product development and modifications on customer property are acceptable - they are not!

The railroads must actively participate in the product design process from start to finish ensuring that their requirements are understood and achieved in the product design. This will require the railroads to enhance their own reliability engineering design knowledge and expertise and actively participate in OEM design reviews. Additionally, the railroads must change their own paradigm that the locomotive acquisition process is based solely on product acquisition cost to an acquisition process that is based on life cycle cost. As noted at the beginning of the paper the product acquisition price may be higher but the program Life Cycle Cost can be significantly lower.

Main Generators - AR Type Traction Alternators - Best Practices - Identification and Maintenance

Presented by:
Richard Aranda, Belt Railway and James Sherbrook, Loco Docs

Introduction

A locomotive is a power plant on wheels. If the main generator is not properly maintained, the locomotive will not move. The purpose of this paper is to provide a mechanical maintenance overview of the main generator from a Midwest railroad's perspective, concentrating on what we find are the best maintenance practices for our type of service. The alternator rectifier (AR) type traction alternator with a D14 or D18 companion alternator will be the focus of this paper (4L-87). The AR type traction alternator is standard equipment throughout our fleet.

The term "main generator" is generically used throughout the locomotive industry to refer to a locomotive's generator or alternator. A generator is a direct current (DC) device. An alternator is an alternating current (AC) device. The main generator or traction alternator consists of two, three phase, alternating current generators utilizing a single spherical bearing. The spiders of the two machines are bolted together; the coupling disc of the companion alternator is bolted to the coupling of the engine. The outboard end of the alternator rotor is supported by a bearing (ITS/MI 3317-1).

A D14 or D18 companion alternator is physically connected to, but is electrically independent of, the traction alternator. The alternator is a variable frequency, variable voltage three phase machine having a rotating field and stationary armature. The alternator efficiently drives auxiliaries, such as the engine cooling fans and inertial filter blower motor, as well as provides current for excitation to the main generator (MI3306). The alternator stator assembly is bolted to the main generator frame. The rotating field assembly is bolted at one end to the main generator field assembly and to the engine at the other end by a disc type coupling connection (MI3306).

Identification

In 1983, EMD changed its AR-type main generator model designation system. The system employs a series of letters following the basic number model designation. There are three letter positions after the model number with a potential for a fourth position for future use. The last letter is followed by a slant bar and the model designation of the companion alternator connected to the main generator (4L-87).

Example

1972 Designation

AR10A-D14 (Source No 190/1972).

Alternator Rectifier

Model Number

Companion Alternator

1983 Redesignation

AR 10 NKA / D14 (Source 4L-87)

Alternator Rectifier

Model Number

First Letter

N means Foot Height 14-5/8" below - cannot be used with 710 engines; extra space is needed to clear aftercooler ducts. Changed from thin to thick disc in 1983 (4L-87).

Second Letter

K means Blower Aspirated, thru shaft, no AC power take-off, slip ring access doors (4L-87).

Third Letter

A means 2000/2400V Diode, Type 2 of 3 (4L-87).

Companion Alternator

D14

Some confusion exists regarding D14 and D18 rotor interchangeability. Although either are physically interchangeable, the two rotors are electrically different. If a D18 rotor and D14 stator are combined, the normal voltage output will double. A D14 rotor combined with a D18 stator will drastically reduce the output voltage. D14 and D18 rotors can be identified by measuring the lamination stack length. D14 rotor poles measure 5". D18 rotor poles measure 6-3/32" (7L-84). D14 and D18 alternators are only interchangeable on locomotives equipped with field forcing circuitry. Field forcing circuitry was not applied on locomotives delivered before April 1981. D14 stator assemblies cannot be used with D18 rotor assemblies, and D18 stator assemblies cannot be used with D14 rotor assemblies (6L-81).

Maintenance

The traction alternator is designed to provide a long service life, optimum performance while minimizing maintenance. The type of operation and service to which the alternator is subject will largely determine the extent and maintenance requirements.

The interior and the exterior of the traction alternator should be kept clean and free of dirt, dust, water and oil. All of these will have a detrimental effect on performance and insulation (MI 3317-1). For general cleaning of the main generator, the electrical equipment should not be sprayed or cleaned with a liquid of any kind. Cleaning the coils and windings with any liquid cleaner will destroy the protective coating, causing it to crack or peel. One may use dry compressed air and low pressure (30 to 50 pounds per square inch (PSI)) to blow out dirt from the stator and rotor assembly. High air pressure will loosen the insulation binding and blown particles may damage the insulation (MI 3306). The alternator should be blown out with low pressure air every 92 days. Maintenance personnel should be advised to exhibit safety, use personal protective equipment (PPE) and check policies and safeguards when using compressed air to clean or blow dirt off of parts.

Dry wiping cloths should be used as necessary to remove oil and dirt accumulation (MI 3306). For imbedded deposits of dirt in connection areas, a stiff brush, soft wood or fiber scrapers may be used. For severe cases, where compressed air or a stiff brush does not work, a cloth dampened with alcohol may be used to remove the dirt from rotating field terminals and connectors (MI 3306). The rectifier section needs to be kept clean as possible. Mechanical and electrical connections should be tight (MI 3317-1).

Collector Rings and Brushes

Collector rings and brushes should be checked every 92 days while the generator is in operation. The negative ring will wear more rapidly than the positive ring. To minimize unequal wear, reverse the ring polarity every six months (MI 3306).

Spiral grooved collector rings have been applied to AR traction generators and companion alternators since 1974. Spiral grooving improves ring and brush life. This design eliminates threading and film stripping on the collector ring brush surface (5L-79).

It must be noted that misapplication of AR10 and D14 collector ring leads can result in continuous excitation of the main generator from the D14 field leads with the potential to cause a serious accident. With the diesel engine running, power contactors may pick up when the locomotive isolation switch is placed into the run position. When working with collector ring connections, a continuity test should be performed with all field leads disconnected and all brushes lifted to ensure proper connections have been made (9L-74).

Slip ring brush temperature investigation has revealed a substantial temperature reduction is obtained by scavenging the snow guard area. New snow guards have two 3/4" diameter holes in line with the rear slip ring, just above and below the armature centerline. Upper and lower brush inspection doors have 1/2" diameter holes located on the right hand side (when facing the generator). Existing older style snow guards and inspection doors can be modified by adding these holes (13L-78).

A Midwest railroad has found with its slow speed switching operation that, as a best practice, collector rings are changed out as part of a 1104 inspection. Collector rings are removed and sent our for machining to bring the part back to within tolerance (Belt). The collector ring concentricity should be within 0.15 millimeter (mm) or (0.006") with a lateral runout within 0.8 mm (0.03"). If theses tolerances are exceeded, the rings must be machined. One must be careful not to allow the assembly to be turned below the minimum acceptable diameter of 260 mm or 10-1/4" (MI 3306).

Sparking can be caused by oil on the collector ring surface. Sparking conditions should be eliminated immediately. Wipe off rings and brushes with a clean, dry, lintless cloth (MI 3308). The generator is equipped with eight constant pressure brush holders; four are mounted at the top and four are mounted at the bottom of the collector ring assembly (MI 3308). Another source of sparking is loose brush holders. If a brush holder is unsecured at the stud, the brushes will bounce against the collector ring, resulting in a spark. Make sure all bolts are tight (MI 3317-1).

Brush length must be maintained. Brushes shorter than 19 mm (3/4") must be replaced (MI 3317-1). New brushes must be sanded in using a 00 grade sandpaper. The sandpaper must be placed under the brush with the sand side contacting the brush and moving the sandpaper in the rotation direction (MI 3306). Never use carborundum, emery cloth or emery paper for sanding in brushes (MI 3306). Seat one brush at a time by sanding in. Repeat this procedure for each brush (MI 3308).

Bearings

Since the AR type main generator's introduction in 1970's, modifications and part changes have been made to improve traction alternator performance. Roller bearing change is one area. EMD has approved roller-riding cage design bearings for all of its traction generator applications. This design ensures adequate lubrication between the cage and inner race of bearings when operating above 900 revolutions per minute (RPM). SKF Bearing number 9439612 / PTC Bearing (Link Belt) 9437992 require no modification of existing bearing cap, seals, cover or housing. No modification of the generator shaft is required (3L-83).

The larger 259.999 mm (10.2362”) bearing will operate for a longer service than the smaller bearing (MI 3317-1). Both small and large bearings have a different maintenance cycle. The larger bearing, measuring 259.999 mm (10.2362”), requires less maintenance (MI 3317-1). For low speed, high revolution switching service, the larger bearing works best (Belt).

AR10 bearing housing design improvements have been made on the large spherical housing assembly 8418960 to ensure that the bearing’s outer race is always free to move in the bearing housing with expansion and contraction of the alternator rotor and engine crankshaft. This assembly consists of a hardened sleeve pressed into a machined housing. The inner diameter of the bearing housing sleeve has been increased and nickel plated to resist fretting (8L-73). A new vented bearing housing design is available for all AR model generators, part number 40086499 (MI 3317-1).

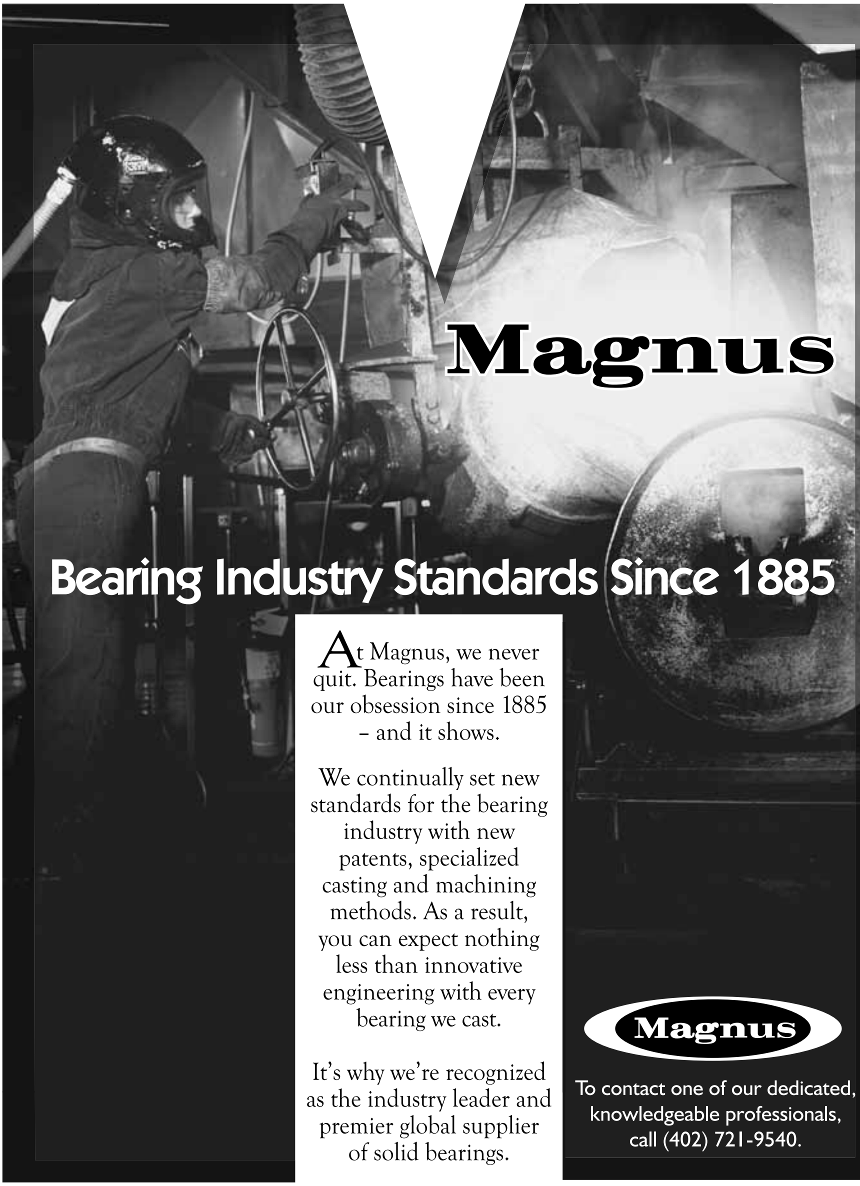
When inspecting bearings, one will find dents, nicks, pits and craters. If these are found small and scattered, it should not be cause for rejection. Findings should be evaluated carefully, taking into account the overall bearing condition. Questionable parts should be discarded. Failed parts must be replaced (MI 3317-1).

Grease

Inspecting, investigating and evaluating locomotives has indicated that the condition of main generator grease after seven (7) years in service is very marginal. Bearings found on the verge of catastrophic failure are a result of lubrication starvation. Oil becomes depleted from the grease with time and bearing revolutions, the grease dries out and becomes ineffective. The brass bearing cage is the first component to suffer with wear, causing brass particles to accumulate in the bearing. Consequently, the cage will no longer guide the rollers, causing bearing destruction and potential loss of the generator (4L-91).

Locomotives operated in low speed, high throttle (notch 8) operation accumulate a higher number of generator revolutions for a given span of time or mileage. It is recommended that AR type generators run in this type of service have bearing relubrication performed at a six (6) year maintenance interval (4L-91). When an eight (8) year relubrication schedule is specified, the lubrication interval should be changed to the six (6) year schedule, or timed to coincide with engine overhaul (4L-91).

Lubricant applied to AR type generators with single spherical bearings has been changed to ESSO Unirex N-2 grease. When applied, it is a lighter grade, which allows oil to bleed more freely to the bearing surfaces. Reference part numbers 9507146 for 35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pounds and 9507147 for 120 pounds (13L-78/MI 3317-1).

Generator bearing housing lubricant specifications have changed. Lubricants 8168822 and 9316707 have been replaced by molybdenum disulfide paste, Molykote “G” paste, part number 9517921. A thin coating should be evenly brushed on when applied to generator bearing housings. Molykote does not require air drying (9L-79/MI 3317-1).

Collector ring puller tools can be fabricated, as detailed in drawings provided within MI 3317-1. After removing the collector ring, outer seal and brush holder, the bearing is exposed. One can inspect the cover and exposed bearing sides for metal particles in the grease, excessive housing wear and roller damage. Use only your fingers or a putty knife to remove old grease from the exposed side of the bearing and as much as possible from between the rollers and cage. Do not use any solvents. If evidence is found of overheating, the bearing should be changed. If no distress is found, thoroughly clean the bearing and grease (MI 3317-1). When greasing the bearing, follow MI 3317. The bearing can be inspected and regreased in place or removed from the generator, inspected and regreased (4L-91). It must be stressed that care should be taken in relubrication to ensure that as much grease as possible is pushed into the roller spaces, especially filling the back rollers. Use a grease gun with a needle fitting to fill hard to fill rollers (4L-91).

When applying bearing grease to the labyrinth grooves, it does not have to be measured; however, it must be weighed when applying it to the inner and outer bearing covers. Adequate lubrication depends on the precise weight of the grease when applied to the bearing covers; too much grease is as detrimental to bearing life as too little (MI 3317-1).

Pack the brush holder cover leaving free space on the top part of the cover to allow grease liquefaction when the bearing starts to heat up. Shape the grease into a nice contour extending it out about 3/8” to a point at the upper opening (MI 3317-1). A piece of cardboard is an adequate tool to shape the grease (Belt). Install the bearing cover with a new gasket. Make sure the space free of grease is at the top. Torque 1/2”-13 cover mounting bolt to 50 to 55 foot pounds (ft-lbs) using three passes (MI 3317-1).

Heat the outer seal in an oil bath, electric heater or an induction heater. Heat the seal to 220 degrees. Periodically check the temperature with a pyrometer. Make sure the current is off while performing temperature checks. Once the proper temperature is reached, apply the outer seal to the shaft and allow it to cool (MI 3317-1).

The collector ring is cleaned on the inside with emery cloth. One Midwest railroad has found it better to heat the shaft with a standard 100 watt light bulb instead of using an induction heater. Place the light bulb inside the collector ring for 30 to 45 minutes and apply onto the shaft rotating the assembly on the shaft until properly positioned to make lead connections, then allow it to cool. It does not make a difference whether this step is performed within the locomotive or with the main generator removed from the locomotive (Belt).

Investigation has revealed grease "purging" is a direct result of a pressure drop across the bearing. Positive pressure must be maintained to keep the grease in the bearing, bearing cap and cover. A one inch draw of water pressure behind the bearing is enough to purge bearing grease past the seals. This type of pressure drop is often the result of slip ring and air box covers and doors that are not properly sealed or closed after inspections or repairs have been performed on the generator (4L-91).

Conclusion

A locomotive is a power plant on wheels. If the main generator is not properly maintained, the locomotive will not move. If one focuses a mechanical mind on the main generator by keeping the generator clean, maintaining the collector ring and brushes and the bearing greased, the cost of performing the preventative maintenance will outweigh the cost of component failure and unscheduled unit downtime.

Resources

Belt Railway of Chicago, The, Interview: Richard Aranda: January 10, 2011.

Electro-Motive Division (EMD), Maintenance Instruction (MI) M.I. 3306, D14 Alternator, Revision B, (May 1978): 1, 4 and 5.

EMD M.I. 3308, CA Series Alternators Running Maintenance and Overhaul Instructions, Revision B, (June 29, 2001): 9, 14 and 16.

EMD M.I. 3317-1, Scheduled Maintenance and Overhaul Instructions AR and TA-Type Traction Alternators, Revision F, (October 2001): 5, 9, 10, 11, 18, 21, 24, 28, 55, 66 and 72.

EMD, Pointers, (June 12, 1972): 3.

EMD 8L-73, Pointers, (August 13, 1973): 2.

EMD 9L-74, Pointers, (July 30, 1974): 1 and 2.

EMD 13L-78, Pointers, (December 4, 1978): 2 and 4.

EMD 5L-79, Pointers, (May 25, 1979): 4.

EMD 9L-79, Pointers, (September 28, 1979): 2.

EMD 6L-81, Pointers, (September 14, 1981): 3.

EMD 3L-83, Pointers, (March 7, 1983): 1.

EMD, 7L-84, Pointers, (December 10, 1984): 3.

EMD 4L-87, Pointers, (July 13, 1987): 5 and 6.

EMD 4L-91, Pointers, (August 1991): 3.

EMD Replacement Parts Catalog No. 190, General Purpose and Special Duty Locomotives, Volume 2, Plate H3317, Item 1, (October 1981): 1.

ITS Locomotive Training Series, Switcher Electrical, Third Edition, (October 1998): 1-12.

Report on the Committee on Fuel, Lubricants and Environmental

Monday, September 19, 2011

10:45 A.M.

Chairman

Dwight Beebe

Vice President

Temple Engineering

Liberty, MO

Vice Chairman

Kevin Bills

VP-RR Operations

Searle Petroleum Co

Council Bluffs, IA

Commitee Members

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C. Kunkel	Sr. Mgr-R&D	Union Pacific	Omaha, NE
G. Lau	Senior Reliability Specialist	CN	Edmonton, Alberta
M. Maddox	Tech. Support	Industrial Specialty Chem	Harvey, IL
D. Mattey	Key Acct Mgr	Alfa Laval Inc	Hermitage, PA
D. McAndrew	Fuel & Lube Spec.	GE Transp Rail	Erie, PA
J. McDonald	Off of Trans & Air Quality	EPA	Ann Arbor, MI
D. Meyerkord	Senior Project Engineer	Electro Motive Dsls	LaGrange, IL
C. Ruch	Engineer II-Special Projects	BNSF	Topeka, KS
T. Savage	Business Manager	ALS-Staveley Svcs	Kansas City, KS
W. Strickland	Mgr-Test & Lab Svcs	CSX	Jacksonville, FL
J. Timar	Technical Team Leader	Oronite	Richmond, CA
D. Tuttle	Mgr-RR& Marine Sls	American Refining	Roswell, GA
K. Wazney	Chemist/Testing Specialist	CP	Winnipeg, Manitoba

Note: Messrs. Chuck Kunkel, Dennis McAndrew and 1st VP Glenn Bowen announced their retirements from their respective companies.

PERSONAL HISTORY

Dwight Beebe

Dwight Beebe is Vice President of Temple Engineering, Inc. He has worked in the railroad industry for over 15 years. First he was manager for TSL Inc. (originally the Frisco Railroad Laboratory) which provided a variety of testing for the rail industry. Later he worked for Nalco Chemical Company as the Account Representative for railroads in the Midwest. In 2003, he started Temple Engineering, Inc. with his wife Michelle. Temple provides fine chemicals and service to the transportation and manufacturing industries.

Dwight is a retired Lieutenant Colonel of the U.S. Army Reserves. He received a Bronze Star for his work planning transportation for the surge while serving in Iraq. He is a member of ASTM International and the American Society of Civil Engineers. He holds a BS in Chemistry from Missouri State University.

The Fuel, Lubricants and Environmental Committee conducted two conference calls during the year—One on December 10, 2010 which was hosted by Tom Gallagher of Oronite; the other in mid July hosted by Fred Girshick of Infineum—The Committee wishes to thank both Tom and Fred for setting up these teleconference calls.

The Committee would also like to thank Oronite for hosting their committee meeting on January 27, 2011 in Richmond, California—Special thanks to Tom Gallagher for arranging the meeting.


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Diesel Exhaust Fluid Properties & Technical Information

Prepared by:
Joseph J. Hiznay - Colonial Chemical Company

ABSTRACT

The US Federal Clean Air Act and amendments have mandated lower airborne pollutant levels being discharged from many sources, including diesel engines. The efforts to reduce one targeted pollutant, nitrogen oxides (NOx), have resulted in a new catalytic process being developed called Selective Catalytic Reduction (SCR). SCR uses a new fluid called Diesel Exhaust Fluid (DEF) that is sprayed into the engine exhaust stream to reduce the NOx levels to the mandated emission levels via a catalytic chemical reaction. SCR technology is one potential path to achieve the Tier IV compliance in the diesel locomotive segment in 2015. This paper discusses the technology behind SCR, the handling and technical aspects of DEF, and how the infrastructure for this new DEF fluid can be developed in order to meet the needs in the railroad market.

SCR technology uses DEF, which is highly purified urea in solution with de-ionized water, and a catalytic converter placed in the exhaust system to significantly reduce NOx emissions from diesel engines by chemically reducing the nitrogen oxides to nitrogen gas and water. DEF usage in a vehicle is about 2 – 5% of fuel consumption based on results in the Heavy Duty (H-D) truck market [Lockridge, 2009]. All U. S. Truck Engine manufacturers, with the exception of International, have chosen to use SCR technology as the method of meeting 2010 compliance with the on-highway emission requirements. SCR technology, based on US field experience offers a 3-5% improvement in fuel economy in the H-D market from pre-2010 truck engine technology, while meeting the new lower NOx emission levels [Bulk transporter 2010]. SCR technology is also a capable platform for greenhouse gas emission reductions by way of potential for improved fuel economy at low NOx levels, presently under discussion in many countries.

The Federal Clean Air Act and Amendments for NOx emissions mandates lower emissions but does not specify a technology path to reach the lower levels. Implementation timelines for the new very low NOx levels are given for various vehicle markets, with the Heavy Duty On-Highway trucks being first in 2010, Off-Road vehicles (farm/mining/construction) in 2012.

Locomotives in 2015, as well as various ships and ocean vessels in 2014 and 2016. Technology and engines must be certified as compliant by the Federal EPA. In the On-Highway market, since 1994 the NOx emissions have been reduced from 5.0 (grams/hp-hr) to 0.5 (grams/hr-hr) in 2007, to the current maximum level of 0.2 (grams/hp-hr). The change from the 2007 level to current level forced the truck OEM's to fundamentally redesign the engine to reach these low NOx levels. Prior to the 2010 emission standard, OEM's were able to meet the NOx emission standards by using massive exhaust gas recirculation (EGR) in the engine and a particulate filter downstream to deal with the particulates (engine soot) created from the compromised combustion using EGR. Heavy Duty trucks from the 2007-2010 period are experiencing maintenance/longevity difficulties, suffer from performance shortcomings such as lack of power/responsiveness and the need to pull over to perform a regeneration of the particulate filter [TheTrucker.com, 2009]. OEM's had to go back to a more fundamental engine design that allowed an engine to perform combustion more efficiently, use much less EGR, but produced more NOx which could now be controlled with the SCR system. . The power and responsiveness of the engine and vehicle performance were improved and the effect is pronounced. The forced particulate filter regenerations were eliminated, which improve fleet productivity and fuel economy. The overall fuel economy was able to be improved 3-5% on average, with some fleets reporting improvements of 9- 11% [Birkland, et al, 2010]. The strategy was to treat the NOx emissions in the exhaust system; incorporating the catalytic SCR system to significantly reduce the NOx in the exhaust stream.

Figure 1 shows a simple schematic of the SCR system on an H-D Truck engine. The system is downstream of

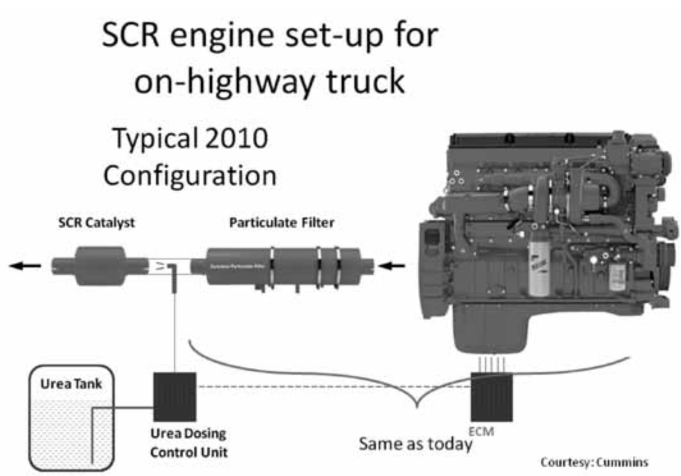


Figure 1

the engine and treats the exhaust gases by spraying the DEF into the exhaust stream. Figure 2 shows a more detailed schematic of the SCR system, the process control mechanism and DEF storage tank. Also, the chemical reactions occurring in the SCR systems are summarized. It is important to note that the DEF (urea) breaks down into ammonia at the pressures/temperatures in the exhaust stream. The ammonia reacts with the nitrogen oxides (NOx) within the catalyst to accomplish the transformation of these pollutant gases into harmless nitrogen and water.

SCR systems require an on-board supply of ammonia or other nitrogen based chemical that can decompose into ammonia in the engine exhaust system in order to accomplish the NOx reduction reactions. Urea was chosen to become the source of the nitrogen containing chemical for safety, health, and ease of handling reasons. Storing large quantities of ammonia on-board a vehicle poses several hazards because it is corrosive and is an acute health hazard if spilled or vented. Using urea (DEF) offers a means of generating the ammonia while posing minimal health and corrosion issues. Urea is widely used in agriculture as fertilizer and is available in large quantities. DEF is a non-toxic, biodegradable and an easy to handle material. Also, urea has been successfully used for more than fifteen (15) years in a similar NOx abatement SCR application in the power generation industry.

While similar in application for the power plant market, making acceptable DEF (urea) poses greater challenges for the vehicular market. The size of the SCR systems and catalyst beds in particular are much smaller than what can be designed into a power plant. Protecting the smaller catalyst surface has driven the need for more purity in the urea (DEF) being used for vehicles

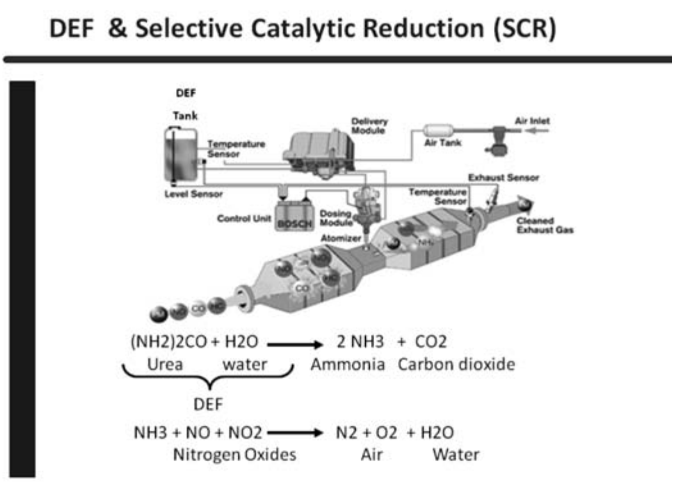


Figure 2

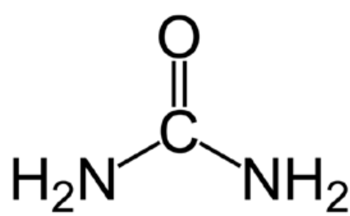
as compared to its sister market.

In North America, the first vehicle segment where SCR/DEF was implemented was the H-D Truck segment in 2010. About 1% of the 8,000,000 trucks in the US fleet are SCR trucks today. About 14 million gallons of DEF were consumed in 2010 and 64 million gallons are forecast to be consumed in 2011. The DEF industry has emerged as a viable infrastructure, with availability at most major truckstops, truck dealerships, and healthy competition present to supply DEF to fleet locations. In Europe, the DEF market began in 2006 and approximately 35% of the truck population is now SCR based. [Integer Research, Adblue & DEF Monitor, 2010]

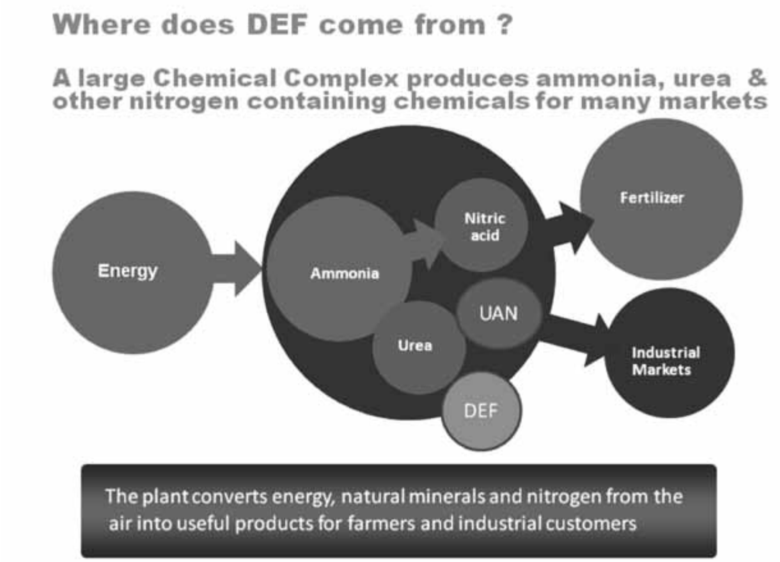
The implication for the railroad industry is that the SCR technology is a viable technology to meet upcoming locomotive Tier IV NOx levels. There will need to be a supply and dispensing infrastructure developed to handle the DEF effectively and efficiently. Since the DEF supply industry has geared up to supply the H-D Truck segment, supply arrangements to the railroad industry can be leveraged from this market without major difficulty. Also, the industry must be aware of the fluid properties to design proper storage, handling, and dispensing systems. This is necessary to assure the proper operation of the vehicle SCR system and to protect this investment on the locomotive. As a new fluid, the industry must also be aware of the aspects of handling this new fluid from the perspective of environmental and personnel protection.

A closer examination of DEF starts with the nomenclature in the market. Diesel Exhaust Fluid (DEF) is the name given to this fluid by the Automotive Alliance Stakeholders group as a generic term to identify it. The multinational organization, Society of Automotive Engineers (SAE) that drafts specifications, performance requirements for fluids refers to DEF as "AUS-32". The European equivalent generic name given by the German Auto Industry Association is "Adblue". There are still many references to the European name among the German vehicle manufacturers in the US. Then there are the tradenames used by producers of DEF fluid such as C-Blue®, Air1® and the like. The common chemical name is "urea solution". All of these terms describe the fluid that is a 32.5 % concentration of high purity urea in de-ionized (high purity) water.

DEF is a water based solution of a nitrogen containing chemical called urea. It has a water clear appearance, is non-hazardous, readily available and easy to use.



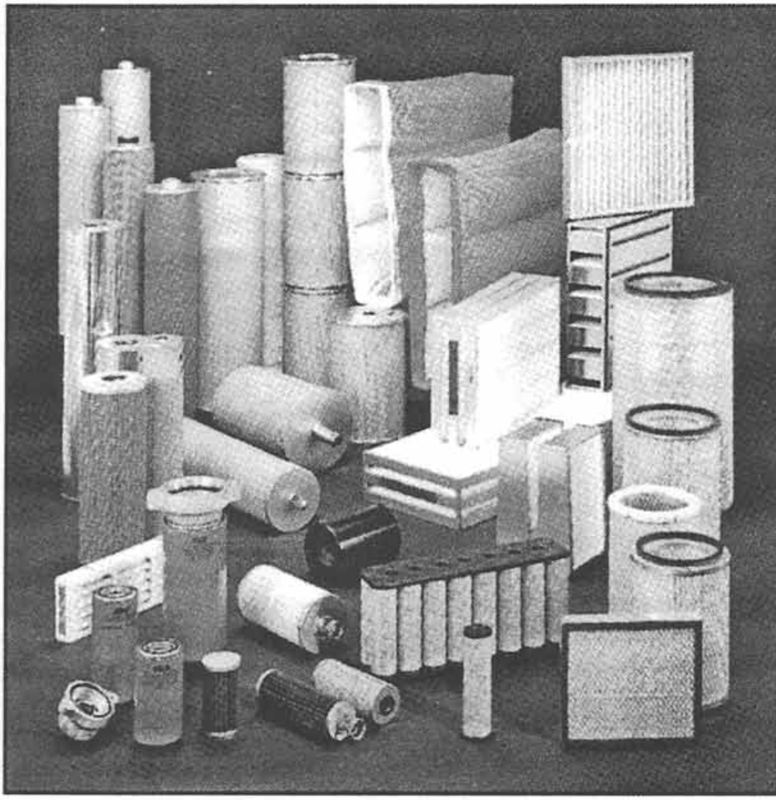
Urea is commercially produced from a manufacturing process which begins with natural gas being burned in air under controlled conditions in a large chemical complex that produces a series of nitrogen compounds. The pro-



duction plant can be envisioned as a nitrogen chemicals producing homologue as an oil refinery is to hydrocarbons. The nitrogen is introduced from the air into the combustion process. The products from the combustion are produced at carefully controlled conditions and ammonia (NH3) and carbon dioxide (CO2) are produced. The CO2 is chemically separated and purified. Some ammonia is purified and sold as an item of commerce, while some ammonia is further reacted under a different set of pressure/temperature conditions and a catalyst in another chemical reaction that combines the ammonia (NH3) and carbon dioxide (CO2) into urea: CO(NH2)2 The urea is separated from the formation process and purified into various grades suitable for automotive, agricultural, and industrial grades. DEF comes from selected points in this urea manufacturing process step where high purity urea can be captured and separated. In a similar manner the nitrogen production complex produces further derivative molecules with a variety of agricultural and industrial uses.

There are urea production plants in all regions of the world; however, not all of them are currently suitable for making the higher purity urea needed for DEF. Urea plants are generally built where a source a large quantity of stable low cost natural gas exists. There are many plants in North America and the US. Building a nitrogen complex is a formidable investment, over $ 1 B and therefore requires a long term return on investment to be a viable venture.

After the DEF is produced, it must be brought to these emerging segments in the vehicle market. Three key attributes are needed to assure that the DEF will be usable: the highest quality, assured delivery, and the lowest cost. The



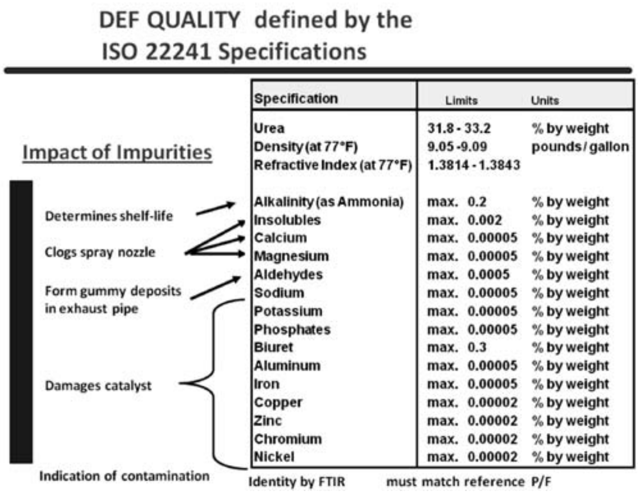


Figure 3

quality is created in the manufacturing plant and carried to market by the supply chain. The supply chain controls the delivery and both the manufacturing economics and distribution economics control the cost.

Product quality is measured at the production site and must be maintained through the supply chain to the point of introduction into a vehicle. The quality requirements have been determined by the International Standards Organization (ISO) and are defined for DEF by ISO 22241, Figure 3. The specifications were set by a multinational group, including those from the US and Canada. At any point where a physical or chemical change occurs with DEF, a new full quality analysis must be performed. The analysis is quite detailed, precise and thereby relatively expensive. The analysis measures fluid purity as well as impurities known to have deleterious effects in a vehicle SCR application. Additionally, special precautions are taken to handle DEF in materials and systems compatible with the fluid's chemistry to prevent unwanted introductions of contaminants. Prevention of particulate contamination is also ensured as the fluid is filtered at several points along the supply chain. Because the purity requirements are so demanding, manufacturers and distributors use closed, (to the outside environment) dedicated equipment, vessels, and dispensing systems to control the quality.

Users of DEF need to know there are three (3) simple factors that must be clearly understood to use it effectively in vehicles. The purity and quality of DEF is critical for vehicle performance. The supply chain determines the purity. DEF requires proper storage and handling by both the supplier and the user to assure quality.

An overview of the physical properties will help define the steps that must be taken to store the DEF properly. It is a water-based urea solution. It is NOT flammable and it is not considered a hazardous chemical by the regulatory authorities. It is much less dangerous to handle when compared to gasoline or diesel fuel.

Much of the care given to handling DEF is designed to protect the SCR system in the vehicle. Some key aspects for handling DEF include – maintaining the purity of the DEF, do not allow outside contaminants to contact the DEF fluid, including dirt, grease or any foreign matter. Do not alter the fluid content. Do not add water or any other materials or chemicals to DEF. Use the recommended materials of construction for storing, handling, and dispensing DEF. Use dedicated equipment for DEF; do not share parts or equipment with diesel fuel or other materials or liquid.

The American Petroleum Institute (API) has created a certification and quality maintenance program. Suppliers can apply for a license based on their quality systems and sample submission. Suppliers undergo random sampling from the marketplace and compliance enforcement to maintain the right to use the mark. It provides the market with an independent assurance for the quality of DEF.

Care must be taken at both cold and warm temperature extremes to protect the DEF and the systems that handle it. Ideally, DEF should be stored between 15- 80 degrees Fahrenheit (° F) When the average ambient temperature can fall outside that range some protective measures are recommended.

As a water solution, DEF freezes at 11° F. While this is a much colder temperature than water, it does present some challenges to handle when operating in some climates and during the winter season. Handling considerations are necessary for the storage and dispensing systems. These usually involve a low wattage heater of the ambient area near the storage tank, or gentle heating of the fluid with a low surface temperature heater or insulation. Using similar methods for heating smaller volume pipe lines and dispensers that can freeze more quickly is more challenging from a system design perspective.

The systems on the vehicles have been designed to function in low temperature ambient environments. Electric heaters and use of warm engine coolant are used in the vehicle systems to prevent and control freezing of the DEF.

From a product quality and integrity standpoint, if DEF is frozen, it will return to a good quality, homogeneous solution of 32.5% urea. There will be no separation, stratification or crystallization. Solidified DEF has a approximately 7% larger volume than liquid DEF and may cause a fully filled, closed container to burst. This effect does present some design consideration in piping and equipment.

On the warm side, DEF is stable at the warmer temperatures in most climates. The DEF fluid will exhibit a natural tendency to break down or dissociate to a small degree (in the parts per million range) at all temperatures and as a function of time. This effect is greater at higher temperatures. At temperatures below 80 deg F, this effect, called hydrolysis, has a minimal influence on the functional properties of the DEF. The fluid might exhibit a slight pungent odor of ammonia. At the temperatures in the vehicle exhaust system, there is a complete and desirable breakdown to release the ammonia needed to react with the engine exhaust NOx gases. There is a relationship between how much the DEF will undergo hydrolysis. It is linear with time at constant temperature and logarithmic at constant time versus temperature. It is important to note that the temperatures noted here are average temperatures that the fluid sees, not peak temperatures; meaning 24 hrs/day, 7 days/week. Heating or storing DEF at 85 degrees F. does not ruin it or inhibit its performance in the vehicle. A limit was placed by the ISO Specifications Committee on how much of this effect would be tolerated in an effort to offer personnel handling the DEF the ability to do so without a personnel respiratory protection requirement from the ammonia vapors. This limit is set by measuring the fluid alkalinity which is done by a simple chemical titration test. The limit is 2000 ppm of alkalinity, measured as ammonia. The limit effectively defines a product shelf life for DEF. When DEF is stored at an average temperature between the recommended (average) temperature range of 15 – 80° F, the shelf life will be between 1-3 years. This relationship is shown below in Figure 4:

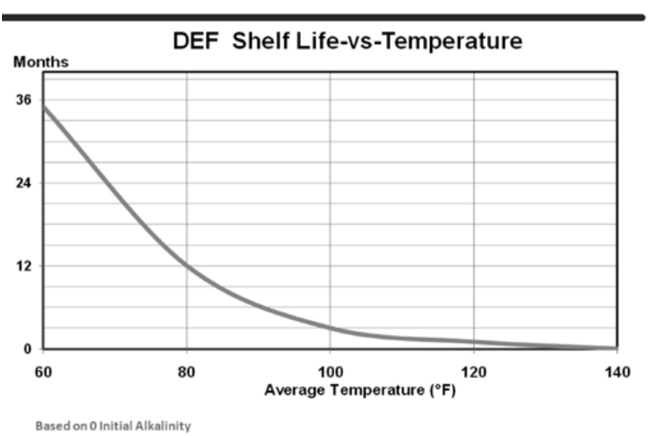


Figure 4

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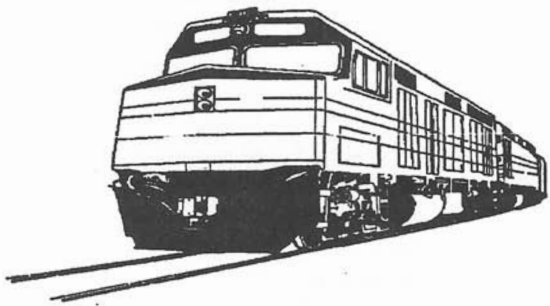

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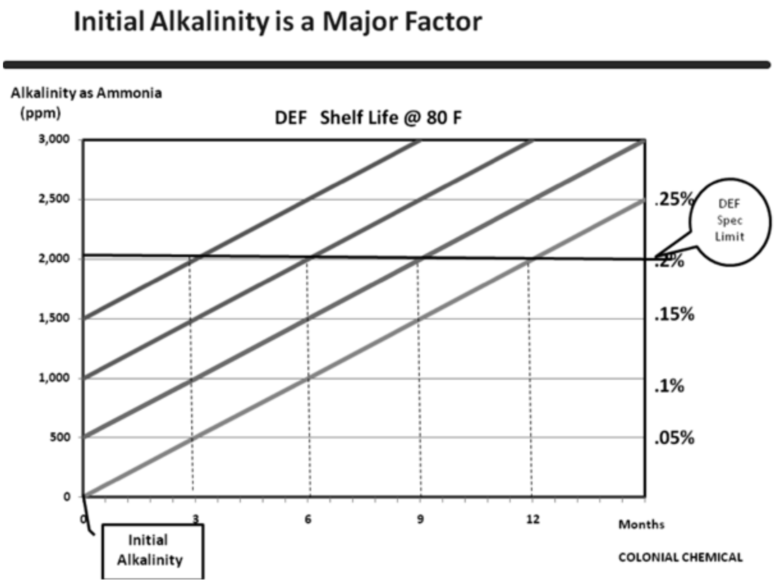

Figure 5

There are some differences and ability to control the alkalinity among suppliers at the urea plant producing the DEF. It is a function of the plant design and manufacturing process capability. Some DEF is better than others in this respect. So this effect can cause different brands of DEF to have different initial alkalinity and this is compounded by the storage conditions, the shelf life can be much shorter than the figures noted above. Figure 5 looks at the extreme example of storing DEF of varying initial alkalinity at a relatively hot 80 deg. F. Again, it will not affect the DEF performance in the vehicle to any great degree or harm the vehicle's SCR system, it will make handling it a bit more uncomfortable for personnel.

The key to managing the DEF alkalinity change is to store the DEF in a cool dry place, out of direct sunlight. Use air conditioning or fans in extreme temperature environments such as in the desert or southern climates during the summer months.

Alkalinity will become less of an issue as the markets grow and there is faster product turnover. Alkalinity is the ONLY specification or property that can change naturally with time. All of the other specifications will not change if DEF is stored within the recommended guidelines using proper materials, the system is closed from the outside environment, and NOT adding anything foreign to it (including water).

There are warning signs for "bad" DEF. A simple visual inspection of the appearance tells a lot. It should be clear and water white. There should be no color to the solution, no solid particles floating in it or on the bottom, no haziness or translucence, no layers of fluids or separation. It is good practice to keep a retain sample of the DEF received; a good supplier will have a retain sample from what was shipped also. A refractometer is a hand held device that can be used to quickly measure the assay of DEF by measuring the refractive index (RI) of the solution. Each chemical and concentration has a unique refractive index. While the device will work well in pure urea, it can lead to false positive tests if contaminants are present. Refractometers should only be used in conjunction with other tests such as a visual inspection to assure that DEF is of proper quality.

If a user of DEF suspects that they have a "bad batch", they should immediately consult with their supplier for advice. Samples will need to be analyzed by more sophisticated means to determine if the DEF is within specification. The user should absolutely NOT attempt to "fix it" or "recondition it".

Using the proper materials of construction to store, handle and dispense DEF is very important to preserve the quality of the fluid. The Figure 6 shows the recommended and not-recommended materials. Stainless steels and high density polyethylene are the best choices. One should avoid using the traditional favorite materials used for diesel and other fuel. DEF is slightly or moderately corrosive to these materials. DEF will dissolve the metals into solution. This could cause damage to the catalyst in the SCR system.

It is not expected that interactions with engine oils, hydraulic fluids or fu-

Fluid Storage & Dispensing – Materials of Construction

Materials compatible with DEF

To avoid contamination of DEF and to resist corrosion all containers, valves, fittings, gaskets, hoses, etc, all materials in direct contact with DEF must be compatible with DEF.

Examples of materials recommended for use with DEF are:

a) Stainless steel 304 (S30400), 304L (S30403), 316 (S31600)
b) Titanium
c) Polyethylene, free of additives
d) Epoxy resins
e) Polytetrafluoroethylene (PTFE), free of additives

The following is a partial list of incompatible materials:

a) Carbon steels, zinc coated carbon steels, mild iron
b) Non ferrous metals and alloys (copper, zinc, lead)
c) Solders containing lead, silver, zinc or copper
d) Aluminum, aluminum alloys
e) Magnesium, magnesium alloys

Figure 6

els will cause chemical reactions. The mixture will separate into water and organic layers. The impact on engine components is unknown. It is recommended that a mixture like this be removed from the vehicle and disposed of according to local regulations and supplier recommendations.

DEF is a non-hazardous substance, so spill clean-up and disposal does not require any special precautions. In general, DEF storage areas should be contained or diked as a good general practice. DEF that is spilled can be absorbed with an inert material such as sand or saw dust, placed into a suitable container and disposed of according to local regulations. Product that has exceeded its shelf life expiration or is out of specification should be disposed of in a similar manner, or by working with the DEF supplier to help with the disposition. Spilling DEF into waterways should be avoided as it will act as a nutrient and could cause algae bloom.

The on-highway truck fluid dispensing equipment industry has provided dispensing technology to prevent mis-filling on the vehicle. DEF is added to a SEPARATE TANK, that is generally much smaller than the fuel tank, has a blue cap and a smaller nozzle opening, 19 mm. DEF is not a diesel fuel additive and is NOT added to diesel fuel. The diesel fuel nozzle will not fit into the DEF tank. Additionally, dispenser suppliers and vehicle OEM's have created a magnetic ring that is on the tip of the dispenser nozzle and the neck of the vehicle's DEF tank. The magnets need to couple to complete a control circuit and for actual dispensing to begin.

From a personnel exposure standpoint, DEF is an aqueous solution of urea. Urea is a normal product of protein metabolism in the human body and is present in the body. It is not considered a hazardous material. There are no known significant effects or critical hazards when recommended handling practices are followed. DEF may cause minor skin irritation on some individuals. Putting DEF in your eyes or ingesting it is not recommended. DEF may have a slight pungent ammonia odor depending on the age/quality/storage temperature the fluid has seen. Ventilation aspects should be considered during facility design to avoid closed spaces. Personnel respiratory protection is not required during routine dispensing. Rubber gloves and safety glasses would be good practice for those who handle it constantly.

DEF will act as a nutrient or fertilizer if discharged to the environment. Stop a leak if this action can be done without risk. Avoid discharge into waterways or down sewers as DEF will act as a nutrient. Inform the relevant authorities if the product has caused environmental pollution.

As a material hazard, the MHIS code for DEF is 0,0,0. It is non-flammable, non-toxic and stable under the recommended storage and use conditions. Avoid contact with oxidizing materials such as acids, alkalis and hypochlorite bleach. DEF will not hazardously decompose or polymerize.

Installing a DEF storage and handling system will often involve permitting from local regulators, including Fire Marshalls. The National Fire

Prevention Association has reviewed the relevant documents and have concluded that the liquid handling components in a DEF system do not have to be listed in accordance with NFPA 30A, electrical systems do not have to be designed for hazardous (classified) locations, IF situated adjacent to diesel-only dispensing units. Systems for DEF have to be designed for hazardous locations only if they are located adjacent to gasoline dispensing units. This is because of the requirement for the gasoline, not the DEF.

The physical and chemical properties of DEF create some interesting design challenges when engineering systems to store and dispense DEF. DEF has excellent creeping abilities due to its high capillary action. It can manage to creep thru seemingly tight threaded connections and emerge from the threads. With air contact, the DEF will dry out and the resulting urea crystals effloresce, creating a white powder. To mitigate this effect from a design standpoint, threaded joints in piping/equipment should generally be avoided. Recommended practice would be to use joints with sealing surfaces such as membranes, gaskets or o-rings. Electrical wires need special sealing at their connectors. The ability of DEF to crystallize and creep when exposed to air means that special care must be given to the DEF/air mixing area, such as tank vents.

DEF freezes and expands approximately 7% as it goes through the freezing process. Components must be purged at shutdown or designed to accommodate the expansion. Components must be heated to ensure thawing and function at low temperatures. Designs should avoid trapping DEF between two fixed volumes such as between two valves where it could freeze.

DEF is slightly alkaline and has a very high conductivity, about 50 times greater than water. Only materials that are recommended by the ISO Specification and the Petroleum Equipment Institute RP1100 guide to use and practice for DEF should be used. Extensive compatibility testing is required for all other materials. It is incumbent on the equipment supplier proposing use of unlisted materials to prove that the new material is compatible with DEF. Avoiding combinations of different metals in direct contact should also be avoided to prevent electrochemical corrosion cell formation.

The DEF supply industry has grown rapidly and DEF is now available in most areas of the US. Infrastructure to store and dispense bulk quantities is being installed as more vehicles are added to the SCR census. The railroad industry should expect that a DEF supply model similar to diesel fuel could be readily developed. Typical installations will involve terminal supply from large above ground or underground bulk tanks. On-location supply will also be available. DEF will be available to railroad customers by railcar or by tanker truck to the fueling site. The special dispensers adapted for DEF are available from the traditional fuel dispenser suppliers. The design details are important, it is essential to work with a competent partner. Your supplier should be willing to help.

Conclusion

In conclusion, the introduction of new SCR technology on diesel vehicles to meet new lower NOx standards has been a success. Diesel Exhaust Fluid is a new fluid used with this technology to accomplish the low emissions. DEF is a new unique fluid to the industry and requires some special considerations for storage and handling. It is different than what has traditionally been used for fuels, but not that difficult. Successful use of DEF requires having storage and dispensing systems made of the proper materials, add thermal protection to control the fluid temperature between 15 – 80 degrees F, and fill it with API certified Diesel Exhaust Fluid.

Choose a supplier who has a defined quality system and is knowledgeable on the technical aspects and can bring this support where and when necessary.

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List of Abbreviations

API American Petroleum Institute

AUS-32 Name give to Diesel Exhaust Fluid by the Society of Automotive Engineers

DEF Diesel Exhaust Fluid

EGR Exhaust Gas Recirculation

H-D Heavy Duty

ISO International Standards Organization

NOx Oxides of Nitrogen (generic term for nitrogen containing pollutant gases in engine exhaust)

OEM's Original Equipment Manufacturer (Truck)

SAE Society of Automotive engineers

SCR Selective Catalytic Reduction

US United States

Locomotive Biodiesel Fuel Update

Prepared by:
Steven G. Fritz, P.E. – Southwest Research Institute

ABSTRACT

Biodiesel is "coming to a railroad near you." In fact, many railroads are likely already using biodiesel fuel blended into conventional diesel fuel, and may not even know it. One of the reasons for this is that in 2008, sufficient performance data became available to change the ASTM D975 diesel fuel specification to permit the blending of up to 5 percent biodiesel (B5) as a fungible, unlabeled component in the traditional diesel fuel pool. The neat biodiesel (B100) blend stock, however, must meet specifications in ASTM D6751 for pure biodiesel (B100) prior to blending, and the B5 blend must continue to meet all the parameters of D975. Other significant changes in the market, such as the adoption of Ultra Low Sulfur Diesel Fuel (ULSD) and new federal renewable fuel standards, are also driving increased incorporation of biodiesel into D975 diesel fuel by large petroleum refiners and blenders. This paper is intended to be an update to the 2005 biodiesel paper presented by the FL&E Committee [Bowen 2005], and will present information on government requirements for increased biodiesel production and use, included in the Energy Independence and Security Act of 2007 (EISA). This paper also covers the activities of the SAE Technical Committee 7 (Fuels) "Biodiesel in Railroad Applications" Subcommittee, and gives highlights of two studies looking at locomotive exhaust emissions when operating on biodiesel fuel blends.

2005 LMOA Paper

In 2005, the Locomotive Maintenance Officers Association (LMOA) Fuel, Lube, and Environment (FL&E) Committee presented a biodiesel paper that covered much of the background information on biodiesel and provides a high-level overview of the advantages and disadvantages of biodiesel fuel currently available in North America from a railroad perspective. Topics covered included cold flow characteristics, compatibility with existing diesel fuel, volumetric energy content, stability, and microbial growth [Bowen 2005]. This 2011 update paper is intended to provide supplemental information to the 2005 LMOA paper.

Another source of biodiesel information related to the railroad industry is a 2008 Alternative Fuels report prepared by Southwest Research Institute® (SwRI®) for the Association of American Railroads (AAR) Research Committee [Majeweski 2008]. The biodiesel section of this report covered biodiesel properties and specifications, commercial and economic factors, environmental impacts, and engine performance. The AAR report highlighted the lack of significant data on locomotive engines.

Biodiesel Specifications

The ASTM Biodiesel Task Force began efforts to set biodiesel specifications in 1993. After 8 years of testing and data to address questions from the petroleum and engine manufacturing industries, ASTM D6751 Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels was approved by ASTM in 2001 for blending up to 20 percent biodiesel with No. 1 or No. 2 diesel fuels falling under ASTM D975. For No. 1 and No. 2 petrodiesel fuel, if No. 1 meets its grade requirements in D975 and the No. 2 meets its grade requirement in D975 the two may be blended together and used without re-analysis. There is no separate, individual specification for blends of No. 1 and No. 2 petrodiesel. ASTM D6751 was developed using that same thinking—if B100 meets D6751 and diesel fuel meets D975, then up to 20 percent biodiesel could be used and there was no separate specification for the finished blend of biodiesel with petrodiesel. The most important quality control functions were conducted at the parent fuel level, with downstream testing only needed to check for contamination or aging in storage or transport.

Engine companies and users, however, demanded ASTM specifications for the finished blended fuel since that is what the engine sees and that is what users purchase. The ASTM Biodiesel Task Force set out to develop the data needed to secure finished blended fuel specifications for up to B20. The same philosophy as No. 1 and No. 2 petrodiesel was maintained, i.e. if B100 meets D6751 and the diesel fuel meets D975 the two may be blended without the need for re-analysis and quality control was primarily performed at the parent fuel level. In order to secure passage of the finished blended fuel specification, and to maintain the philosophy that if the parent fuels met specification no additional analysis were needed on the finished blend, several important improvements were made to D6751 between 2001 and 2008:

- The acid number parameter was lowered from 0.8 to 0.5 mg KOH/gm maximum
- A stability parameter of 3 hours minimum induction period was added
- A cold soak filtration value of 360 seconds maximum was added (200 seconds maximum for cold weather applications)

In addition, a significant amount of additional in-use experience in on-highway and smaller nonroad diesel engines occurred and was better documented for technical aspects over longer periods of time, and additional engine emissions testing was performed. The improvements to D6751, and the additional experience from the field in a variety of applications, were necessary in order for a successful balloting to occur at ASTM for finished biodiesel blends. As with the current D975 spec-

ification, the biodiesel blended fuel specifications are based on the parameters necessary to ensure proper engine performance and are not based on the exact refinery feedstock or process utilized to get to those parameters.

In 2008, ASTM balloted and approved specifications for finished biodiesel blends covering blends up to B5 (ASTM D975) and blends containing between B6 and B20 (ASTM D7467) for both on and off road applications. In all cases, the B100 must meet the improved D6751 standard prior to blending.

With B100 meeting D6751 as a prerequisite, data showed blending of up to B5 did not substantially affect the finished properties of petrodiesel and no additional parameters were needed for blends of B5 and lower. The specification values for normal D975 petrodiesel could also be utilized for B5 and lower as a fungible component of petrodiesel without change, and are valid regardless of biodiesel content so long as the content remains at B5 or lower. Therefore, the D975 diesel fuel specification was revised to allow use of up to five volume percent biodiesel fuel (B5), without any special reporting or disclosure requirements. The neat biodiesel (B100) blend stock, however, must meet specifications in ASTM D6751.

For blends between 6 percent and 20 percent biodiesel, it was determined the T-90 specification should be raised by 5°C compared to D975, and that it would be useful to include two additional specifications (acid number of 0.3 mg KOH/gm maximum, stability induction period of 6 hours minimum) compared to ASTM D975. Similar to D975, the D7467 values were protective of engines as long as the biodiesel content remains between 6 percent and 20 percent and the exact level of biodiesel is not important to the engine—so long as it remains between 6 percent and 20 percent, the B100 met D6751, and the blended fuel meets D7467. ASTM D7467 was, therefore, also adopted in 2008 as a new specification covering diesel fuel with biodiesel blends between six percent (B6) and twenty percent (B20) for both on-highway and non-road use. For further information on biodiesel specifications and background, please see the 8th edition of Significance of Tests For Petroleum Products, ASTM International. (Salvatore 2010).

EISA Requirements

The Energy Independence and Security Act of 2007 (EISA 2007) expanded the Renewable Fuels Standard previously adopted in 2005 (RFS1) and for the first time specifically provided for a renewable fuel component with U.S. diesel fuel, and which is applicable to off-road applications such as locomotives. Congress tasked the U.S. EPA with adopting percentage-based renewable fuel standards, which resulted in the EISA 2007, or the Renewable Fuel Standard 2 (RFS2) program as it is now commonly called. Based on the EPA RFS2, each refiner, importer and non-oxygenate blender of gasoline and/or diesel is obligated to use a minimum volume of renewable fuel, and must ensure its use as a transportation fuel.

The RFS greatly expands the total volume of all renewable fuels to be used in the market by up to 36 billion gallons per year in 2022.

In February 2010, EPA finalized the RFS2 program. This program set out specific volume requirements for various fuels that make up the 36 billion gallons required by 2022:

- Traditional Corn Based Ethanol: 15 billion
- Bio-mass based Diesel: 1 billion
- Advanced Biofuel, not differentiated: 4 billion
- Cellulosic Biofuel: 16 billion

Advanced Biofuel was defined as a fuel that reduces carbon emissions over 50 percent from a 2005 petrodiesel baseline, and the final RFS2 program certified biodiesel as an 'advanced biofuel' providing a minimum of 50% carbon reduction. Pertinent to the rail industry, the final RFS2 required the use of 1.150 billion gallons of Biomass-based Diesel for the combined two-year period of 2009 and 2010, increasing to 1 billion gallons each year starting in 2012. From 2012 through 2022, a minimum of 1 billion gallons per year must be used domestically, and the Administrator of the EPA is given authority to increase the minimum volume requirement. To qualify as Biomass-based Diesel, the fuel must also reduce greenhouse gas (GHG) emissions by at least 50 percent from a 2005 petroleum diesel baseline. Currently biodiesel is the only commercial fuel to meet the Advanced Biofuel requirement category, as well as fitting in the Biomass-based diesel requirement. The NBB anticipates 800 million gallons in 2011 and 1 billion plus for 2012 and beyond.

What this means for the railroad industry is that biodiesel (B5) is entering into railroad diesel fuel in increasing concentrations over the next few years. Concentrations of biodiesel are likely to be less than the 5 percent maximum limit permitted in ASTM D975 in these early years, but higher concentrations up to B5 are expected to be routine in future years.

Screening for Presence of Biodiesel in Railroad Diesel Fuel

A Mid Infrared Spectroscopy method can be used to quantify the amount of FAME (fatty acid methyl ester) biodiesel in diesel fuel, as specified in ASTM D7371 and EN 14078, for concentrations ranging from 1 to 20 volume percent. This FTIR (Fourier Transform Infrared) method uses a wave number of 1745 ± 5 cm-1 for quantification of the ester peak, and biodiesel content can be measured down to 0.05 volume percent. As a cautionary note, this absorbance relates to ester functionality, and non-biodiesel ester-based components found in some conventional diesel additive packages can also be contributors, although concentrations of traditional additive packages are usually 0.5 percent or lower.

One Western railroad began looking for the presence of biodiesel in their routine diesel fuel quality analyses starting in 2010. A commercially available analyzer was used that reportedly provides results comparable to the ASTM D7371 and EN 14078 methods, with a range of 0 to 20 percent FAME, an accuracy of ± 0.2 percent, and a repeatability of 0.1 percent. Approximately 145 samples were tested starting in June 2010, with most samples coming from the August to December, 2010 time period. The highest level of biodiesel tested was one sample from Iowa dated 9/26/2010, where the fuel sample tested at 1.6 percent biodiesel. Figure 1 summarizes the results of this survey, and shows that small concentrations of biodiesel were present in many of the samples. Although it is not known whether biodiesel was found in these samples due to its use to meet RFS2 or due to its naturally high lubricity (adding 2 percent biodiesel to even the poorest lubricity petrodiesel can bring a fuel back into lubricity specification compliance) or both, but biodiesel is making its way into the fuel used by railroads.

EPA Diesel Fuel Regulations

Non-road diesel fuel was not regulated by EPA until June 2007, when the EPA Non-road diesel fuel regulations included provisions for locomotive and marine diesel fuel nationwide. Effective June 1, 2007, EPA limited the sulfur content of non-road diesel fuel to 500 ppm maximum. They also required the Cetane Number be greater than 40, and the volumetric aromatic content be less than 35 percent.

Effective June 1, 2010, non-road diesel fuel, except Locomotive and Marine, had a 15 ppm Sulfur maximum. Locomotive and marine diesel will be ULSD, 15 ppm max Sulfur starting June 1, 2012. This EPA fuel regulation did not address the issue of biodiesel although it has had the impact of encouraging biodiesel use. This is because biodiesel has naturally high cetane (over 47), zero aromatics, ultra-

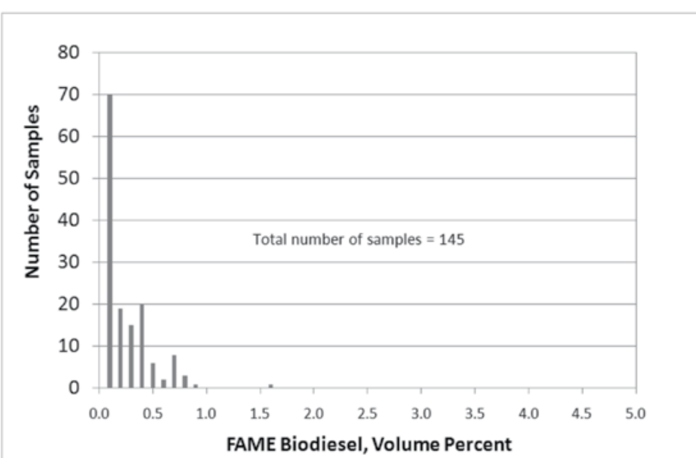

Figure 1. Western Railroad Survey of Biodiesel in Diesel Fuel Samples

low sulfur (most biodiesel is already below 15 ppm sulfur), and ULSD will require the use of a lubricity additive or incorporation of low levels of biodiesel to meet the lubricity needs of existing and new diesel engines.

CARB Diesel Fuel Regulations

The California Air Resources Board (CARB) established regulations for intrastate locomotives and marine harbor craft effective January 1, 2007. The CARB regulations state all intrastate locomotives (i.e., those effectively captive within the State) must use CARB diesel fuel, which specifies less than 15 ppm maximum Sulfur, 10 percent maximum aromatics, a minimum lubricity standard, and meeting the ASTM D975 performance specification. Alternatively, refiners can certify diesel as a CARB fuel with aromatic levels higher than 10 percent if such a fuel has equivalent emissions using CARB specified testing protocols. Most commercial petrodiesel in California is currently of the 'emissions equivalent' variety as very little has less than 10 percent or less aromatics.

Biodiesel is naturally zero aromatic, ultra low sulfur, and high lubricity, so B20 and lower blends are also legal in California if the finished blends meet their ASTM performance specifications (D975 for blends of B5 and lower, D7467 for blends between B6 and B20, B100 must meet D6751 prior to blending). Higher levels do not currently have an approved ASTM performance specifications, and are considered legal if used under the waiver program of the California Division of Weights and Measures for fuels that do not have approved ASTM specifications.

CARB is in the process of evaluating emission impact on all new diesel fuels, including biodiesel, and determining if there is a need for additional testing or certification for biodiesel blends in California for on/off road diesel fuel. It is assumed any changes needed for California for on/off road diesel engines will also apply equally to railroad applications, but this needs to be confirmed, possibly through the SAE committee discussed below.

SAE Technical Committee 7 (Fuels) Biodiesel in Railroad Applications Subcommittee

A forum titled "Biodiesel in Railroad Applications" was held at the SAE International World Congress in April 2010, in Detroit, Michigan. The subject of forum was to consider the impact of renewable fuel mandates on railroad applications. Presentations covered topics such as EPA exhaust emission standards for locomotives, regulations and mandates, railroad fuel logistics, railroad concerns, OEM statements, low temperature operability, fuel stability, emissions lessons from automotive experience and current and past demonstration programs. One of the outcomes of this forum was to establish a Subcommittee under the SAE umbrella of SAE Technical Committee 7 (Fuels). The Charter of the Subcommittee is to "Identify issues of concern to the railroads, engine and equipment manufacturers, and fuel suppliers upon introduction of biodiesel blends in the diesel pool in North America. Formulate and propose a practical path forward."

The subcommittee voted to concentrate on three major focus areas:

- Exhaust Emissions
- Engine Durability
- Fuel Handling and Material Compatibility

The Subcommittee held a workshop in January 2011 in Richmond, California. Highlights from that meeting included:

- There was general agreement that, based on experience in other applications and the advent of B5 incorporation into the ASTM D975 specification, use of up to 5 percent biodiesel in regular diesel as specified by ASTM D975 using biodiesel blend stock meeting ASTM D6751 is acceptable and unavoidable in most cases. However, continued monitoring of potential long term impacts specific to railroads are warranted.
- Many performance issues common to other diesel engine applications have been addressed through the ASTM process but that information has not been provided to the railroad/locomotive community. The National Biodiesel Board (NBB) is working toward having a practical information package prepared and will provide it to the members of the Subcommittee. The NBB is also assembling data from existing locomotive biodiesel test programs for subcommittee members' consideration, knowing that in many cases such programs have produced limited information.
- The LMOA Fuel, Lube, and Environment Committee was to make recommendations for the scope of any future locomotive biodiesel testing to ensure that durability is addressed, and that the number of units and test duration are sufficient.

One of the major issues for railroads regarding the use of biodiesel fuels is uncertainty about the impact on exhaust emissions. One significant concern for railroads involves changes in the exhaust emissions of a locomotive due to the use of biodiesel blends that could result in the locomotive being noncompliant with applicable EPA regulations. At issue is an increase in NOX emissions that has been observed in some instances with use of biodiesel fuel. A definitive answer to this question may require significant additional testing since changes in NOx with low biodiesel blends can fall within normal test to test variability of petrodiesel alone, but the general consensus is B5 is a legal fuel, and can be used in locomotives without concerns as to EPA compliance. The point is made that any in-use exhaust emissions compliance testing will be done with EPA certification diesel fuel, which does not include biodiesel.

Another NOX-related issue involving biodiesel has to do with calculating railroad NOX inventories, and the impact on fleet average agreements. As an example, Union Pacific Railroad and BNSF Railway have entered into a voluntary Memorandum of Understanding (MOU) with the California Air Resources Board to limit NOX emissions from locomotives operating in the SCAQMD (South Coast Air Quality Management District) to an average of 5.5 g/hp-hr (Tier 2) starting in 2010 (often referred to as the South Coast Fleet Average Agreement) [MOU - 1998]. At issue is whether the current specification efforts by CARB for other on/off road uses will allow the continued use of current emissions values for biodiesel blends, or whether railroads will need to adjust the NOX emission factors used to calculate their fleet-average NOX emissions by some yet-to-be-determined factor due to the use of biodiesel fuel. At this time, this remains an open issue.

Concerns over potential NOX increases are a particular concern for Canadian Railroads that operate under a MOU that caps NOX emissions. Estimated NOX emissions are near the capped limit and increases cannot be tolerated [Dunn 2003].

Biodiesel Effects on Locomotive Exhaust Emissions

The impact of biodiesel fuel in relatively small-bore, high-speed on-highway diesel truck engines has been extensively studied over the last 15 years, and the effects are well documented [EPA 2002]. Figure 2 shows some average trends on emissions for pre-1998 high-speed diesel engines from an EPA survey for different blend levels of biodiesel. On average, PM, CO and THC emissions decrease while NOX emissions increased in proportion to biodiesel in the fuel, although there were relatively few data points below B20.

Very limited data exists on biodiesel effects in larger-bore, medium-speed locomotive engines, and results from smaller, newer engines using different EPA testing protocols may not apply to locomotive engines. One area of concern raised by the SAE Subcommittee was some of the locomotive biodiesel studies that have been per-

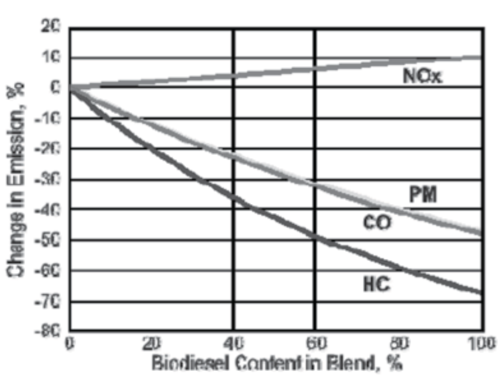

Figure 2. Average Impact of Biodiesel on Emissions for High-Speed On-Highway Diesel Engines

formed recently or are currently underway include exhaust emissions testing not performed using EPA's Federal Test Procedure (FTP) for locomotives, as specified in Title 40 of the US Code of Federal Regulations (CFR), Part 92. Inspection of test reports from some of these studies indicates clear deviation from EPA FTP requirements. This can result in confusion over biodiesel fuel effects in locomotives, especially for reported PM and visible smoke emissions, due to the fact that PM results are highly dependent on sampling methodology and engine technology. In EPA on-road testing, biodiesel reduced the solid carbon fraction of particulate matter (this is the portion of particulate most visible to the naked eye) but does not affect the lubricating oil contribution to particulate. If the carbon portion of the total particulate matter is small, which is the case for many older locomotives, there may be a visible smoke reduction but not a corresponding reduction in measured particulate matter. Members of the SAE Subcommittee stressed any future locomotive biodiesel studies that include exhaust emissions testing be performed "by the book" using the EPA FTP for locomotives.

There are two known locomotive biodiesel research studies in the literature where EPA FTP testing was used. Both were performed by SwRI. One study performed in 2002 for the US Department of Energy's National Renewable Energy Laboratory (NREL) investigated biodiesel in a 2,000 HP EMD GP38 locomotive [Fritz 2002]. In this study, fuel consumption and exhaust emission tests were performed on a pre-Tier 0 EMD GP38-2 locomotive when operating on four different fuels; a 2-D diesel fuel meeting U.S. EPA locomotive certification test specifications, a diesel fuel meeting the requirements of the California Air Resources Board (CARB), a blend of 20 percent bio-fuel into the EPA locomotive certification fuel (B20), and a second blend of 20 percent bio-fuel with the CARB diesel (C20). Regulated emission measurements of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOX), particulate (PM), and smoke opacity were made using U.S. EPA locomotive test procedures specified in 40 CFR Part 92. Test results from this study are summarized in Table 1 and showed a 5 to 6 percent increase in average NOX emissions with B20 fuel compared to EPA locomotive certification diesel. A lack of measured PM response with any of the test fuels was attributed to the fact that PM emissions from this two-stroke EMD engine are largely lubricating-oil derived. Long term durability and reliability associated with the routine use of biodiesel were not addressed in this study.

In 2010, GE published results of a biodiesel study performed in cooperation with BNSF Railway for a Tier 2, 4,400 HP, GE ES44DC locomotive [Osborne 2011]. Low Sulfur Diesel (LSD) with sulfur concentration of 391 ppm was used for baseline testing and also as the base fuel for fuel blends of 2 percent, 10 percent, and 20 percent biodiesel by volume. Neat biodiesel for this program was supplied by Cargill, and was derived from soybean.

Table 1. Pre-Tier 0 EMD GP38 Biodiesel Test Results Summary

Fuel	HC	CO	NO_x	PM
EPA Line-Haul Duty-Cycle Weighted Emissions, g/hp-hr [a]				
EPA Loco. Cert. Diesel	0.64	5.4	12.4	0.46
CARB diesel	0.64	4.3	12.3	0.46
B20	0.64	4.5	13.1	0.50
C20	0.64	4.0	12.8	0.48
EPA Switch Duty-Cycle Weighted Emissions, g/hp-hr [a]				
EPA Loco. Cert. Diesel	0.82	2.2	12.8	0.38
CARB diesel	0.76	1.8	12.5	0.34
B20	0.78	2.0	13.5	0.37
C20	0.73	1.8	13.1	0.37

[a] Average of three runs on each fuel.

Table 2. GE ES44DC Biodiesel Study Test Fuel Properties

Determinations	ASTM Test Method	LSD	B2	B10	B20	B100
API Gravity @ 15.6 °C Specific gravity Density (kg/m³)	D4052	35.9 0.845 842.6	35.8 0.846 843.1	35.2 0.849 846.3	34.4 0.853 850.3	28.3 0.886 883.0
Viscosity @ 40°C (cSt)	D445	2.4	2.4	2.5	2.7	4.2
Sulfur (Wt%)	D2622	0.0391	ND	ND	ND	ND
Sulfur (ppm)	D5453	ND	372.9	336.4	298.5	0.8
Cetane Index	D4737	45.2	45.9	46.6	46.8	52.8
Cetane Number	D613	43.3	42.7	44.1	45.0	52.3
Heat of Combustion Gross (kJ/kg) Net (kJ/kg) Gross (kJ/L) Net (kJ/L)	D4809	 45,666 42,842 38,477 36,097	 45,568 42,770 38,417 36,057	 44,952 42,168 38,041 35,685	 44,324 41,571 37,690 35,350	 39,877 37,344 35,213 32,976
wt% Carbon wt% Hydrogen wt% Oxygen by difference Hydrogen/Carbon Oxygen/Carbon	D5291	86.67 13.31 0.02 1.83 0.00	85.84 13.19 0.97 1.83 0.01	85.10 13.12 1.78 1.84 0.02	83.92 12.97 3.11 1.84 0.03	76.76 11.94 11.30 1.85 0.11
Cloud Point (°C)	D2500	-20	-17	-17	-14	1
Hydrocarbon Type Aromatics (%) Olefins (%) Saturates (%)	D1319	 24.9 1.9 73.2	 26.8 2.9 70.3	 29.0 4.4 66.6	 36.7 3.3 60	 ND ND ND
Flash Point (°C)	D93-80	61	54	55	58	163
Free Glycerin (wt%) Total Glycerin (wt%) Monoglyceride (wt%) Diglyceride (wt%) Triglyceride (wt%)	D6584	ND	ND	ND	ND	<0.002 0.153 0.515 0.098 0.042
Distillation	D1160 % Recovered IBP 10 50 90 FBP	 Temp. °C 188 211 263 331 374	 Temp. °C 182 206 256 332 364	 Temp. °C 173 200 262 342 362	 Temp. °C 179 207 290 358 371	 Temp. °C 326 345 348 351 371

Notes:
ND – not determined

B2, B10, B20, and B100 refer to the fuel blends that contain 2 percent, 10 percent, 20 percent, and 100 percent biodiesel by volume, respectively. The blending of these test fuels was completed at SwRI. A summary of the final fuel properties from this test program is presented in Table 2.

Gaseous and particulate emissions were sampled using the EPA locomotive FTP, per 40 CFR Part 92. Regulated brake-specific gaseous emissions weighted over the EPA Line-Haul and Switch Locomotive Duty Cycles are summarized in Figure 3 for the Line-Haul Cycle, and in Figure 4 for Switch Cycle. The change in NOx duty cycle composite values for B2, B10, and B20 as compared to the LSD base fuel was not greater than one standard deviation of the triplicate certification diesel fuel tests, and was likely within the range of normal test to test variation. However, B100 NOx increases of 15 percent over the Line-Haul Cycle and 11 percent over the Switch Cycle were well outside expected test to test variation.

Changes in HC emissions relative to the base fuel were within normal test measurement variation except for B100, where HC was reduced by 21 percent and 24 percent over the Line-Haul and Switch cycles, respectively. B20 and B100 showed significant CO reductions of 17 percent and 34 percent, respectively, over the Line-Haul cycle, and 11 percent and 35 percent over the Switch cycle. CO changes for B2 and B10 were within the expected test measurement variability. These test results suggest biodiesel induced HC and CO reductions are substantially smaller for this Tier 2 four-cycle medium speed GE locomotive engine than for high speed heavy duty highway engines, in which extensive testing has shown on average much greater HC and CO reductions than what is observed in the current work.

The sulfate portion of diesel PM is derived from sulfur contained in the

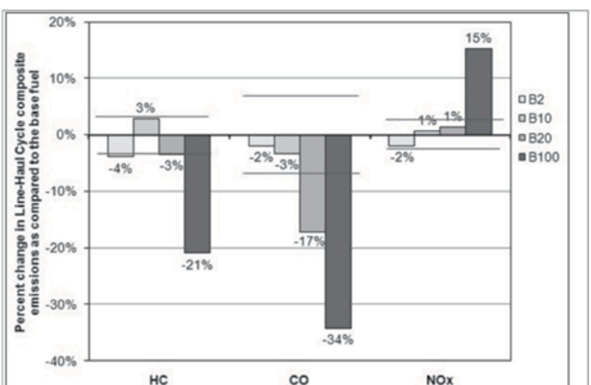

Figure 3. Percent change in GE ES44DC Line-Haul Cycle composite gaseous emissions for each biodiesel blend as compared to LSD base fuel. The horizontal lines indicate hypothetical change in emissions associated with ±1Stdev of the Line-Haul Cycle composite results from triplicate tests with EPA certification fuel.

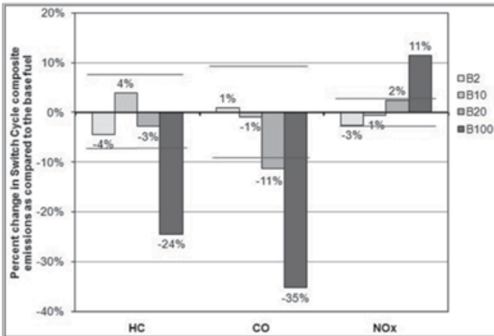

Figure 4. Percent change in GE ES44DC Switch Cycle composite gaseous emissions for each biodiesel blend as compared to LSD base Fuel. The horizontal lines indicate hypothetical change in emissions associated with ±1Stdev of the Switch Cycle composite results from triplicate tests with EPA certification fuel.

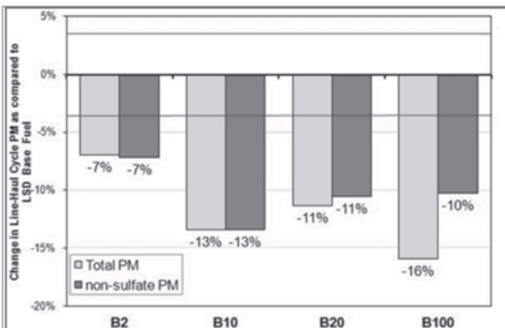

Figure 5. Percent change in Line-Haul Cycle total PM and non-sulfate PM emissions for each biodiesel blend as compared to LSD Base Fuel. The horizontal lines indicate hypothetical change in emissions associated with ±1Stdev of Line-Haul Cycle composite PM results from triplicate control tests with EPA

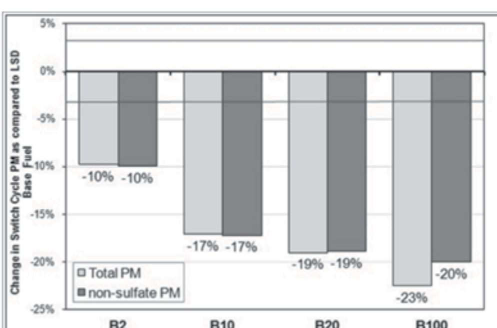

Figure 6. Percent change in Switch Cycle total PM and non-sulfate PM emissions for each biodiesel blend as compared to LSD Base Fuel. The horizontal lines indicate hypothetical change in emissions associated with ±1Stdev of Switch Cycle composite PM results from triplicate control tests with EPA certification

fuel and lubricant. The amount of sulfur present in the fuel can affect PM significantly. Biodiesel inherently does not have significant amounts of sulfur and blending increased amounts of biodiesel with a fuel that contains higher levels of sulfur results in a downward trend in-fuel sulfur concentration. To isolate the effects of biodiesel on PM from the effects of fuel sulfur concentration, non-sulfate PM values were determined for each test and are shown along with the total PM in Figure 5 for the Line-Haul Cycle and in Figure 6 for the Switch Cycle. Sulfate measurements from the LSD test were linearly applied to PM results from each of the other fuel blends based on the sulfur concentration of each blend. From the non-sulfate PM results it can be observed that PM reduction over the line-haul cycle did not increase with increasing amounts of biodiesel beyond the B10 fuel blend. However, Switch Cycle PM reduction increased for each step in biodiesel fuel blend concentration. In both cases the bulk of the PM reduction benefit was realized at the B10 level, followed by diminished returns in PM reduction with increasing levels of biodiesel. PM reduction benefits were observed even for B2, where PM reductions relative to LSD of 7% and 10% over the Line-Haul and Switch Cycle occurred.

Smoke test results for each test fuel are shown in Figure 7. Under FTP regulations, PM is measured gravimetrically, and smoke measured optically. Although changes in smoke opacity do not necessarily correlate to gravimetrically determined PM, especially as it pertains to fine and ultrafine PM, smoke opacity can be an indicator for soot PM. As such, the downward trend in smoke opacity with increasing amounts of biodiesel may be another indication of the lower soot levels associated with biodiesel in this testing.

The change in brake specific volumetric fuel consumption for each biodiesel blend as compared to the LSD base fuel is shown in Figure 8. Volumetric fuel consumption increased about 1 percent for B2 and B10 over the Line-Haul cycle, and increased 2 per-

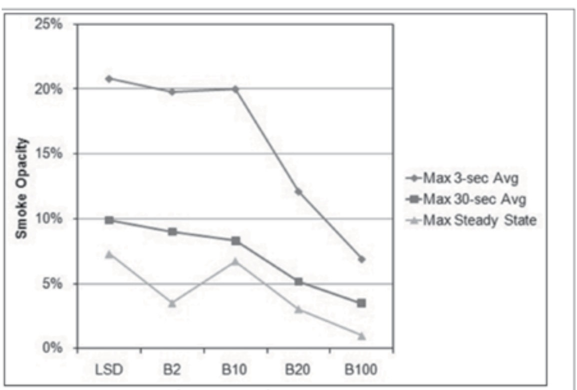

Figure 7. GE ES44DC Smoke Test Results

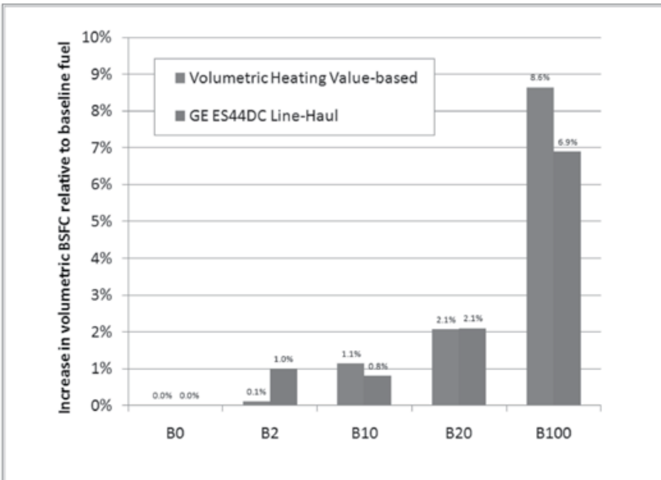

Figure 8. Increase in observed volumetric BSFC relative to the LSD base fuel for each biodiesel blend over the EPA Line-Haul Cycle.

cent and 7 percent for B20 and B100, respectively. The fuel energy density penalty associated with biodiesel has negative implications for locomotives, such as the need for more frequent fueling and possibly reduced maximum power. In this study, the ES44DC locomotive controls were able to compensate for the lower energy density test fuels, hitting target power during all of the fuels testing except at Notch 8 during B100 testing, where fuel injection became volume limited and the resulting brake power was approximately 2 percent below target.

Conclusions

Due to the EISA 2007 (RFS2) requirements, biodiesel "is coming to a railroad near you." Over the next few years, B5 is expected to be routinely found in locomotive fuel throughout the country.

Next Steps

As diesel fuel prices and required RFS2 volumes continue to increase, there will likely be pressure to increase the biodiesel blend concentration beyond the current ASTM D975 limit of 5 percent. The SAE Technical Committee 7 (Fuels) Biodiesel in Railroad Applications Subcommittee is expected to follow developments in this area, and participate in planning research programs investigating durability, fuel handling, and exhaust emissions for the railroad industry. The LMOA FL&E Committee has several representatives on the SAE Subcommittee, and will provide future updates to the LMOA membership.

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List of Abbreviations

AAR	Association of American Railroads
ASTM	ASTM International (formerly American Society for Testing and Materials)
BNSF	BNSF Railway Company
Bx	B5, B20, etc. Biodiesel blended at x percent into diesel fuel
C20	CARB diesel fuel blended with 20 volume percent biodiesel
CARB	California Air Resources Board
CFR	U.S. Code of Federal Regulations
CO	Carbon Monoxide
EMD	Electro Motive Diesel
EISA	Energy Independence and Security Act of 2007
EPA	U.S. Environmental Protection Agency
FAME	fatty acid methyl ester
FL&E	Fuel, Lube, and Environment Committee
FTIR	Fourier Transform Infrared (spectroscopy)
FTP	Federal Test Procedure
GE	General Electric Company
GHG	greenhouse gas
HC	hydrocarbons
HP	horsepower
LMOA	Locomotive Maintenance Officers Association
LSD	low sulfur diesel (< 500 ppm S)
MOU	Memorandum of Understanding
NBB	National Biodiesel Board
NOX	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
PM	particulate matter
RFS	Renewable Fuel Standard, created under the Energy Policy Act of 2005
RFS2	2007 expansion of the Revised Renewable Fuel Standard in 2007 by EISA
SAE	SAE International (formerly the Society of Automotive Engineers)
SCAQMD	South Coast Air Quality Management District
SwRI®	Southwest Research Institute®
THC	total hydrocarbons
ULSD	ultra low sulfur diesel (< 15 ppm S)

Report on the Committee on Diesel Electrical Maintenance

Monday, September 19, 2011

1:45 P.M.

Chairman

Mike Drylie
Director-Electrical Systems
CSX Transportation
Jacksonville, FL

Vice Chairman

Tom Nudds
Quality Manager
ZTR Control Systems
London, Ontario

Commitee Members

D. Becker	Design Engr	Electro Motive Diesels, Inc	LaGrange, IL
D. Bruss	Engr- New Cap. Equipt.	Amtrak	Philadelphia, PA
B. Hathaway	Consultant		Port Orange, FL
M. Henry	Mgr-Loco. Engrg I	Union Pacific RR	Omaha, NE
B. Kirdeikis	Sr. Rel Specialist-Elect	CN RR	Edmonton, Alberta
G. Lozowski	Tech Mgr-RR Products	Morgan AM&T/National	Greenville, SC
B. McCaffrey	Consultant	Transupply, Inc.	Wilmington, DE
K. Mellin	N.E. Sales Manager	Peaker Services, Inc.	Brighton, MI
S. Mueting	Field Service Engineer	Siemens Mobility	Aurora, CO
B. Reynolds	Sales Manager	Amglo Kemlite	Calgary, Alberta
S. Sledge	Electrical Engineer	Norfolk Southern	Atlanta, GA
C. Taylor	Application Specialist	Bach-Simpson	London, Ontario
L. White	Application Specialist	Bach-Simpson	London, Ontario
B. Wilds	Senior Manager-Locos	BNSF Rwy	Fort Worth, TX

Note: Brian Hathaway, Bob Reynolds and Les White are Past Presidents of LMOA
Ron Bartels, 2nd VP of LMOA and Stuart Olson, Regional Executive, are both very active on this committee

PERSONAL HISTORY

Mike Drylie

Director-Electrical Systems
CSX Transportation

Mike Drylie was born in Ohio in 1956. He received an Associates of Arts Degree, General Studies from Kent State University in 1978, a Bachelors of Science, Electrical Engineering, from Ohio State University in 1983, and a Masters of Science Degree, Electrical Engineering from The Air Force Institute of Technology in 1986. Mike is a licensed Professional Engineer in the state of Florida.

Mike served in the US Air Force for many years as an aircraft electrical systems maintainer, radar systems design engineer, and guidance systems engineer on space launch vehicles.

Mike has been with CSX since January 1996. He has been on the mechanical departments engineering staff involved with improvements and modifications to locomotive systems. In recent years Mike has worked on the reduction of 92 day maintenance requirements and reducing locomotive Out of Service time through the use of development of reliable systems not requiring service and regular inspections or maintenance.

Mike is married to Debbie Anderson Drylie and they have 4 children, Tara, Michael Jr, Stephen and James. Mike and Debbie also have 5 grandchildren, Christian, Jacob, Edward, Sarah and James.

Mike's hobbies include going to the gym, visiting grandchildren, reading, various computer, number, and logic games.

The Diesel Electrical Maintenance Committee would like to extend their sincere gratitude to CSX and Amglo Kemlite for hosting a committee meeting in Belleair, Florida on February 18, 2011. Special thanks to Bob Reynolds, Past-President, who coordinated the meeting.

The committee toured the CSX facility in Winston, Florida and Amglo's shop in Largo, Florida. Thanks to both the CSX and Amglo Kemlite for their support and hospitality.

Efficiency and Maintenance Aspects of the New Amtrak Electric Locomotive ACS 64

Prepared by:
Michael Latour, Siemens Mobility

Fig. 1: Amtrak Cities Sprinter ACS 64

Amtrak Electric Locomotives – Status

The National Railroad Passenger Corporation (Amtrak) is presently operating 68 electric locomotives (54 AEM 7 and 15 HHP-8) on its only electrified line between Boston and Washington, the so called North East Corridor (NEC). These units are now up to 33 years old and the number of technical issues that jeopardize on time, reliable service is increasing. Reliability problems resulting from seasonal temperature variations as well as complex, maintenance intensive designs contribute to a number of reliability, availability and maintenance issues. Hence, the only effective solution to meet the required level of service is the replacement of the fleet.

The Amtrak Cities Sprinter ACS 64 Project

In mid 2009, Amtrak called for proposals for up to 70 new electric locomotives. The key requirements for these new units for operation on the NEC and the Pennsylvania Keystone corridor are: 1) conformity with all FRA regulations, 2) 'Buy American' compliance, 3) excellent acceleration to avoid slowing down Amtrak's Acela high speed trains and 4) the capability to haul 18 Amfleet coaches at a sustained speed of 125mph. As well, Amtrak expected to benefit from reduced life cycle costs, higher efficiency, dramatically improved reliability and availability and a customer appealing design.

To allow higher throughput on the heavily frequented NEC and meet FRA Positive Train Control (PTC) requirements, these units will be the first equipped with an Advanced Civil Speed Enforcement System, (ACSES) that provides both Speed Enforcement and Positive Train Stop capability in one integrated package.

Fig. 2: Table Technical Main Data

Mechanical Design and Carbody

The unit will fit the latest version of Amtrak Clearance Diagram 05-1355 Rev E, which enables it to be operated all over the United States. It is an integral monocoque wide body, double cab design suited for push pull operation without turning.

The locomotive body is comprised of the four major elements underframe, side walls, operator cabs and three detachable roof sections, one of which includes a roof access hatch. The carbody is designed to allow compression forces up 800,000 lbs of buff load, applied in the line of the coupler draft gear. It is equipped with an AAR F-type coupler with push back mechanism to achieve full anti-climber engagement and a Crash Energy Management (CEM) system that provides enhanced safety for the crews.

Engine Room Layout

Contrary to Amtrak's existing electric locomotive designs, the new locomotive will have a middle isle instead of a side isle arrangement. This has the advantage that more space is available for the installation of components, maintenance access is significantly improved and the components thermal influence on each other is minimized thus enabling better ventilation.

This standard engine room layout is similar to the European EuroSprinter locomotive and most of the electrical components are identical.

To further enhance reliability, all wiring, cabling and piping is routed inside the locomotive carbody under the middle aisle, protected from environmental influences.

Fig. 3: Interior Appointments and Layout

Electrical Design

The locomotive is designed for the three catenary power supply voltages, 25 kV AC 60 Hz, 12.5 kV 60 Hz, and 12 kV 25 Hz.

A rotary switch in the transformer casing connects the transformer windings for the required configuration. The electrical main diagram (Fig. 4) displays one half of the locomotive traction control system. The total traction control system consists of two cubicles, arranged in the middle of the locomotive on each side of the isle, each containing the components for one bogie as well as the Head End Power (HEP) supply.

Each converter cubicle has two water cooled input inverters (4 Quadrant Choppers) and three water cooled output inverters with IGBT power semi conductors. The two input inverters feed one common DC link for all the output inverters of one cubicle. Two of these output inverters are connected to the two AC traction motors of one bogie in a single axle control configuration and each DC link supplies power to one HEP inverter thus ensuring 100% redundancy for the HEP supply.

Fig. 4: Main Circuit Diagram

Traction and locomotive control is performed by the Siemens SIBAS® 32 control system. The core of the control system is the Multi-Vehicle-Bus (MVB), interfacing with the subsystem control computers, all the I/O stations as well as the Man-Machine-Interfaces such as controls and displays on the engineer's console.

New on this locomotive is the installation of the ACSES control unit with Automatic Train - and Positive Train Control. Locomotives connected in multiple unit and passenger coaches interface via the standard 27pin MU-trainlines.

As an option, a Wired Train Bus (WTB) interface for all train communications will be installed.

Fig. 5: Control Circuit Block Diagram

Driver's Cab

The locomotive has two identical operator cabs, one at each end of the unit. The cab can be accessed via hinged doors from both sides of the locomotive or through the engine room. In case of an accident, emergency egress is possible via a hatch in the roof. Both cabs have one driver and one conductor seat as well as a flap seat mounted to the rear wall. A roof mounted air-conditioning/heater unit with air temperature control as well as additional heaters in the console ensure convenient cab climate. The design is supported and approved by the Brotherhood of Engineers Drivers Cab Committee.

The ergonomically designed operator's consol is an adaptation from the European Vectron design to combine proven cab control technology with the specific North American requirements. Side opening slide windows with retractable mirrors, a forward and two backward facing cameras to enable the operator to control the platform are installed.

Furthermore, for the convenience of the crew, a thermal cooler/warmer is provided. This is a combination of a fridge and a microwave oven that can be used to either cool or heat beverages.

Fig. 6: Drivers Cab

Truck & Drive System Components

The truck is of the center pin traction pivot type, providing a low centre of gravity connection to the carbody. It has a steel fabricated frame with integrated traction drive connections.

Each wheel has a disc brake unit and on one axle per truck it includes spring applied parking brakes. A small tread brake unit is mounted to clean the wheels. Sanding nozzles on the outer wheels, a flange lubrication system, and hot journal bearing detection are installed as well.

For ease of maintenance, wheelsets and traction motors can be removed independently without disassembling the trucks.

Fig. 7: 3D model drawing of the truck

The traction motor is fully suspended and frame mounted to minimize the unsprung mass of the drive. The connection between motor and gear consists of a hollow shaft axle with pinion drive. Each of the forced air cooled traction motors delivers 1630 kW of power. The gearbox is partially unsprung, mounted to the axle on one end and with reaction rods to the traction motor on the other end. Two multiple disc clutches are installed between motor and gear allowing improved component movement and more resilience.

Safety Concept with Crash Energy Management (CEM)

As already mentioned the locomotive carbody is designed for the 800,000 lbs buff strength and equipped with an anti-climber as required by

Federal regulations and standards. But instead of a 'conventional' mechanical safety concept in accordance with AAR S-580 featuring static elements such as collision and corner posts, the ACS 64 offers a concept with a front end Crash Energy Management (CEM) system that provides better safety to the crews while at the same time has the advantage of lower weight and better reparability after an accident.

After investigation and simulation of various load cases as suggested by American and European standards and FRA, a three stage system consisting of a shear back coupler with energy absorption, an anti-climber, and a deformable crash element was designed to protect the safety cage of the locomotive in head on collisions with other locomotives up to 25 mph as well as in grade crossing accidents with freight trucks up to 68 mph.

Fig. 8: Safety Concept with CEM

Maintenance & Life Cycle Costs

During the tender phase the potential bidders were given the opportunity to visit Amtrak's maintenance facilities in Ivy City and Wilmington. The objective was to educate the suppliers on the issues with the current locomotives and to enable them to draw the right conclusions for a locomotive design with improved efficiency, reliability and availability. In summary, the following design factors were identified by Siemens engineers and were incorporated into the engineering of the new locomotive (only the most critical ones are cited here):

- Heat susceptible components need special and careful consideration,
- An optimized redundancy concept has to be adopted,
- Service proven components to be used to the greatest extent possible,
- Maintenance access to critical components needs to be improved.

The first factor is - among other measures - being mitigated by the layout of the locomotive: The narrow, tightly packed engine room arrangement of the previous designs has been avoided. This allows better ventilation of the components and air flow throughout the locomotive.

The redundancy design of the locomotive contains a 100% redundant HEP and Auxiliary (AUX) inverter system. The locomotive can still complete its mission on time with 100% traction power with one failed HEP inverter or with some potential delay with one or two traction inverters or traction motor failures.

System critical, service proven components such as traction motors, inverters and control system components are derived from systems operating reliably and safely in various numbers and applications all over the world.

It was recognized that the maintenance effort for the existing locomotives was high due to its complex and compact design. To optimize the new electric locomotive for higher improved maintenance, a number of design measures had to be taken:

- Middle aisle arrangement for easier and faster access to all engine room components,

- Modularized machinery compartment equipment with easy removal through removable roof sections,
- Easy access to critical components for ease of maintenance, no interference with wiring, cabling or piping,
- Assembly/disassembly of traction motors and/or of wheelset & axle without disassembling the truck (Fig. 9),
- Brake units, disks can be removed without disassembling the truck (Fig. 10),
- Traction motor temperature sensors are no longer required,
- Revolutions per minute (rpm) sensor are easily accessible,
- Easy access/installation of the roof mounted HVAC (Fig. 5).

Fig. 9: Exchange of Traction Motors or Wheelset/Gear

Fig. 10: Exchange of Brake Components and Dampers

Environmental Aspects

One of the new features of this locomotive for the US market is that it is not equipped with a dynamic brake resistor. Instead, regenerative braking up to 100% rated power is possible, depending on the actual receptiveness of the grid.

With a locomotive that spends on average approximately 8% of its operational time in electrical brake mode, and at today's electrical energy cost of ~10c/kWh, this can sum up to considerable savings of energy, for example:

50% of rated power in 8% of the operational time

➔ 1,8 million kWh of energy saved per unit per year

Another example is the load dependent AUX consumption control:

A voltage-to-frequency control of cooling plant-, inverter- and traction motor blowers improves locomotive efficiency by at least 1%, for example:

1% higher efficiency

➔ 350,000 kWh of energy saved per unit per year

With these assumptions, a fleet of 70 units can thus save the operator over 20 years 3,010,000,000 kWh, or more than $300,000,000 USD in today's money (=inflation not considered).

Summary

This lightweight, modern high speed passenger electric locomotive will be easy on the track and infrastructure and will provide high efficiency through the use of state of the art power semiconductor and microprocessor controls.

With its sophisticated redundancy design, the consistent use of mature subsystems and components as well as the careful consideration of the required maintenance aspects, this unit will not only offer highly efficient and reliable service, but due to the easier and faster maintenance also improve the availability to state of the art values.

Fig. 1: Amtrak Cities Sprinter ACS 64

Wheel Arrangement	Bo'Bo'
Weight	215,537 pounds /97 t
Length	approx. 66.77 ft / 20,320 mm
Width (incl. Handrails)	approx. 9.71 ft / 2,984 mm
Height (without Pantograph)	approx. 14.26 ft / 3,810 mm
Distance between Bogie Centers	approx. 32.5 ft / 9,900 mm
Wheel Diameter (new / worn)	44/41 in / 1,118 / 1,041 mm
Maximum Speed	125 mph / 200 km/h
Catenary Voltage & Frequency	25 /12,5 kV 60 Hz 12 kV 25Hz
Rated Power	6,400 kW max
Head End Power	1,000 kVA
Tractive Effort (max.)	72,000 lbs / 320 kN
Minimum Curve Radius	250 ft / 76 m

Fig. 2: Table technical Main Data

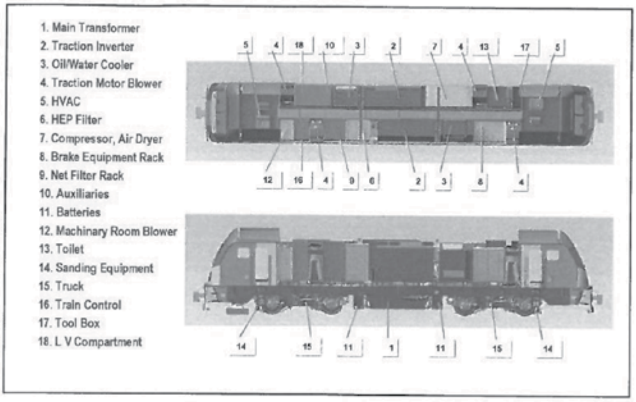

Fig. 3: Interior Appointments and Layout

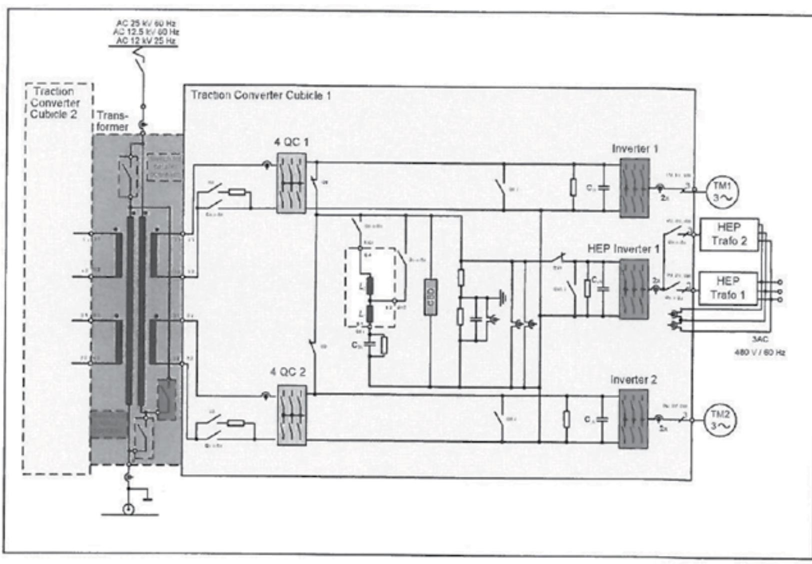

Fig. 4: Main Circuit Diagram

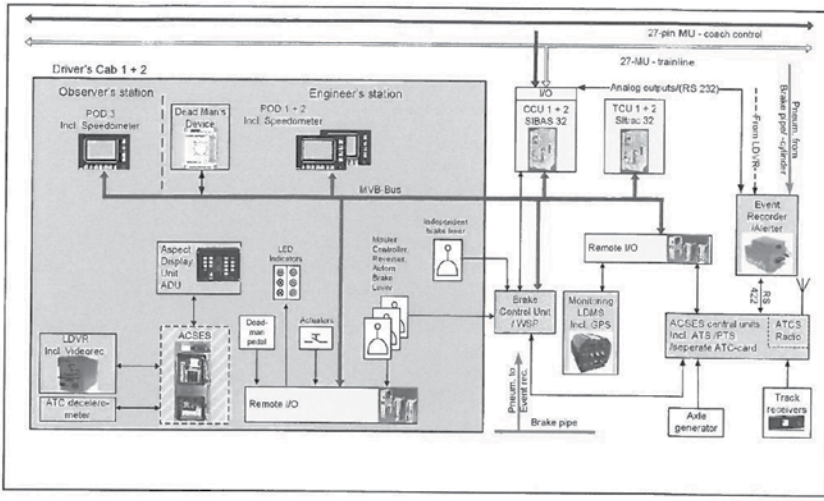

Fig. 5: Control Circuit Block Diagram

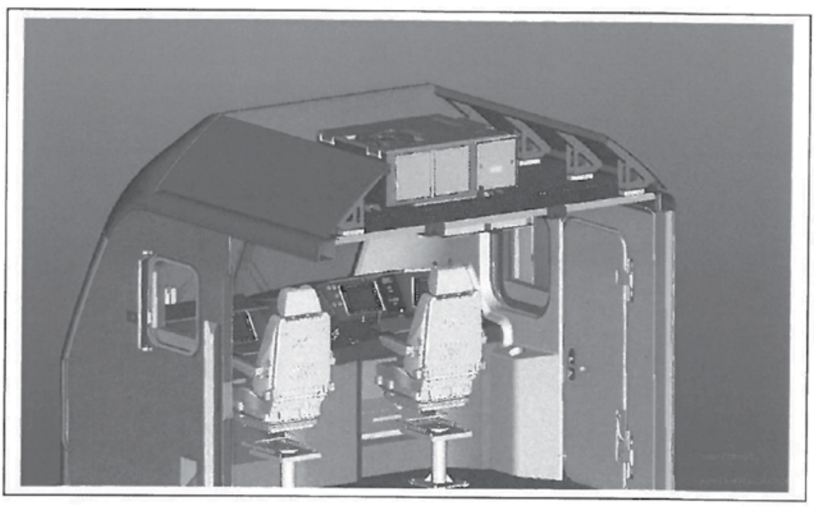

Fig. 6: Drivers Cab

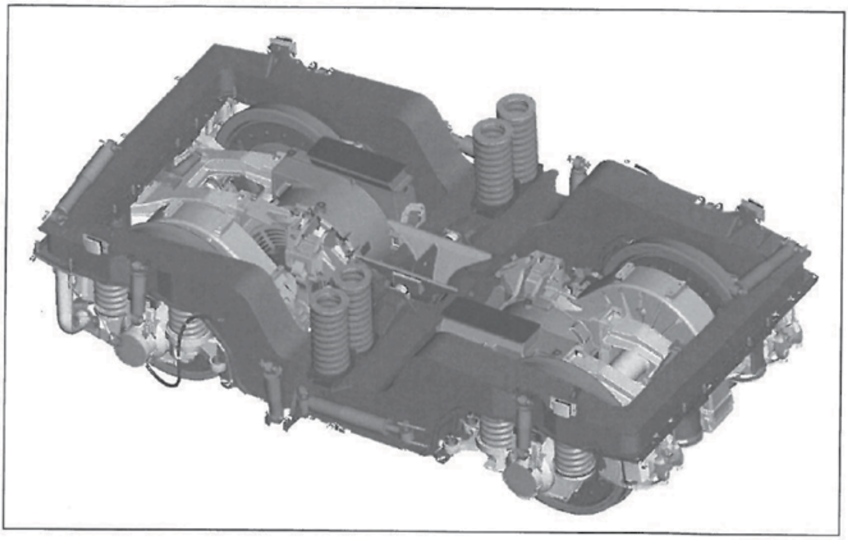

Fig. 7: 3D model drawing of the truck

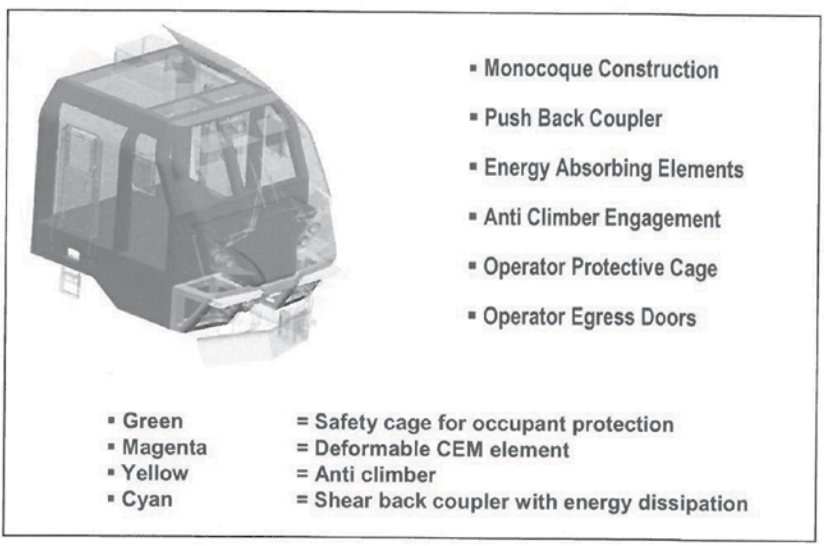

Fig. 8: Safety Concept with CEM

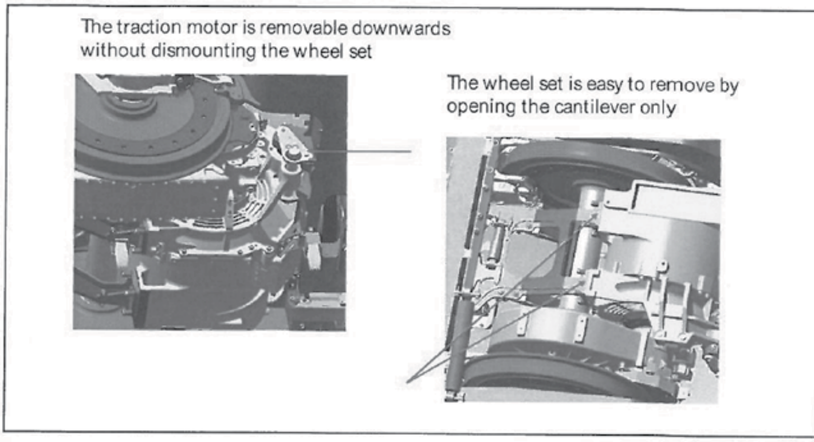

Fig. 9: Exchange of Traction Motors or Wheelset/Gear

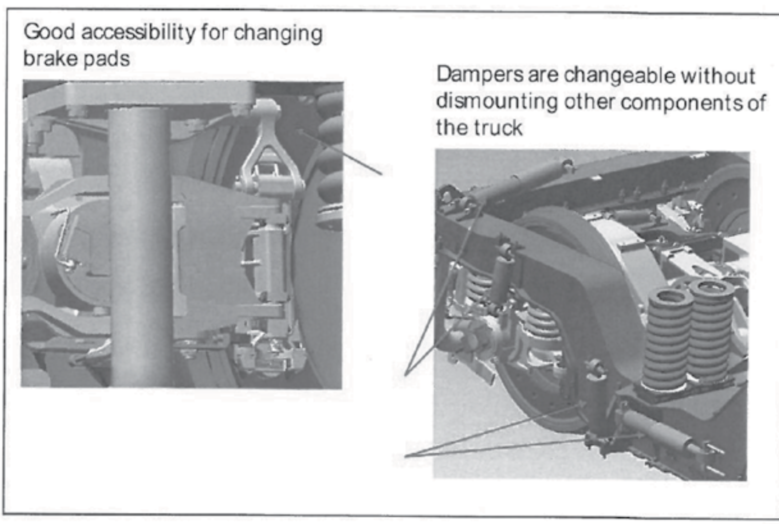

Fig: 10 Exchange of Brake Components & Dampers

Modernizing an Aging Heavy Haul Locomotive Fleet

Prepared by:
Tom Nudds, ZTR Control Systems

Demographics is a powerful tool that can identify challenges and opportunities our future will bring. 20 years ago, Class 1 railroads started to purchase a new horsepower class of locomotives to be used exclusively in their long distance heavy haul and intermodal service. These locomotives were 3,600 horsepower or higher and offered new levels of performance possible only with microprocessor based control technology.

New locomotive purchases are vital to a railroad's future, ensuring the adoption of new technology and higher performance standards. However, there are billions of dollars worth of equity working today that cannot be ignored. The intent of this paper is to present options on how to capitalize on this existing equity and to promote further discussion within our industry on the most promising ways to do this.

Figure 1 shows the make up of Class 1 active heavy haul fleet DC locomotives by major models and in 5 year increments. It started with EMD's 60 series and General Electric's Dash 8's over 20 years ago.

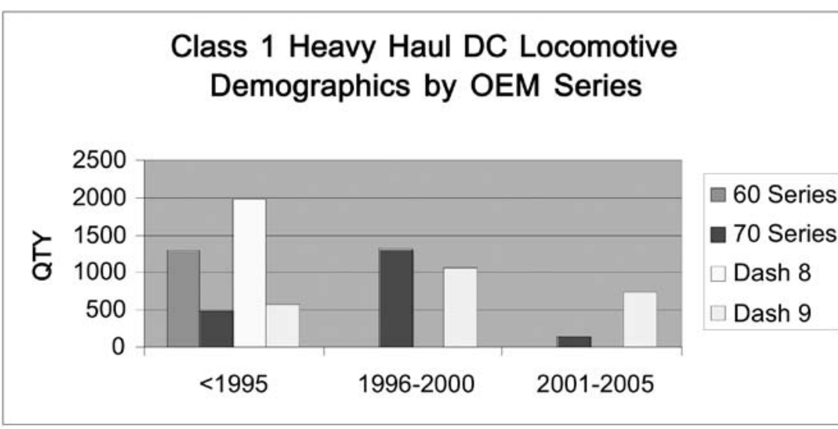

Figure 1

During the next five years, over 4,000 SD60's, SD70's, Dash 8's and Dash 9's will reach or exceed 20 years of service. Five years later, another 2,500 SD70's and Dash 9's will also reach 20 years of service.

There are advantages to re-investing in an existing fleet provided the locomotives' horsepower and tractive effort will integrate into a railroad's present and future heavy haul requirements. Important considerations for wanting to invest in these locomotives include:

- Maintaining their equity;
- Taking advantage of existing spare parts inventory and distribution;
- Continuing to reap the benefits of prior years training invested in your shops and personnel
- Reducing the environmental impact of scrapping

There are two options available when rebuilding a locomotive: One can rebuild in kind or one can modernize. Not to trivialize the effort and cost, rebuilding in kind is the simpler option. There will be issues with component obsolescence and some necessary modifications to comply with modern regulations. But notwithstanding that, the engineering has essentially been done, your assets will continue performing exactly as they have been and the cost benefit analysis is relatively straightforward.

However, today's business pressures require higher performance from your existing assets and that in turn requires a modernization effort. This paper focuses on the challenges and benefits of modernization.

Any modernization effort will take advantage of relevant modern technology to gain significant and measureable benefits. Objectives include:

- Reducing fuel consumption and emissions
- Enhancing your locomotive's performance
- Reducing your operating costs
- Eliminating dependence on obsolete, expensive or otherwise hard to get components
- Improving the reliability and availability of your locomotive

Fuel Consumption and Emissions

The options presented here are locomotive-centric, meaning that these are modifications to the locomotive itself. We will review some technologies that can help you reduce your fuel consumption:

- Automated Engine Stop and Start or AESS
- Auxiliary Power Unit or APU
- Consist management and a new derivative of Consist Management we call Fractional Notch Control

The latest EPA federal rules require that any newly rebuilt locomotive have an AESS installed. The AESS can either be certified under the engine certification kit or it can be separately certified by the EPA. While the actual savings vary with duty cycle and weather conditions, one can conservatively expect an average of 15 gallons per day of reduced fuel consumption for a heavy haul locomotive. That's over 5,400 gallons a year.


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APU's are more expensive to install and maintain, but they do contribute to extended savings by maintaining critical locomotive parameters such as engine water temperature and battery voltage during shutdown. Both APU's and AESS's can be installed and integrated on the same locomotive.

Consist management delivers savings during revenue service. As can be seen in Figure 2, every locomotive develops tractive horsepower at different rates of efficiency in each throttle position. In North America this is measured in horsepower hours per gallon. The highest notches develop this horsepower more efficiently than lower notches.

When an operator with (3) 4,000 horsepower locomotives moves his throttle to notch 5, what he is really saying is he wants 6,000 horsepower. Consist management reduces fuel consumption by controlling each locomotive's throttle position independently of the traditional trainline control and giving the operator his requested 6,000 horsepower the most efficient way possible, in this case possibly by operating the trailing locomotives in notch 3 and the lead locomotive in notch 8. It is extremely dependant on duty cycle. Going up a hill in notch 8 and downhill in dynamic braking will generate no savings. Operating 60 % of the time in notch 4, 5 or 6 can generate 5% savings.

Fractional Notch Control is a newer concept that takes advantage of consist management's ability to control locomotives independently of the trainline signal. When an operator controlling three 4,000 horsepower locomotives moves from N5 to N6 it adds 2,000 horsepower – that's a GP38-2 at

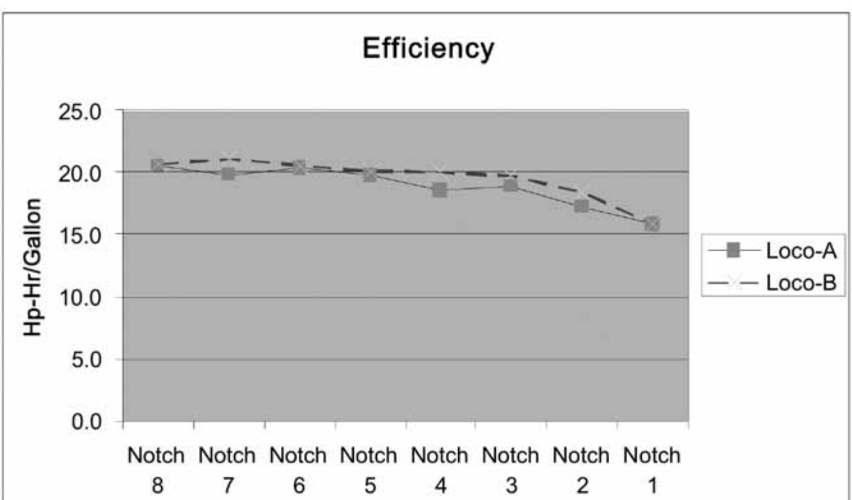


Figure 2

full load. Fractional Notch Control allows the operator to add 1 or 2 smaller increments of horsepower between notches with a dial or pushbutton.

As an example, Figure 3 shows traditional control where all locomotives in a consist operate at the same throttle position as the lead locomotive. If the operator required more horsepower, his only option is to move the throttle handle from Notch 5 to Notch 6, an increase of 2,000 horsepower.

With Fractional Notch Control, the operator can push a button to increment only the trail locomotives as shown in Figure 4. In this example, the consist has added an incremental 1,300 horsepower, which may better suit the operators requirement. The benefit is improved train handling and more fuel efficient speed control. This is a natural fit to enhance trip optimization efforts aggressively pursued today by the Class 1's.

Enhancing Locomotive's Performance

At the end of the day, it's all about getting freight from start to finish safely and we will review the following three basic ways of enhancing locomotive performance:

- Increase tractive effort
- Increase braking effort
- Increase horsepower

Options to improve tractive effort on DC locomotives include:

- Improve the existing excitation / and wheel slip control
- Control power delivered to the traction motors individually
- Convert the locomotive to AC traction
- Separate the traction motor fields from the armature and control them independently

Figure 3

Figure 4

Tractive Effort

Improving existing tractive effort typically involves improvements in wheel slip control using improved sensors or sensing techniques in conjunction with faster, more predictive and effective control algorithms. This approach can be very effective on pre-60 series and pre-dash 8 locomotives, essentially those locomotives that are not microprocessor controlled. The heavy haul locomotives that are targeted in this presentation all have good tractive effort to begin with and we believe this approach would offer incremental improvement at best.

Locomotives equipped with DC traction motors typically control power by controlling the output of the traction alternator. When correcting for a wheelslip, this means that power is reduced to all traction motors – including those that are not slipping. Advancements in power electronics provide an option of controlling the power to each individual traction motor. Figure 5 is a simplified schematic demonstrating how each power electronic device controls current through an individual traction motor. This allows the control system to reduce power to the slipping traction motor only, transferring the excess power to the non-slipping traction motors – ultimately resulting in a measurable tractive effort improvement.

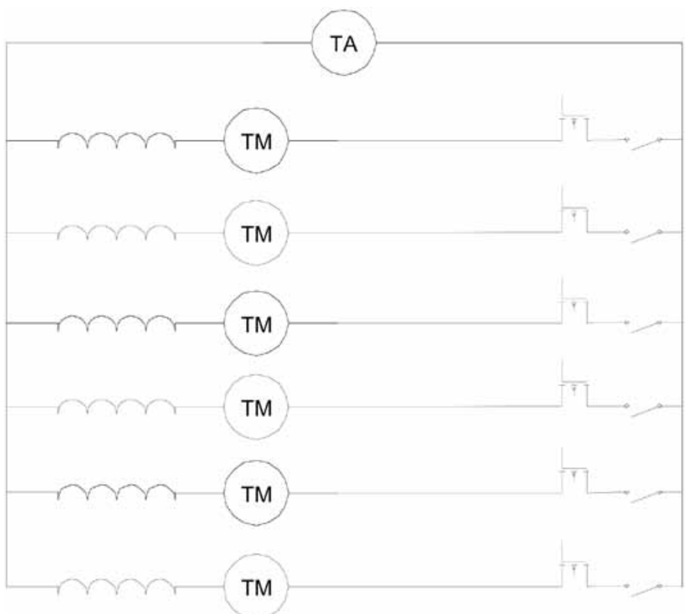


Figure 5

There are several challenges that need to be accounted for when converting a locomotive to individual motor control. Finding the space, re-arranging the contactor configuration and cabling, accounting for higher electrical noise and emissions are just a few. One of the more critical challenges is cooling the power electronics. This is vital to the reliability and robustness of the components. There are 2 prominent methodologies: Liquid cooled and air cooled. Liquid cooled systems require significantly less space and are acoustically quieter. Regrettably, this requires an introduction of another medium onto the locomotive that must be maintained and that may cause a system critical failure if there is any leakage. Air cooled systems are the conventional preference being simpler and as a rule, lower cost to install and maintain. The downside is they are much larger than a liquid cooled system and much louder as well.

Another option to consider when modernizing your DC fleet is convert it to AC traction. As can be seen in Figure 6 below, AC traction offers incredible tractive effort improvements at lower speeds but loses this advantage at higher speeds. This will benefit some operations more than others.

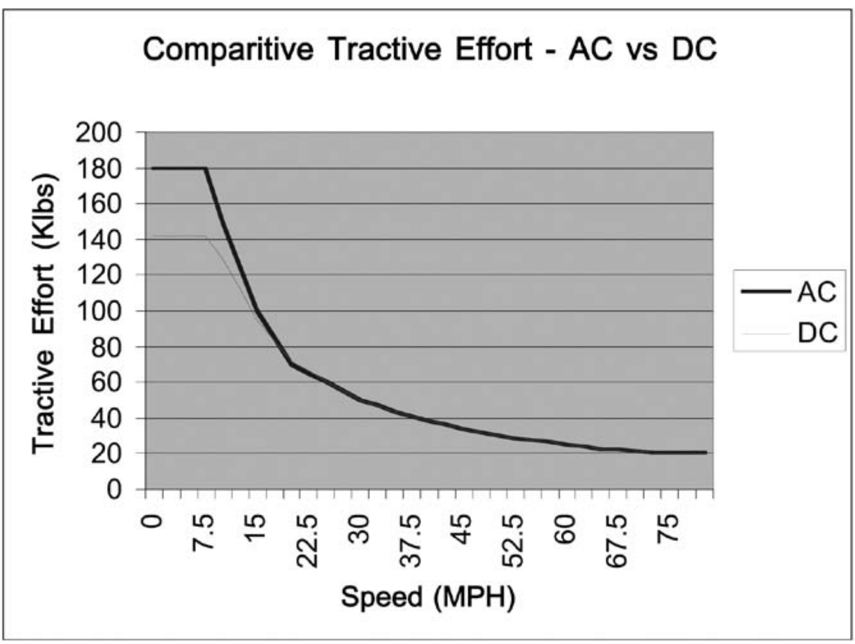


Figure 6

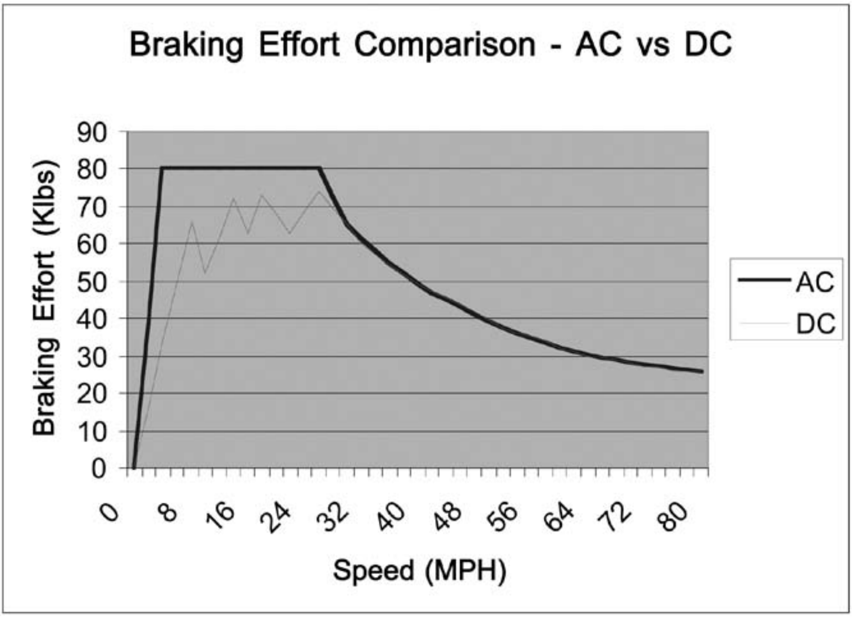


Figure 7

Figure 7 highlights how braking effort performance of AC versus DC is improved, specifically:

- Higher braking effort is achievable
- Braking effort over the extended braking range is not only higher, but smooth and flat
- The effective speed range is significantly extended by achieving full braking effort down to about 4 mph

Other advantages include elimination of dangers of overheating the traction motor and significant reduction in traction motor maintenance.

There are disadvantages and compromises, including: the engineering effort required to redesign the traction system, replacement of the traction alternator and the addition of a high voltage, high power DC bus or link. High value components such as contactors and cabling will need to be removed or replaced. Trucks will need at a minimum some major modification, if not replacement. As noted earlier, traction motors are robust and low maintenance. However, the power electronics needed to run them can be expensive and complex to repair.

Another option to achieving significant tractive effort improvements in your DC fleet is to reconfigure the traction motor windings such that the excitation field coils are permanently connected in series with each other and controlled separately from the armature current. As shown in Figure 8, heavy haul DC traction motors are designed to have their excitation field in series with the armature.

Controlling these fields separately, as shown in Figure 9, is possible today due to advancements of high power electronics and ability to solve and execute complex algorithms.

This configuration changes from controlling power to the traction motor to controlling torque and speed and doing this essentially creates a system with **inherent automatic wheelslip control for each axle!** Wheelslip sensors or control mechanisms are no longer required!

Besides the improvement in adhesion and the elimination of uncontrolled wheelslip, there is an additional benefit that dynamic braking can still be enabled after a traction motor is cut-out.

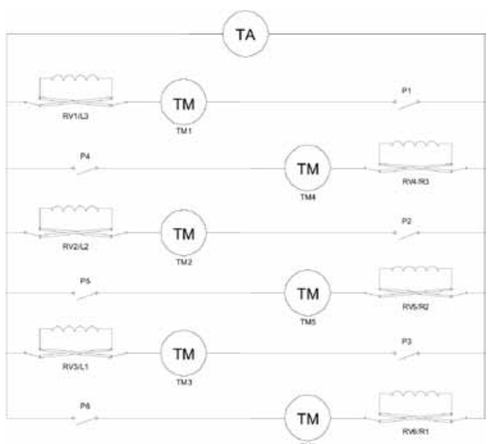


Figure 8

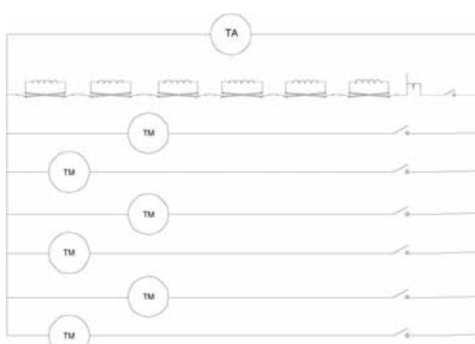


Figure 9

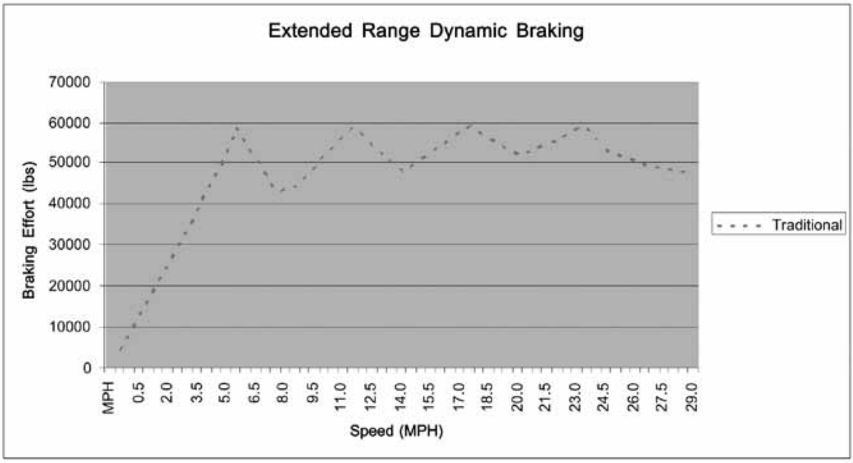


Figure 10

Braking Effort

During dynamic braking, there is a speed where the grid current and field current are both at their maximum values, resulting in the highest available braking effort. As speed diminishes, with field current at its maximum, traction motor armature output drops, resulting in reduced braking effort. Today, this is overcome by shorting out sections of the grid, extending the effective range of dynamic braking but resulting in a saw-tooth shaped braking effort curve as demonstrated in Figure 10.

By replacing the dynamic brake shorting contactors with power electronics, the effective resistance of the DB grids can be reduced in smaller, virtually infinite increments, allowing the maximum braking effort to be sustained in a smooth and consistent manner as demonstrated in Figure 11. The effect is enhanced train control and an increase in overall braking effort.

There is an additional benefit if three power electronic modules are incorporated across each grid paths. As in traditional wheelslip control, when a wheelslide occurs, the control system responds by reducing field current across all of the traction motor fields. By controlling grid resistance in near infinite increments, a wheelslide can now be corrected during the extended range operation by affecting the output of the sliding pair of traction motors. Again, the end result is increased sustainable braking effort.

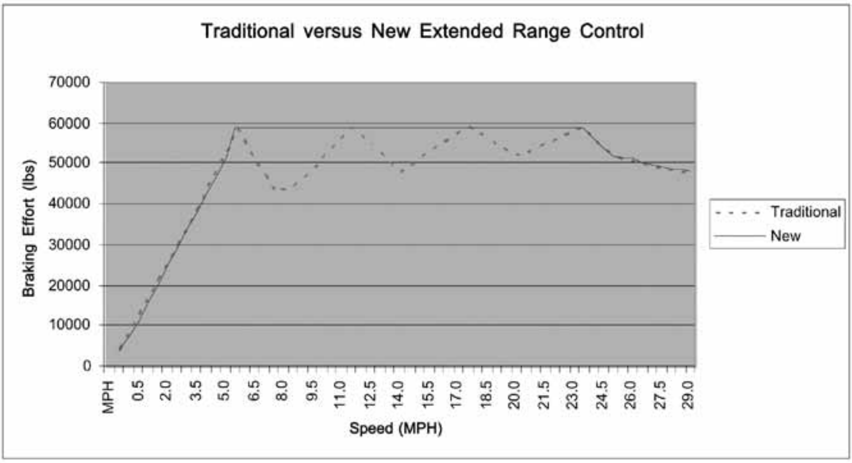


Figure 11

Horsepower

There are limited ways of increasing the horsepower of an existing heavy haul locomotive. One way is to add head end power and to transfer the prime mover's parasitic loads to it. Think of this as a highly specialized multi genset application where compressor and auxiliary generator loads such as battery charging, headlights heating, etc are now handled by head end power exclusively. The equivalent horsepower can now be diverted to tractive effort.

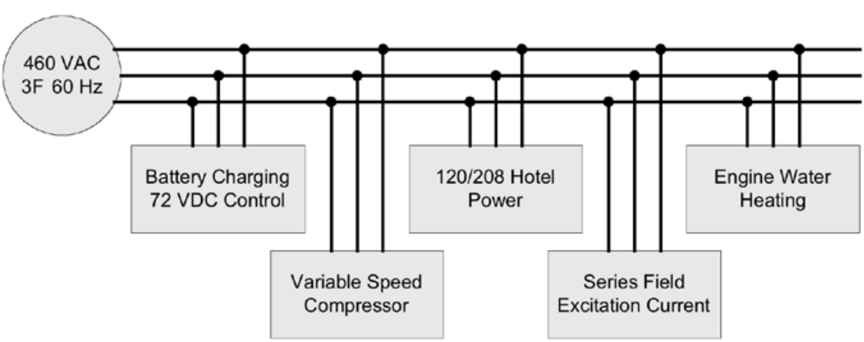


Figure 12

An additional advantage is that the power generated is now commercial grade, allowing the adoption of commercial appliances, equipment and control schemes to the locomotive, reducing costs and taking advantage of improvements in technology driven by other industries.

Depending on the loads transferred and the traction alternator capacity, upwards of 200 horsepower could be added to the locomotive's traction. Additionally, configuring the HEP as an APU to provide engine water heating, battery charging, compressed air and crew comfort during engine shutdown will measurably decrease the locomotive's fuel consumption. One final potential benefit: It is possible that the HEP may contribute to the locomotive's EPA compliance.

Improving Locomotive Utilization

Improved performance has no value if the locomotive is not reliable, unavailable or cannot be found.

One might ask whether the newer technology might be a risk from a quality point of view. The good news is that if chosen carefully, there are control systems available whose technical investment far exceeds what one would normally expect. These massive investments in research and development ultimately ensure that the delivered product provides state of the art technology, open architecture concepts, incredible reliability, support for decades and a path for hardware migration.

Proper diagnostic needs to above all be intuitive, accurate and timely. On board diagnostics need to efficiently identify why an event is happening or not happening and guide the process of fixing a problem. The phrase "a picture is worth a thousand words", hold true: in this case, graphic screens will greatly reduce diagnostic time. Easy and real-time access to the locomotive's key operational parameters as well as historical trends and fault logs add to an effective diagnostic system.

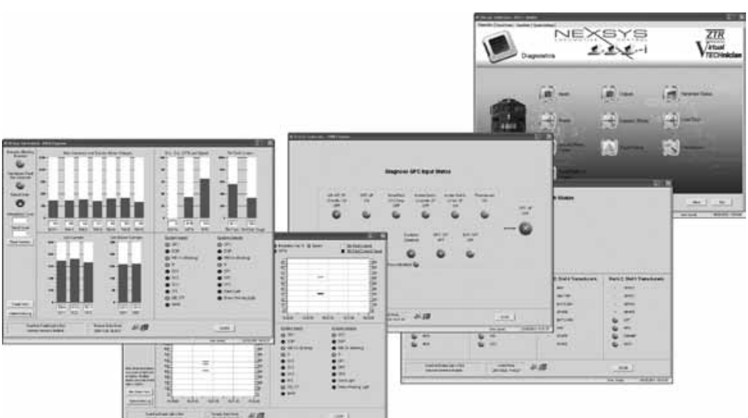


Figure 13

Wireless technology is quickly becoming a business mainstream. Real time access to location, health and operating parameters provides new ways of improving railroad efficiencies. To really implement an effective telematics strategy one needs to move beyond the standard Machine to Machine (M2M) philosophy and implement a solution that integrates with your company's business systems and business processes. In essence you need to extend M2M to truly be an M2B or Machine to Business strategy. An effective M2B strategy will result in bringing the right information to the right people at the right time in the right way.

Critical Success Factors

There are critical success factors to an effective fleet modernization program. The money and resource commitments are significant and these are the go / no-go gauges that will determine a project's viability

The EPA has rules that govern the level of emissions that a rebuilt or remanufactured locomotive can produce. These are clearly spelt out in 40 CFR 1033. If you cannot rebuild an engine to these standards, you cannot move forward. Fortunately, there are solutions and suppliers available for every class of heavy haul locomotive active today.

Engineering is king. Locomotives used to be simpler. But simpler does not fit well into heavy haul operation. Not only does a locomotive have complex subsystems used to put power to the wheels, but must now interface with systems outside of itself. ECP, distributed power, back office integration, crew comfort, to just name a few, all re-

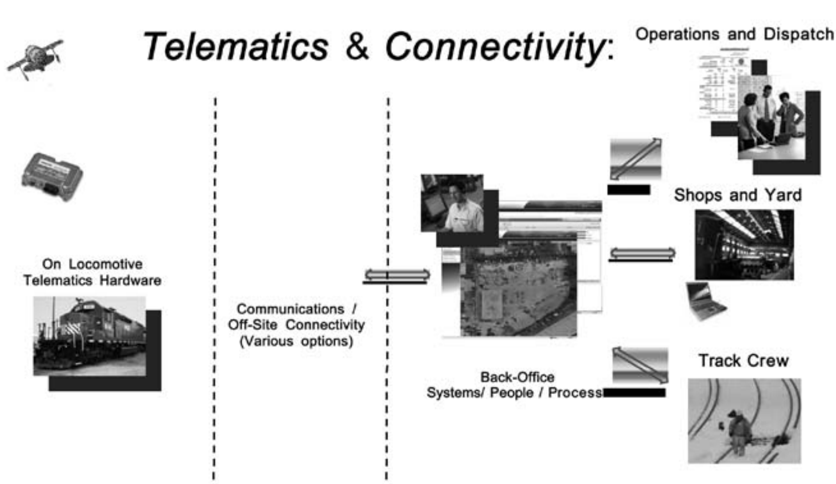


Figure 14

quire several engineering disciplines to ensure that it all works both effectively and efficiently.

Some of these disciplines are more important than others. But to be successful, they will all need to understand what the available technologies are and what benefits, costs and risks are? How they will interact with other systems and how all of this plays into the railroad's needs?

Good project management is the difference between successful execution and wasteful floundering and failure. The effective co-ordination of suppliers, including technology providers, engineering firms and rebuilders, along with railroad's shops and management will result in the timely and cost effective delivery of the desired results.

Finally, there is a need to identify the best of several options and to justify the investment. This can only be done by accurately stating the goals, identifying the benefits, regulatory factors and all costs, both direct and indirect. It is vitally important that all of the resources necessary to complete the project are available. It is important to invest up front in the planning and assessment. Doing this correctly at the beginning can save a lot of money and frustration during the execution of the locomotive overhaul.

The take-aways of this paper are:

- There are billions of dollars in active equity invested in heavy haul locomotives approaching 20 years of service.
- There are several technologies that if applied right, can cost effectively add 1 to 2 decades of life, while improving their performance and return to your railroad
- Understanding the options and quantifying the benefits are keys to proper decision making.
- Execution is vital. Ensure you have the right engineering and project management team to succeed.

Three Stage Battery Charging for EMD Locomotives

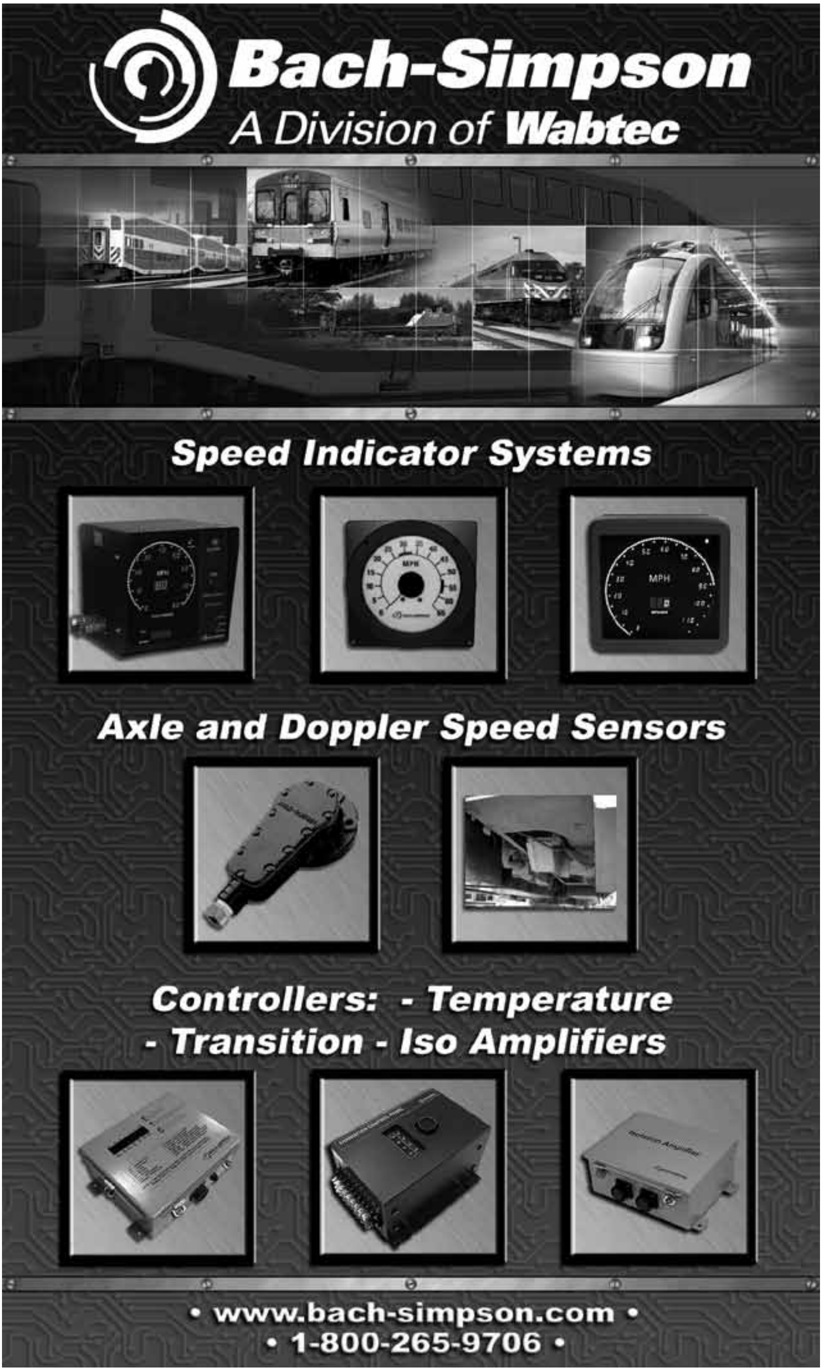
Presented by:
Bud Wilds, BNSF Railway

Locomotives, like the human body, have vital systems which keep them running and working to achieve maximum performance. Like humans, locomotives have muscles (Engine, Alt, and TM's), a brain (computer control systems) and a heart (The Battery). Today's locomotives have plenty of Brawn with more horsepower than ever before: AC traction to provide better pulling power, a computer to control all of its functions and an abundance of the proper weight displacement to utilize maximum tractive effort. All this new technology for today's locomotive certainly makes it better than yesterday's locomotive. What has not changed is the heart of the locomotive, its battery and how it is charged. Not unlike the human body's heart, the battery can have a shortened life if not cared for properly. We certainly do not want our heart to experience a "Dead Won't Start" (DWS) just like we do not want our locomotive to experience a DWS, especially since DWS is one of the leading failure modes that our locomotive fleets face.

There are many reasons why a DWS may happen but at the root, you will find a weakened battery. This is something we can avoid with proper battery maintenance. A healthy battery is even more important today with "Auto Engine Stop Start" (AESS) systems on board. Unlike yesterdays locomotive that was only required to be shut down and restarted once a month or less. An AESS feature can require a locomotive to be shut down and restarted several times a day. With rising fuel cost, emissions requirements and noise reduction requirements AESS makes good business sense. The affects of AESS can greatly diminish the capacity of a starting battery without a strategy to offset this demand.

Properly maintaining and watering locomotive batteries is important. This task can often be a point of neglect and can shorten a batterie's life. Maintenance free batteries are a technology that can alleviate this neglect, though that is a topic for another discussion. This topic covers proper charging of the locomotive battery to meet today's demands whether it is the traditional flooded lead acid battery, an Absorbed Glass Matt (AGM) maintenance free battery or one of the new Lithium Ion smart batteries (L-Ion) being developed by BNSF and Start Pac ®.

Over the last two and a half years the BNSF has been working with Enerpro to develop a three stage charging module for EMD legacy locomotives (VR31) Fig. 1.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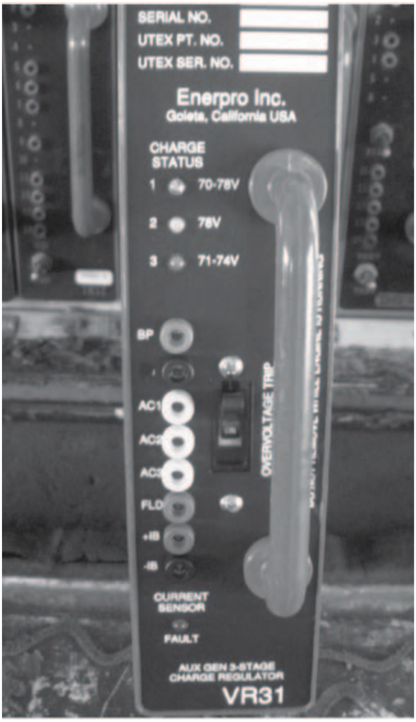

Figure 1

VR31 Module
Status and Test Points

Stage 1 Blue LED indicator 70-78 V

Stage 2 Yellow LED indicator 78 V

Stage 3 Green LED indicator 71-74 V

Rectifier Voltage Test Point

Battery Negative (Future True Battery +)

Three Phase Test Points

Auxiliary Gen/Alt Field Test Point

Current Feedback Test Point

Battery Negative Test Point

Current Feedback Sensor Fault Red LED

VR31 charging takes place in three basic stages; Bulk, Absorption and Float

In the first stage or Bulk Rate; current is sent to the batteries at the maximum rate but not more than is a safe rate at which the battery will accept, or a maximum of 90 amps. The typical battery voltage will range from 67 to 71 volts. The VR31 charging voltage can exceed the battery voltage by about 7 volts (Fig.2) due to the voltage drop in the battery cable resistance (about .02 Ohm), the drop in the current limit charging resister (.05 Ohm) and

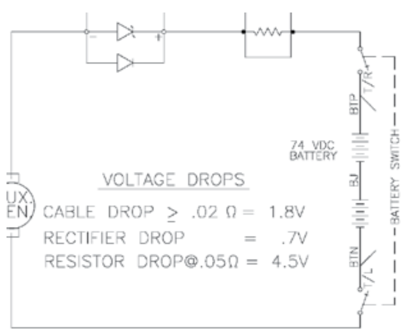

Figure 2

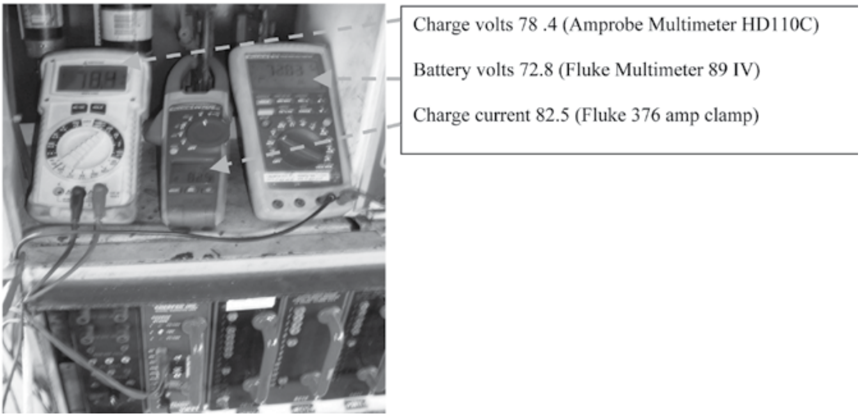

Figure 3

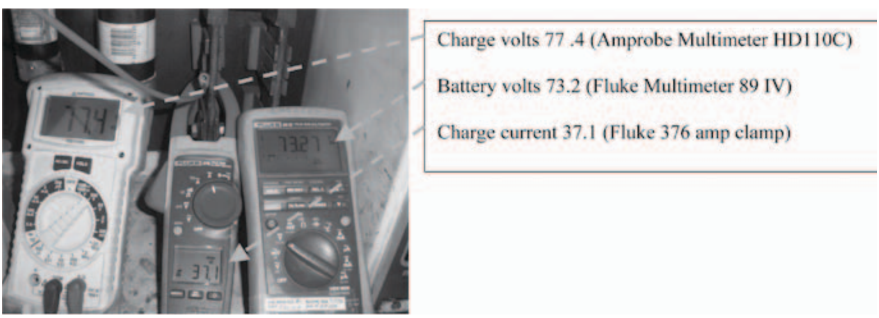

Figure 4

the voltage drops in the blocking diode between the rectifier and battery. At 90 amps these voltage drops are 1.8v, 4.5v, volts and .7v for a total of 7 volts. The bulk rate is applied until the voltage rises to about 80-90% of full charge. This typically occurs in a matter of minutes or longer depending on state of discharge of the battery. Charging voltages at this stage typically range from 76-78v

Voltage setting at the bulk rate stage is set by the maximum allowable voltage as determined by the manufacturer's warranty and the limitations of the wiring to the battery.

Keep in mind the actual voltage seen at the battery will be a few volts lower than the charging volts due to voltage drops on the rectifier, the .05 0ohm charging resister and the amount of voltage drop on the cables to the batteries. See Fig. 2 on previous page

In the second stage or Absorption Rate; the second stage begins when rectifier voltage reaches 78 volts. This voltage will remain a constant 78 volts while the current will taper off gradu-

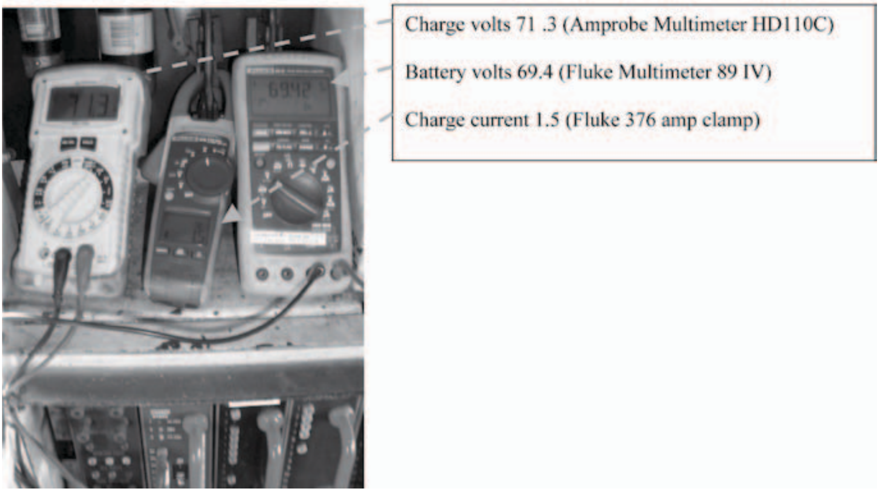

Figure 5

ally as the batteries internal resistance increases. Once the battery current has dropped to 30 amps the VR31 will transition to the third stage. There can be as much as a 7 volt difference between charging voltage and battery voltage because of the drop between the rectifier and the battery. Fig. 4 shows 77.4 charging volts and battery at 73.2, a delta of 4.2 volts.

The third stage is a Float rate; during this stage of charging, once the battery has reached a full state of charge, the VR31 adjusts auxiliary generator field current to reduce the rectifier voltage to 71 volts where it will remain constant until the engine is shut down. This charging voltage provides a maintenance charge allowing the battery to remain fully charged with minimal water consumption. Fig. 5

The typical locomotive VR10 - VR16 type voltage regulator is set to a single charge rate somewhere between 73.5 -74.5 and was sufficient for a locomotive that was only restarted a few times a month or less.

Twenty four VR31 modules have been deployed across BNSF on SD40-2, GP28-2, and SD70mac locomotives. These twenty four locomotives are in service in differing areas of the country in order to capture charging profiles throughout diverse duty cycles and climates. Using an intergraded data logger (HOBO by onset ®) Fig. 6 on these VR31 test cards, we are capturing charging profiles from each of the test locomotives, Fig 7 {(a-d) at the end of this document.} Once confirmed that this type of charging can improve battery reliability and can be used on any locomotive battery, this strategy will be expanded to newer computer control locomotives fleets.

The design of the VR31 has been carefully thought through so it may be used across all locomotive fleets

Figure 6

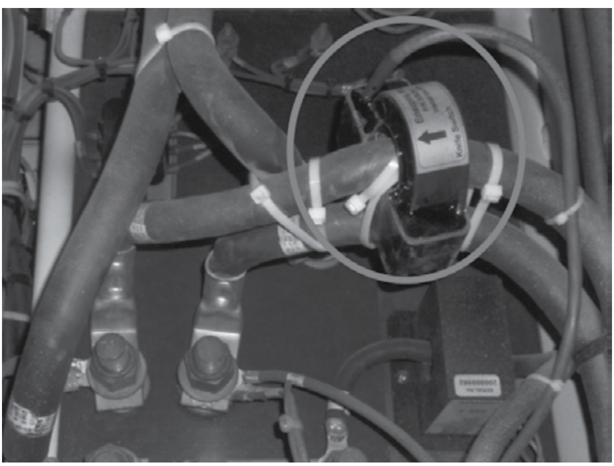

Figure 8

which use a VR Module. The VR31 could provide even better performance and help reduce sulfation in the battery more effectively by the removal of the .05 ohm charging resister which is standard across all EMD legacy locomotives. With the .05 Ohm resister in the circuit, the VR31 module can be easily installed and would be 100% backwards compatible. By jumping out the .05 charging resister, only the VR31 could be used and would result in overcharging of the batteries by use of any other VR module

Installation of the VR31 consists of a current transducer on the BTN cable Fig. 8 at the battery switch and the VR31 module pictured in Fig 1. All other existing wiring remains the same.

In addition to the VR31 test, newer technology batteries like the Absorbed Glass Matt (AGM) maintenance free battery and the new Lithium Ion smart battery currently being developed will be preformed jointly with the traditional flooded lead acid battery to evaluate their performance using the VR31.

Base line charging profiles using VR10 module were taken from BNSF 1996 SD40-2 , Profiles on the BNSF 9622 SD70mac, BNSF 1540 GP28-2 are using the new VR31 module & the profile from BNSF 1855 SD40-2 using a VR31 and a Lithium Ion battery installed.

A follow up paper will be submitted on the performance of three stage charging and its use on newer locomotives fleets at next year's annual LMOA meeting.

Contributors and Acknowledgments:
Frank Bourbeau – President, Enerpro
Tom Bourbeau – Vice President, Enerpro
Jim Wurth – Start Pac
Hugo Schmitz – Consultant TPSC / Excide/GNB

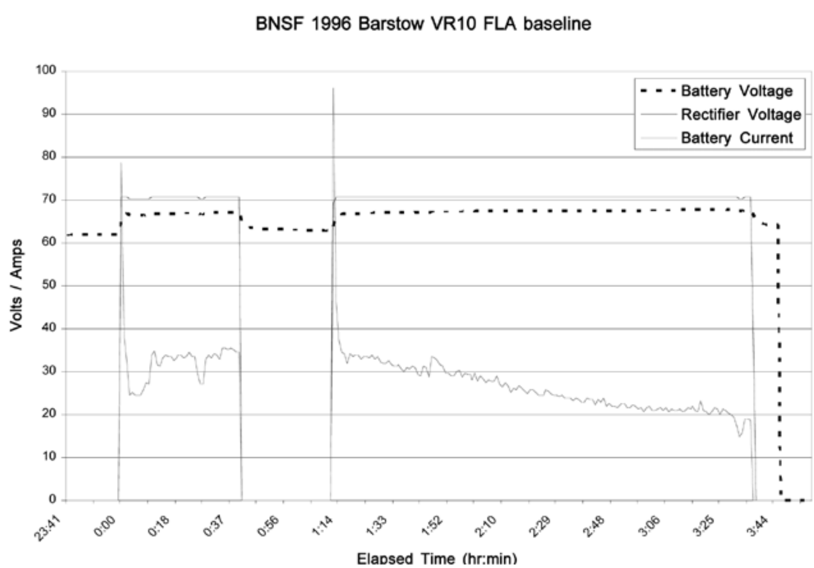

Figure 7a

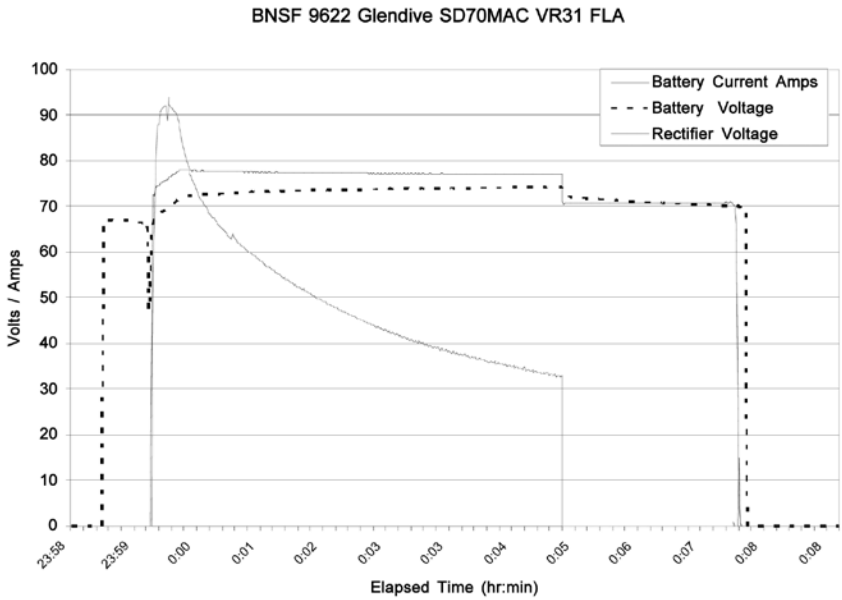

Figure 7b

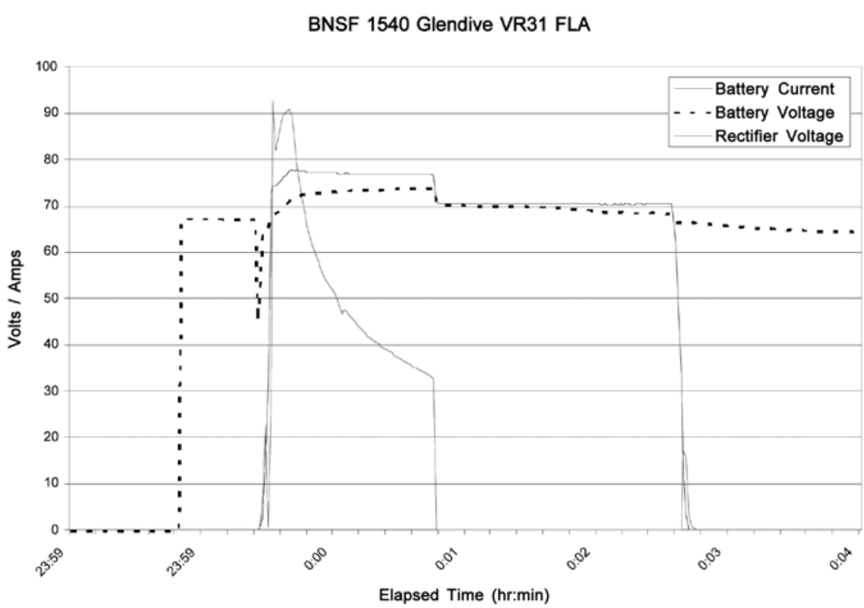

Figure 7c

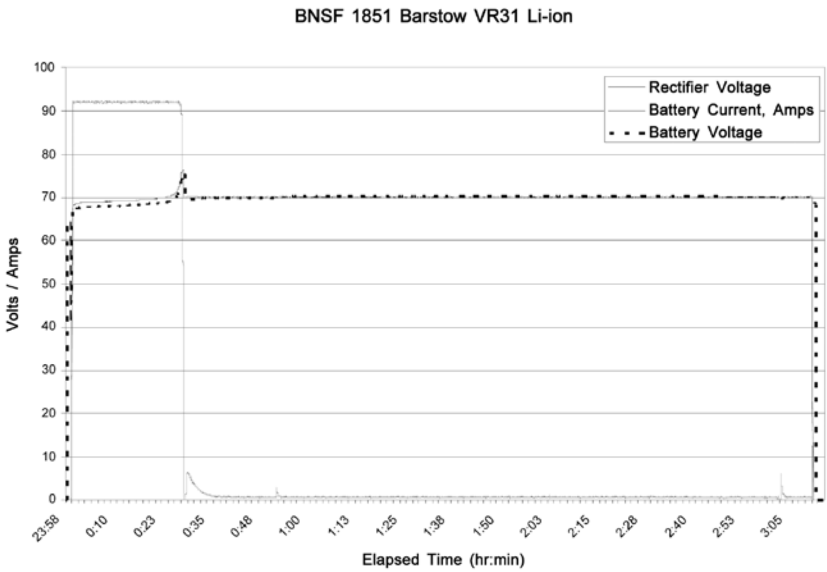
BNSF 1851 Barstow VR31 Li-ion
Rectifier Voltage
Battery Current, Amps
Battery Voltage
Volts / Amps
100
90
80
70
60
50
40
30
20
10
0
23:58
0:10
0:23
0:35
0:48
1:00
1:13
1:25
1:38
1:50
2:03
2:15
2:28
2:40
2:53
3:05
Elapsed Time (hr:min)

Figure 7d

Report on the Committee on Diesel Material Control

Monday, September 19, 2011

3:45 P.M.

Chairman

Ron Sulewski
Sales & Marketing Manager
Business Development
Rail Products International Inc
St. Louis, MO

Vice Chairman
Vacant

Commitee Members

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F. Miller	VP-Sales	Relco Locomotive	Warrenville, IL
P. Pinson	Purchasing Manager	Rail America	Jacksonville, FL
M. Zerafa	Purchasing Manager	National Rwy Equipment	Dixmoor, IL

PERSONAL HISTORY

Ron Sulewski

Ron Sulewski was born in Erie, Pennsylvania and earned his BSME from Rensselaer Polytechnic Institute in 1970. He joined GE upon graduation and worked in Erie Locomotive and the GE St. Louis Apparatus Service Shop for over eighteen years with various positions in Sales Management. Ron joined Gardner Denver for seven years as a distributor Regional Manager and rejoined GE Transportation for a Parts Aftermarket Sales Management Position in Denver.

Ron has been in his current position as National Sales Manager for Rail Products International since 2005. Ron and his wife Marje have five grown children and currently reside in St. Louis. He has been active in LMOA activities for over thirty years.

The Diesel Materials Control Committee would like to extend their gratitude to the Genessee & Wyoming Railroad for hosting their committee meeting in Jacksonville, Florida on January 21, 2011.

The Committee would also like to thank Progress Rail for hosting their committee meeting in Mayfield, Kentucky on March 30, 2011. The committee also thanks VMV for a shop tour of their Paducah, Kentucky facility and to Metro East Industries and Helm for conducting a tour of their facilities on March 31.

Small/Heavy Component Ergonomics Locomotive Starters

Prepared by
Mike Kadar and Jim Brix of the Union Pacific
and Fred Miller of Relco

PROBLEM STATEMENT

An electric starter weighs 76 pounds and there are two per locomotive in most applications (figures 1 and 2).

An air starter weighs 69 pounds and there is one per locomotive in most applications to date (figures 3 and 4).

Both are small enough to be carried in two hands. Their usage has increased dramatically with application of automatic engine start/stop systems. Start cycles have increased as much as six to eight times. Preventive starter change outs on the Union Pacific have increased from every three years to annually on auto start/stop units.

Manual lifting has been used to handle and install these parts for decades. UP has had some recent success in improving safety. Injuries have and will continue to be an issue unless better methods and equipment are identified

1) Back injuries due to lifting and twisting
2) Drops, falls when ascending, descending and walking with the part
3) Pinch points during starter removal and installation
4) Longer term stress-strain injuries from repeated handling

Currently, the starters are stocked 12 per layer and 2-3 layers per pallet, often stored on the floor (figure 5). The pallets are not always accessible from above which requires reaching, pulling and twisting to retrieve them (figure 6).

The location of the starters on the locomotive is low and somewhat obstructed by the car body (figure 7). A crane (when available) is used during removal and installation (figure 8).

When starters are removed from the box, they are rolled from the box onto the floor to facilitate application of the strapping (figure 9). One end is picked up off the floor to get the lifting strap around the starter and solenoid (figure 10).

Starters are pushed into the car body (figure 11) and aligned in the starter bracket. Two people are required to begin torqueing the mounting bolts once the starter is inserted into the bracket (figure 12).

Bad order core is tagged and often returned in its original packaging (figure 13) or may also be returned loose with two or more starter cores per pallet (figure 14).

Using a portable crane is an alternate method (figure 15) It weighs less

than 40 lbs and the lift capacity is 700-900 lbs. It requires mount applied to handrail stanchion.

The risks involved are:

1) Lifting and twisting

-Warehouse storage to cart or dolly
- Cart/Dolly to delivery vehicle
- Delivery vehicle to running board
- Running board to mounting bracket on engine

2) Pinch points during installation on the locomotive and also when rolling starter on the floor or lifting one end to strap.

REMEDIES

GOAL

1) Eliminate manual, single person lifts when handling small/heavy parts
2) Reduce the number of lifts to the minimum required
3) Eliminate location to location, person to person variability in handling practices

CLEAR COMMUNICATION

1) Warnings on product, packaging, warehouse bins, paperwork, etc. (figures 16 and 17 and 18).
2) Job briefings/risk assessments

STANDARD WORK PRACTICES

1) Always involve two people in the repair
2) Always change starter with an overhead or portable crane

MECHANIZATION OF PROCESS

1) Lift assists or other tooling
2) Packaging changes to facilitate handling (room for slings, integrated lifting straps)

Some potential remedies are use of quarter pallets, returnable packaging, lifts/carts and dedicated tooling (figure 19-22).

Other small or heavy components which could be candidates for storage and handling improvements are:

- Air brake components
- Water and fuel pumps
- Governors
- Cab Seats/Glass/Toilets/Heaters
- Contactors/Controllers/Electrical Panels
- Knuckles
- Handbrakes
- Shocks & Dampers
- Slip Rings
- Genset Choppers & Starting Batteries

CONCLUSION

Handling starters continues to present opportunities for safety improvements in railroad shops and warehouses. Any or all of the potential remedies will help contribute to our goal of zero injuries which are preventable with standardization of best practices, training and proper equipment.

Figure 1

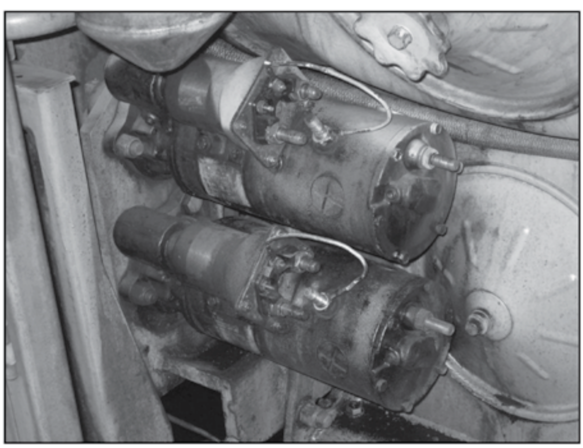


Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

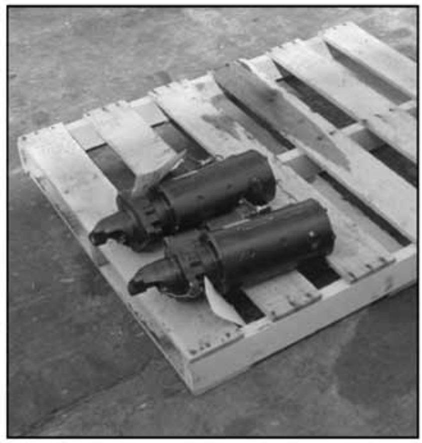


Figure 14

Figure 15

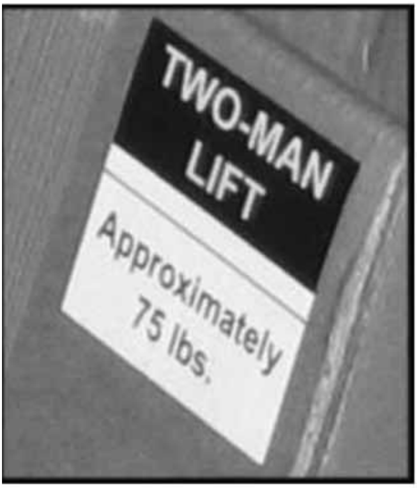


Figure 16

Figure 17

Figure 18

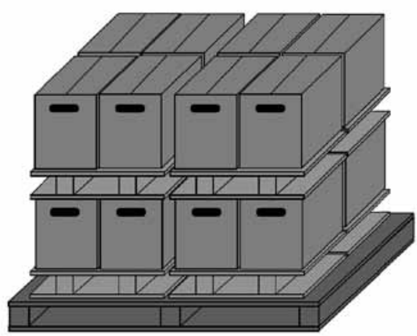


Figure 19

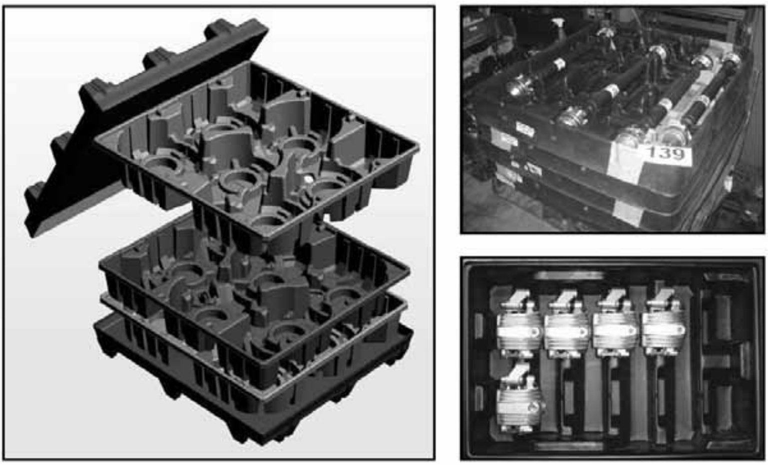


Figure 20

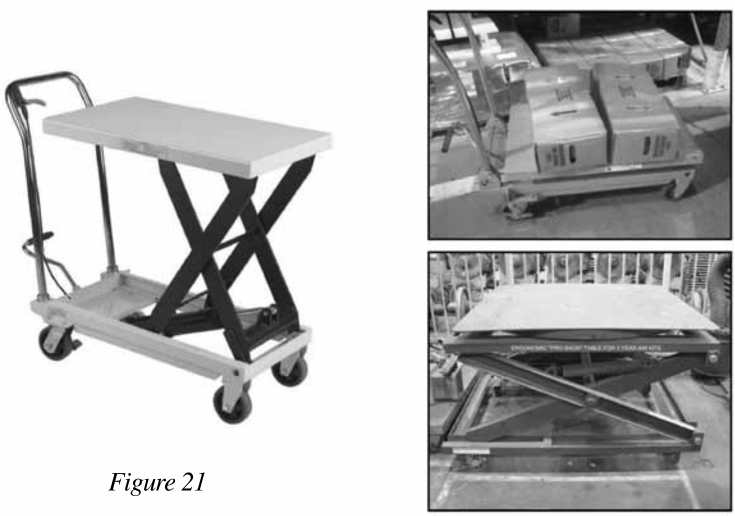


Figure 21

Figure 22

Storage, Handling, and Recycling of Locomotive Batteries

Prepared by Paul Foster, Power Rail Distribution

1- This paper is part of our on-going series of papers on Green Theme- storage, handling and recycling of locomotive batteries.

2- EPA Concerns

Locomotives have had batteries for over 60 years, and railroads have had to deal with storage, handling and installation of batteries for as long as any of us have been in the Industry. But now due to continuing pressure from the EPA to reduce emissions with systems like AESS, APU's Hybrid and Gen Set locomotives the number of batteries that Railroads will have to deal with will increase drastically.

3- Batteries are here to stay

Like it or not, batteries are here to stay and their numbers are increasing which will require more awareness and training.

4- Key Topics-

- What is a Battery
- Battery Types
- Hazards & Concerns
- Transportation
- Handling
- Storage
- Recycling

5- What is a Battery?

- A battery is two or more electrochemical cells connected in series which store chemical energy and make it available as electrical energy.
- Common usage has evolved to include a single electrical cell. There are many types of electrochemical cells. A battery's characteristics may vary due to many factors including internal chemistry, current drain and temperature.
- Typically, in the Locomotive Industry, our battery has been a very old Acid/Metal Design.

6- Locomotive Battery Types (Figure 1)

Although battery technology has improved over the years, the typical battery found on most locomotives is the flooded acid battery, which is old technology. Major concerns of this style are the hazards of corrosives and EPA issues in recycling and disposal. Newer locomotive technology with Gen Sets and Hybrid locomotives require more power which results in more batteries. In these applications the common choice is the Gel style battery. It should be noted that some Class 1 Railroads also use Gel type batteries in standard road units.

7- Hazards and Concerns (Figure 2)

As discussed earlier, because of the corrosive nature of flooded type acid batteries. There are serious dangers related to the transportation and handling of batteries.

8- Battery Hazards Acid Type

Besides the corrosive issues on the lead flooded batteries common accidents are caused by charging improperly, mishandling of the battery, poor maintenance practices including improper watering.

When a battery fails, it can cause severe personal injury to the worker and also cause significant damage to the locomotive and/or facility resulting in financial loss to the Railroad.

9- Gel Style Batteries- Pros

Some major railroads are now using the Gel green electricity battery. The pros of the Gel battery are that it's non corrosive which offers a minimal risk of overcharging and eliminates the boiling over/gases issue.

Gel batteries are much easier to transport (no placards/EPA paperwork/ special manifests).

10- Gel Style Batteries- Cons

The cons are up front cost – these batteries are not cheap, but higher initial purchase price can be justified.

Gel style batteries require a different charging system which adds cost also.

We also need to address the safety concerns.

The weight of the Gel style batteries are almost double the weight (around 425 vs. 800lbs)

11- Battery Transportation- Acid (Figures 3 and 4)

Acid Flooded Batteries are a tremendous concern to the transportation Industry.

The proper placards must be displayed and no other hazardous material can be shipped in the same load.

12- EPA Exemption

However, there is an exemption from Hazmat placarding for Batteries if it is a complete truck load (Dedicated Run) going from one origin to a single point.

By utilizing this exemption, Railroads can save a significant amount of money on Hazmat Shipping costs.

13- Battery Transportation- Acid

Transportation carriers also need MSDS (material data sheets) and all the packaging and skids must be properly marked.

14- Stacking and Wrapping

In order to comply with the US-DOT, State and Local regulations, it is required by law to utilize only personnel trained on the proper handling, stacking and wrapping of batteries for shipment.

It should be noted that training regulations vary from State to State

15- Battery Transportation- Gel (Figure 5)

Transportation of GEL batteries is much easier. No placards are required, MSDS Sheets are optional. Usually packaging is still done like the Flooded acid but that is mainly due to force of habits.

Only key concern is the excessive weights which typically also drives shipping costs higher.

16- Safety

Personal safety concerns with Gel Batteries are greatly reduced compared to the Flooded Acid Type.

The safety precautions required for acid flooded batteries are approved face Shields & goggles, acid resistant gloves, rubber aprons, slip and acid resistant footwear, non conductive tools, mops, spill kit, eye wash.

First aid training is required, and batteries must be handled in a well vented area.

17- Battery Pick

Figure 6 is a pick document from a Class 1 which describes the store sku number, description, location and any important information. Please note the Lifting alert and Hazmat alerts on this document.

18- Battery Storage (Figure 7)

Storage procedures vary from railroad to railroad. Some railroads store indoors in one centralized location; some store inside in multiple warehouses with rotatable inventory. Some roads store outside but inventory needs to be monitored for freeze damage. Top left picture utilizes a run off catch basin.

19- Battery Storage (Figure 8)

- Batteries must be protected from…
- Intense Heat
- Drastic Cold
- Damage due to dropping and/or Stacking of Product

20- Battery Storage and Charging (Figure 9)

Charging Batteries while in storage is also a handling issue. Whether you have a fixed station (picture left) or a portable charger (Picture Right) railroads still have problems with overcharging.

Gel and Flood Batteries take a different type of charger. The above models are dual mode chargers and, although with today's technology with Micro Processors we can reduce overcharging, the operator stills needs to select the correct style of charger.

Bottom picture shows a typical watering wand which again opens risk of injury getting back to why railroads are using more and more Gel type. It should be noted that ventilation in this area is critical due to boiling acids that give off vapors.

21- Battery Storage Concerns

Warning, warning, warning….. Battery is undercharged.

Batteries stored for a lengthy period of time can become undercharged

Batteries need to be treated as perishable items, must use oldest first.

22- Battery Storage- Best Practice

Class 1 railroads also utilize their Suppliers for battery storage, both new and re-manufactured. This allows them to rotate inventory, and reduce cost and lead times. The smaller railroads utilize a distributor to manage inventory levels.

23- Recycling (Figure 10)

Although Gel Batteries can replace Individual Cells, the practice of recycling applies mainly to Flood Acid Batteries.

In discussion with a few Class 1s we estimate that they reclaim 50-60% of batteries. It is very common to take multiple "dirty cores" and piece a remanufactured battery.

The recycling addresses the plastics, which become pellets and are molded into new cases

The acid is reprocessed and the grids are melted down into lead ingots and then turned into new grids.

It should be noted that 99% of Flooded batteries are recycled.

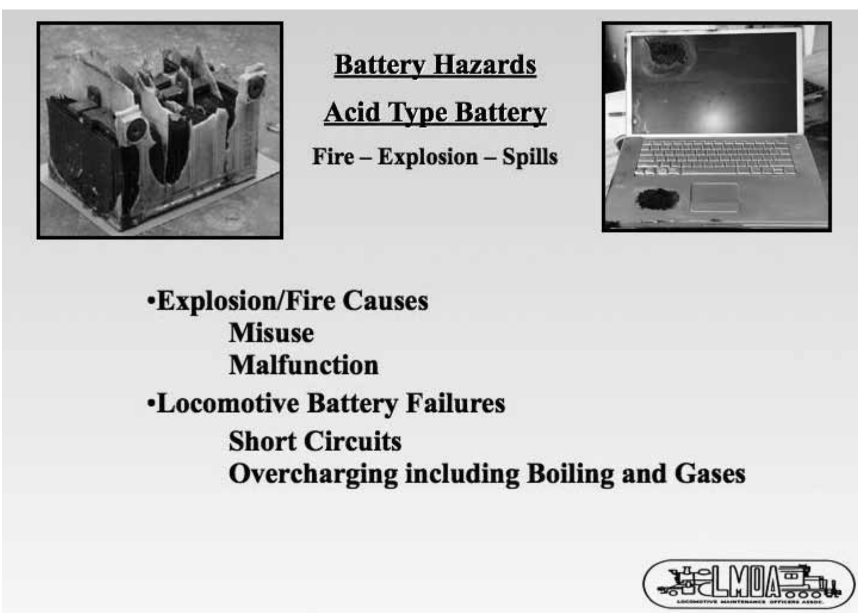
24- Best Bang for Your Buck

GE and EMD maintenance instructions for locomotive batteries recommend that batteries have:

- Correct specific gravity (water/electrolytes)
- Individual cells topped off
- Terminals greased, to prevent corrosion.

Although our scope is focused on Diesel Material Control, proper maintenance and handling of batteries will reduce the rate of consumption, improve performance, and above all reduce costs.

Figure 1



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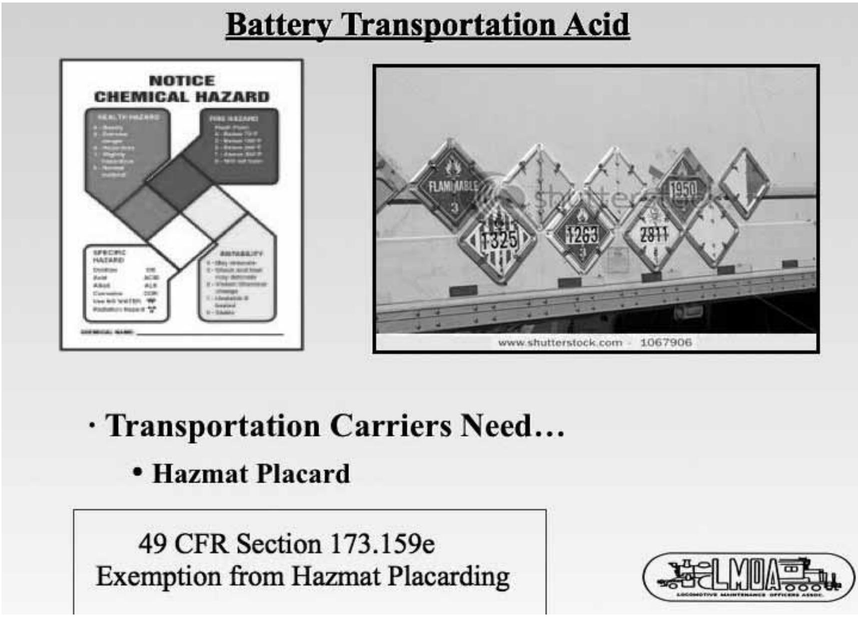


Figure 3

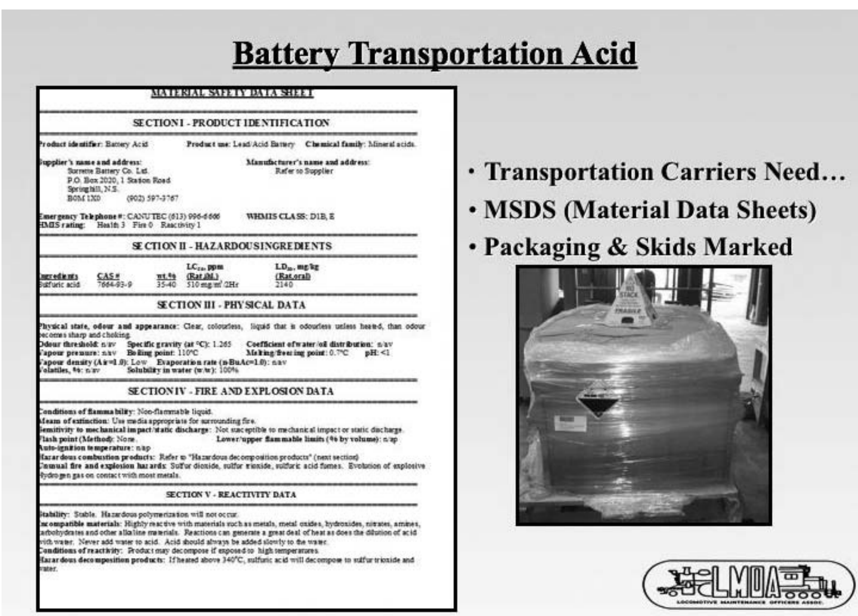
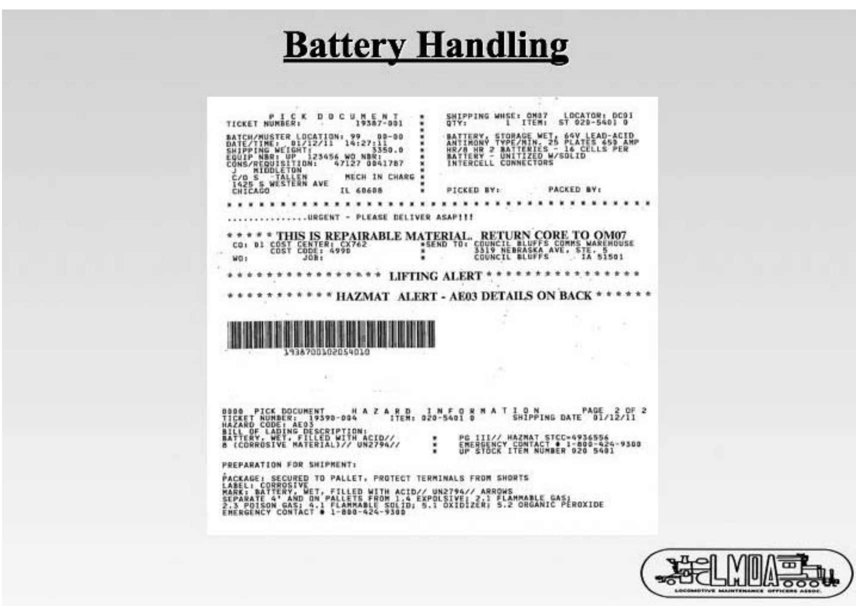


Figure 4

Figure 5



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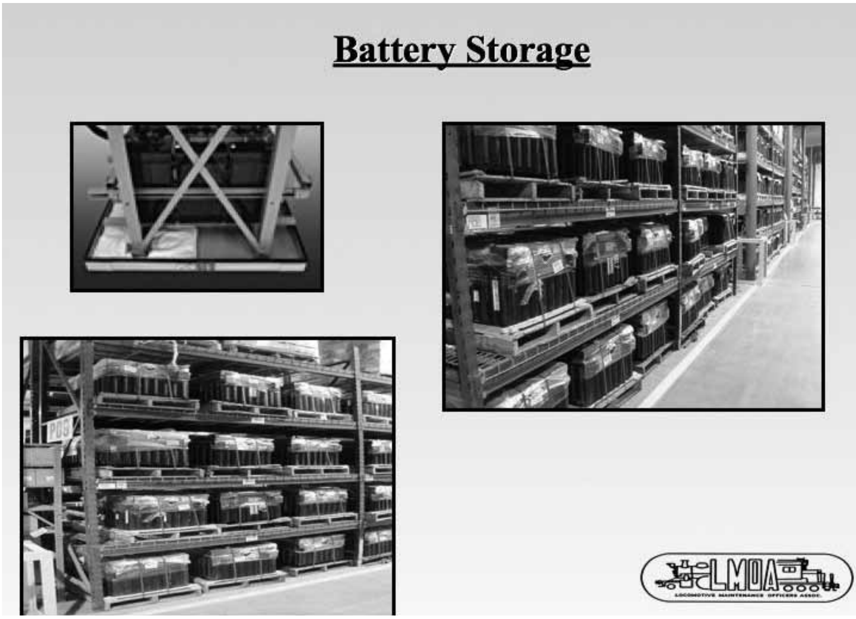

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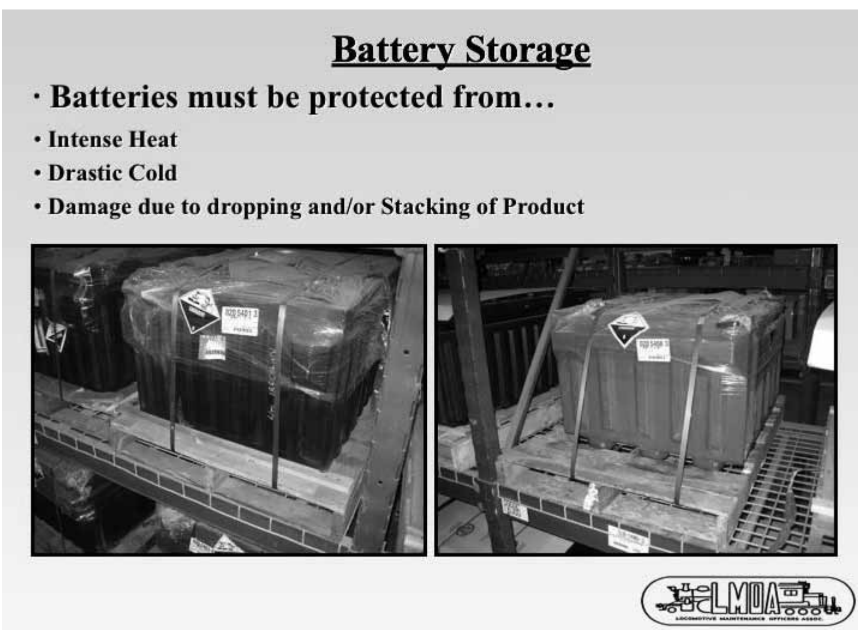


Figure 8

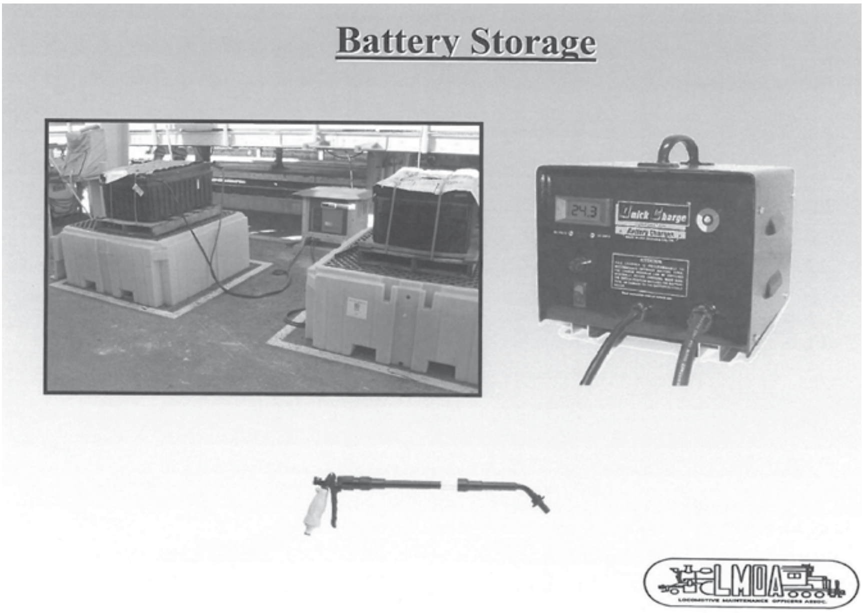


Figure 9

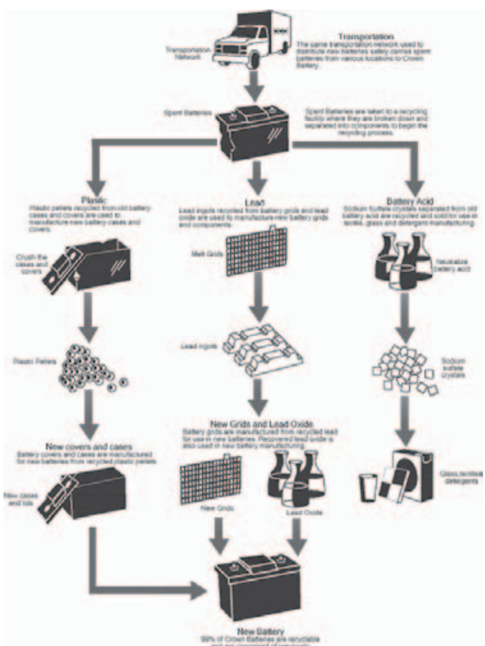


Figure 10

Report on the Committee on Shop Safety, Processes and Equipment

Tuesday, September 20, 2011

9:00 A.M.

Chairman

Bill Peterman
President
Peterman Railway Technologies, Inc.
Baie D'Urfe, Quebec

Vice Chairman

Tom Stefanski
President
Tom's Locomotive and Cars
Plainfield, IL

Commitee Members

R. Begier	Consultant	Portec Rail Products	Broomfield, CO
D. Bossolono	Shop Supt.	BNSF Rwy	Kansas City, KS
R. Collen	Project Mgr.	Simmons Mach. Tool Corp.	Albany, NY
C. Fette	President	TESCO	Erie, PA
L. Gelo	Product Manager	Macton Corp.	Oxford, CT
J. Morin	Director-Sales	Socofer	Tours Codex, France
M. Scaringe	Dir. Locomotives	Amtrak	Beech Grove, IN
S.G. Smith	Engr. Lean Prod. Systems	Norfolk Southern	Chattanooga, TN

Note: Mike Scaringe is a Past President of LMOA.

PERSONAL HISTORY

Bill Peterman

Bill was born and raised in Galt, Ontario Canada and has worked and lived in various parts of Canada during his railroad career including major stints in Calgary and Montreal where he presently resides. His business career included 25 years with Canadian Pacific Railway and several years with Dominion Bridge in Canada in numerous industrial and facilities engineering positions including various positions in the maintenance facilities and head office. Gained a world of rail experience working in all aspects of service facilities. His railway career began as a Time and Motion Analyst completing his time with the railway as Manager Facilities Engineer.

Currently Bill is President of Peterman Railway Technologies a company specializing in assisting with Rail Maintenance designs, equipment and processes, providing specialized rail maintenance serves and acting as a liaison between railway and non railway entities.

He has been Chairman of the Shop Equipment & Process Committee for several years. Bill lives in Montreal and is married with 5 children and finally has 2 grandchildren.

The Shop Safety, Processes and Equipment Committee wish to express their sincere appreciate to Snyder Equipment for hosting their committee meeting in Springfield, Missouri in July 2011.

During the Joint Technical Committee meeting at the Union Pacific in Omaha, NE in June 2011, the Executive Board voted to change the name from Shop Equipment and Processes to Shop Safety, Processes and Equipment. The Committee will devote some of their efforts on shop safety.

New Tooling Development -Level Loading, Extended Reach"C" Frame Lifting Device and Manipulator - Under the Hook Load Limiter Alarm

Prepared by,
Eric Watts
Tesco

Level Loading "C" Frame Lifting Device and Manipulator

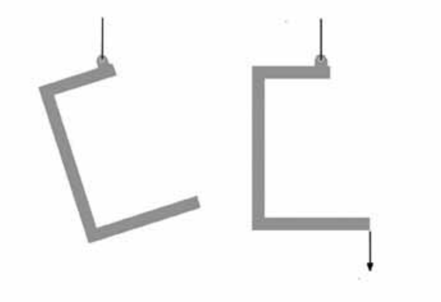
BACKGROUND

- Removing and installing ancillary components and equipment from within the locomotive carbody can be a challenging prospect due to the close proximity of the equipment, wiring and piping obstacles, and the restricted space of the carbody itself.
- Extended reaches inside the locomotive carbody are often required to reach each piece of equipment
- Smaller pieces of equipment may be lifted and removed using a cantilever style arm, attached to an overhead crane and counterbalanced by hand.
- Larger pieces of equipment have required the use of "C" shaped lifters that extend into the cab and are lifted using overhead cranes.

Current Limitations to Certain "C" Frame Lifting Devices

- In order to remain level when loaded, the design of some "C" shaped lifting devices require the lifting device to be oriented at an angle when entered into the locomotive carbody unloaded. When load is applied, the lifter is level.

Unloaded Loaded



- This concept works well for shorter reaches into the locomotive and for removing smaller, lighter components.
- Longer reaches into the locomotive body are often made difficult due to the angle of the unloaded lifter.

- Once the load is removed from this type of lifter, the lifter will then return back to its angled, unloaded position, requiring caution by operators.

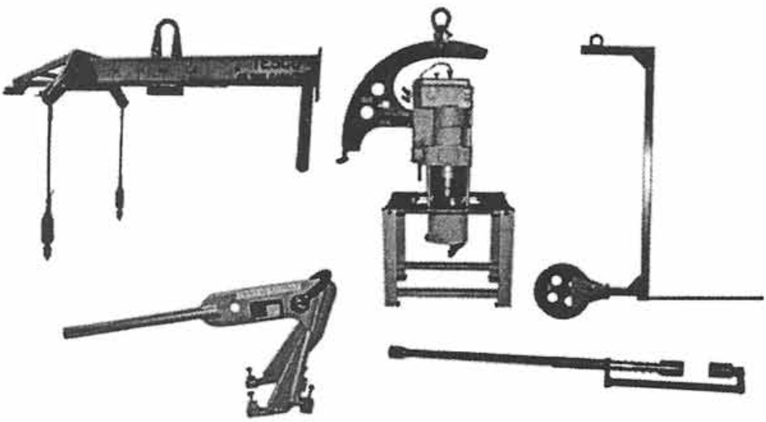
Current Limitations to Certain "C" Lifting Devices

- Other "C" style lifting devices utilize two pickup points on the lifter, one for when the lifter is loaded, one for when it is unloaded.
- This type of lifter requires that one pickup point be used to pick up the unloaded lifter and position it so it can be attached to the load. The crane hook is then lowered and repositioned on the second lift point for lifting the load.
- These lifters can only be used in applications where the crane hook can be safely lowered once the lifter is attached to or positioned under the load.

Development of a Level "C" Frame Lifting Device and Manipulator

Application

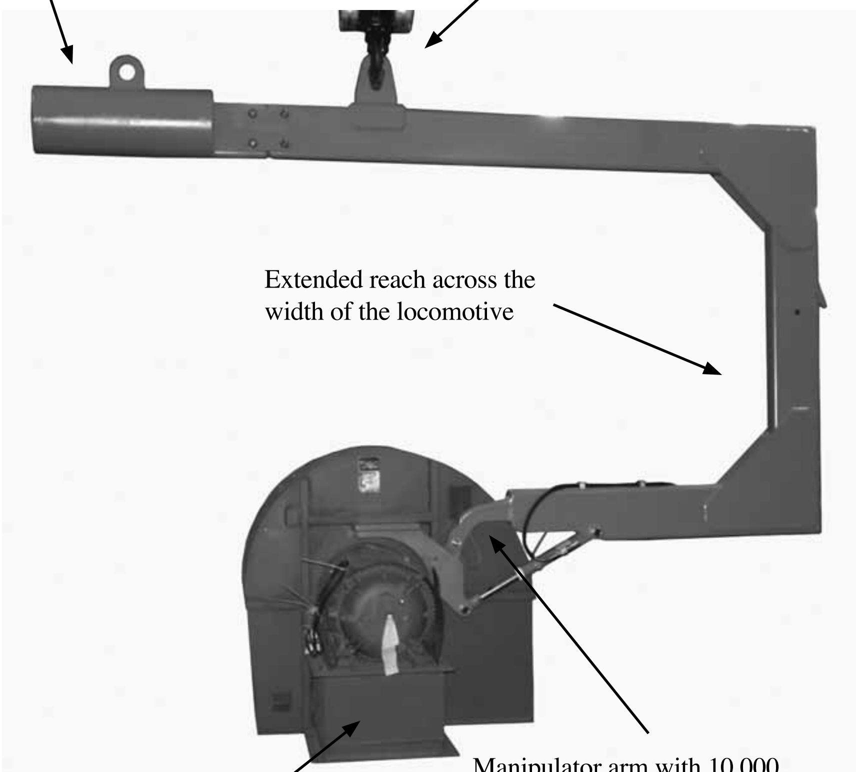
- Removal of traction motor blower from locomotive.
- Space constraints required that the lifting device reach across the entire width of the locomotive carbody to reach the blower motor.
- Additional constraints required the lifting arm to remain level during this reach through the locomotive when accessing the blower motor.
- Once the blower was accessed by the lifter arm, there was limited height in which to lift the blower for removal.



Solution – Extended Reach “C” Frame Manipulator
- Remains Level In Both Loaded and Unloaded State

Counterweight allows lifter to remain level during unloaded state

Single lift point



Extended reach across the width of the locomotive

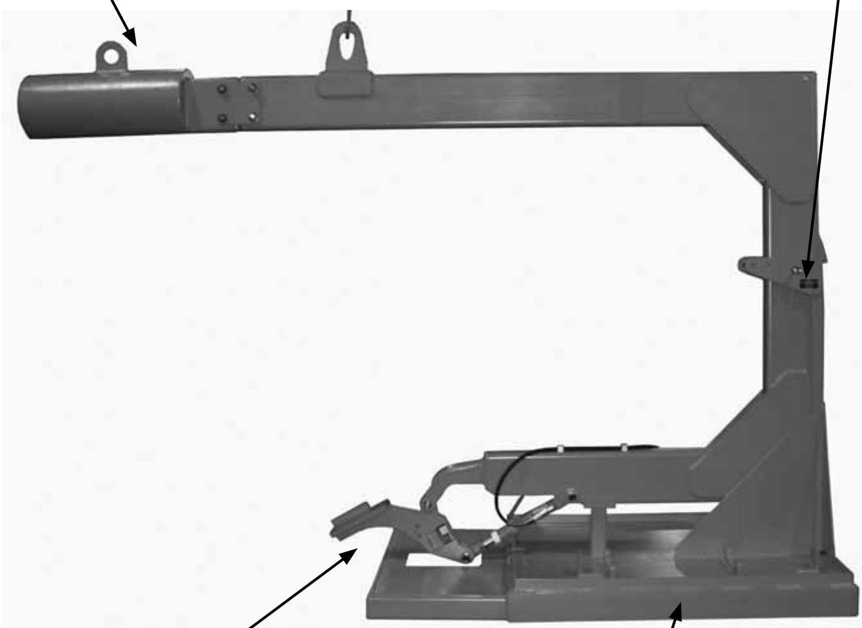
Manipulator arm with 10,000 PSI cylinder and manual pump facilitates lifting of the blower in the tight space requirements

Center of mass of the blower motor is directly below the lift point. No moment is induced on the lifter when the load is lifted

Other Lifter Features

Removable counterweight

Custom storage stand allows for safe storage and transport of lifter



Design allows for interchangeable lifting arms. Can be adapted to level lift other larger items such as air compressors.

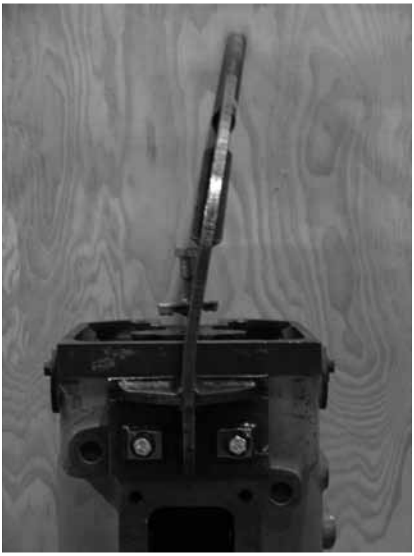
Counterweight storage area

Under the Hook Load Limiter Alarm

Background

- Over the years, there have been instances where lifting devices are damaged while being used due to excessive loading.
- Factors such as failure to remove bolts, components still connected to item being lifted, improper lifting angle combined with large crane sizes can lead to damage as shown below as well as creating serious safety hazards.

Power assembly lifter
Rated Load of 1250 lbs
Proof Tested at 2500 lbs
Load Applied - Unknown



Power assembly lifter
Rated Load of 1050 lbs
Proof Tested at 2100 lbs
Load Applied - Unknown

Under the Hook Load Limiter Alarm

Solution

- The development of a lightweight, compact visual load alarm that can be placed between the crane hook and the lifting device.
- Highly visible flashing LED panels illuminate when pre-set load has been reached.
- Load limit is pre-set based on customer specification.
- This alarm will provide a visual warning to the crane operator prior to lifter damage and potential safety issues occurring during a lift.

Automatic Wheel Inspection Systems

Prepared by
Roger Collen
Simmons Machine Tool Corporation

An Automatic Wheel Measuring System is an electro-mechanical-computer device for measurement of wheel condition either in place on a moving rail vehicle or an individual wheel set. Typical parameters that can be measured in an Automatic Wheel Inspection System are;

- Tread Profile
- Wheel Diameter
- Tread Defects
    - Thin Flange
    - High Flange
    - Slid Spot
    - Shelled Tread
    - Built-up Tread
- Thin Rim
- Out of Round
- Cracks

An Automatic Wheel Inspection System utilizes primarily non-contact systems for identification of the vehicle and wheel set as well as performance of wheel measurement. Typical applications of automatic wheel inspection systems are;

- In-rail System for inspection of wheels on moving vehicles
- Wheel set System for inspection of individual wheel sets on entry to wheel shop and for quality assurance on exit from wheel shop

In-rail System -

An In-rail Wheel Inspection System (Fig 1) can be located in any straight line track section. Performance and accuracy of the In-rail Inspection System is relative to vehicle speed so optimal location is typically on a feeder line into a rail yard or service facility. The In-rail System can be placed outdoors while the supporting computer hardware must be enclosed in an environmentally controlled building near the measuring location. Equipment for performing the measurements is typically at or below rail head height with the exception of the vehicle identification system (Fig 2). While there are multiple vehicle identification systems available, RFID (Radio Frequency Identification) is becoming the system of choice due to reduced cost and technology improvement. The RFID reader identifies each rail vehicle as it passes over the In-Rail System so that measurement parameters can be collated to a specific vehicle. Typical vehicle speed over the In-Rail Systems is 10 MPH for high accuracy measurements. Higher crossing speeds can be accomplished with measurements of less restrictive tolerance.

An In-Rail System typically contains multiple modules for measurement of specific wheel parameters (Fig 3). Modules can be added or removed as needed to customize the measuring system to the rail operator's needs. Typical modules include; wheel defects (out of round, slid flats, shelling, and built up tread) wheel diameter, wheel profile, and crack detection. Each module utilizes technology specific to the parameter to be measured. For example the wheel profile module illuminates the surface of the wheel tread while an optical camera captures the laser image and digitizes it (Fig 4). Once the profile image is digitized it can be compared to an optimum or standard profile and the deviation can be determined and the profile qualified.

Each module of the In-Rail System communicates directly with a basic module (Fig 5) which is a high speed data processing computer. This module performs the analysis to determine if the data collected indicates a fault condition. The basic module also communicates with an onsite computer that displays the wheel inspection data for any observer (Fig 6). Additionally the basic module transfers measurement data and fault reports to a centralized database making the inspection information available to personnel system wide.

Like most automated inspection systems, the In-rail Wheel Inspection System requires routine calibration to confirm measurement accuracy. This calibration process involves the movement of a known calibrated wheel set over the measuring system (Fig 7) at routine intervals. An automatic calibration mode takes measurements of the known standard and then adjusts measurement offsets in the basic module if necessary to maintain accuracy.

The In-rail Wheel Inspection System can be combined with optional modules for inspection of other rail vehicle equipment such as brake shoe thickness (Fig 8). Optical systems capture the image of the brake shoes as the vehicle passes and digitizes the image to determine the thickness of the brake lining. This system can also be used to determine if there are missing brake operating components such as linkages as well as other vehicle safety equipment. The In-Rail System can also work in conjunction with bearing condition inspection equipment utilizing acoustical or thermal measuring equipment.

Wheel Set Inspection -

Equipment is now available for the automated inspection of individual wheel sets (Fig 9). The inspection of wheel sets is accomplished in a standalone machine located at the entrance of a wheel shop for determination of rebuilding processes, or at the exit of the wheel shop to confirm the wheel set complies with the quality standards. The Wheel Set Inspection System can examine the wheel treads for; rim thickness, wheel defects, wheel run out, and profile over the entire circumference of each wheel (Fig 10). In addition to inspection of mounted wheels, the Wheel Set Inspection System can measure the back-to-back distance of the mounted wheels. Further it has the capability to inspect features of the axle including; axle straightness, bearing journal diameter, and bearing journal taper. In addition vision systems are available that can inspect the axle body for nicks and gouges per AAR G-II Rule 1.1.11. All of the measurement data can be transferred to a centralized database for access and work stations in the wheel shop.

There are multiple reasons for implementing a Wheel Inspection System. Access to the wheel tread whether in place on a rail vehicle or on an individual wheel set may require placing hands or measuring instruments in a dangerous location. An automated system eliminates this hazard. Automated Wheel Inspection is extremely efficient operating at a high speed taking thousands of measurements in the normal period a measurement can be taken manually. Measurement by instrumentation is much more accurate over an extended period by eliminating the variability of measurements between different operators or even the same operator attempting to use the measuring instrument in the same manner repeatedly. In addition the automatic transfer of measurement data eliminates the potential for errors that can occur when data is transferred manually. Finally, as data is collected over an extended period, the data can be reviewed and analyzed for trends that can indicate potential equipment or track issues that when rectified, reduce wheel wear and defects adding to the overall operating efficiency of a particular rail system.

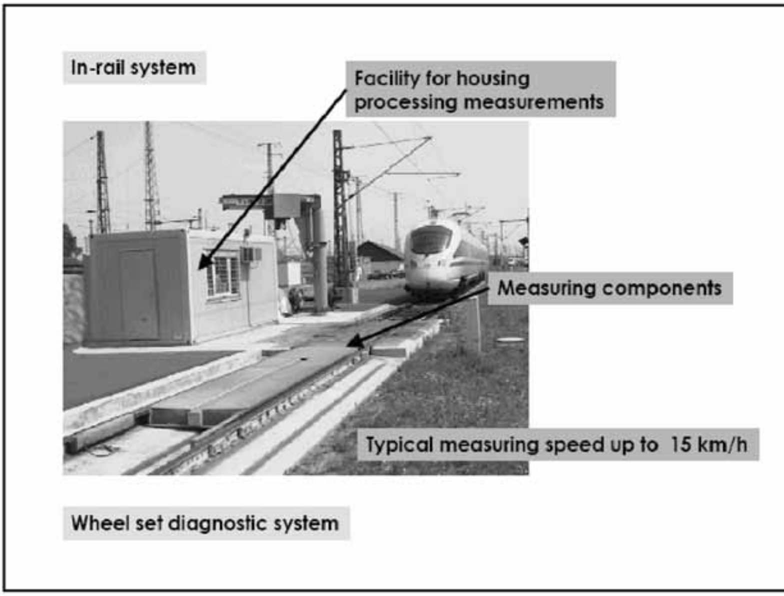


Figure 1

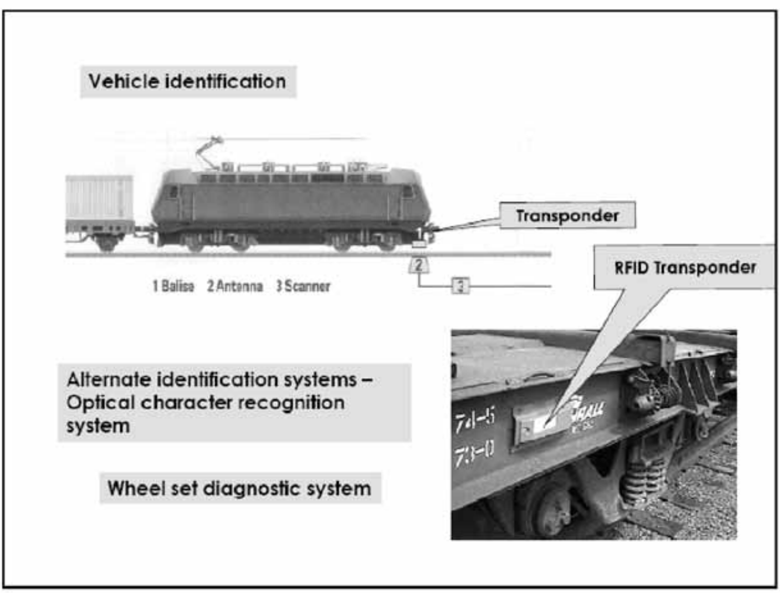


Figure 2

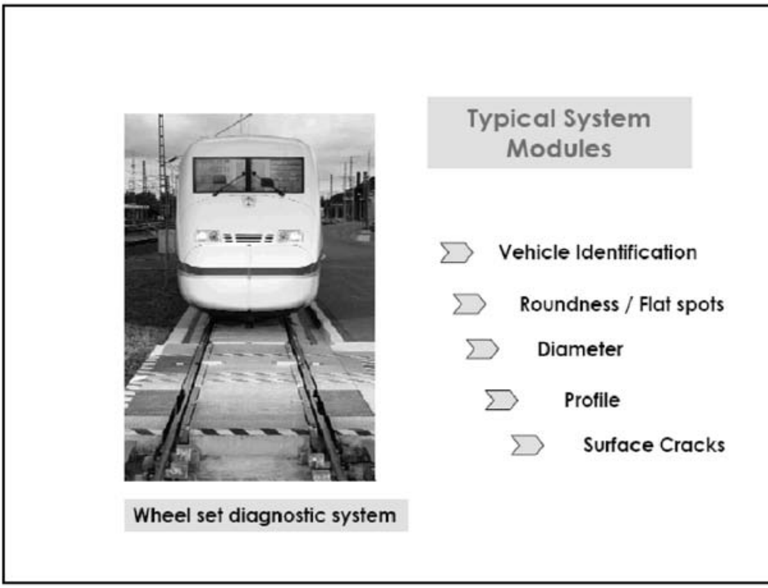
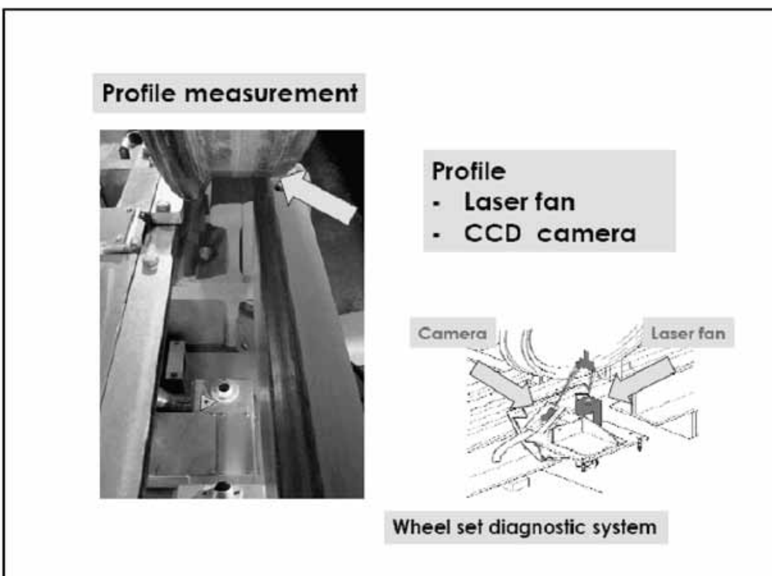


Figure 3



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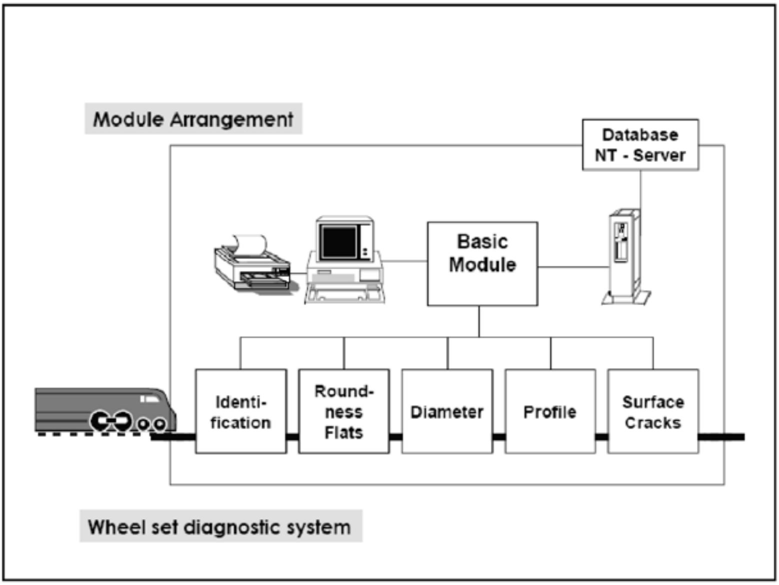

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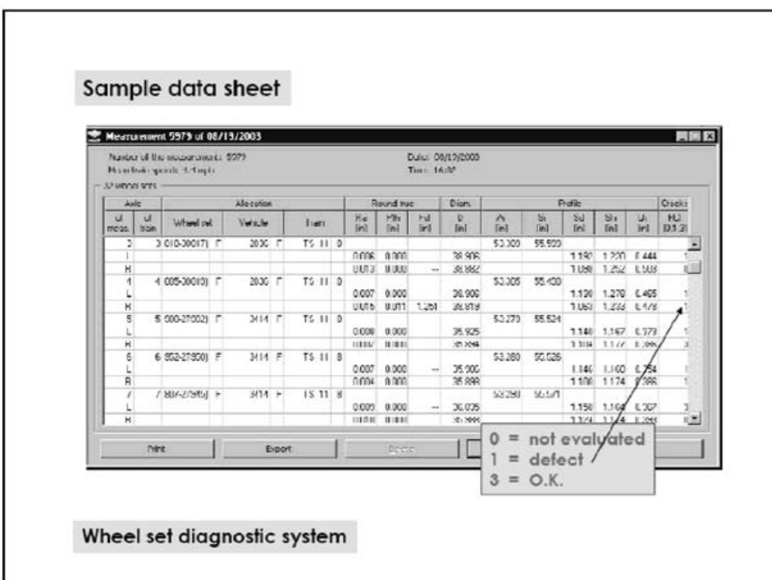

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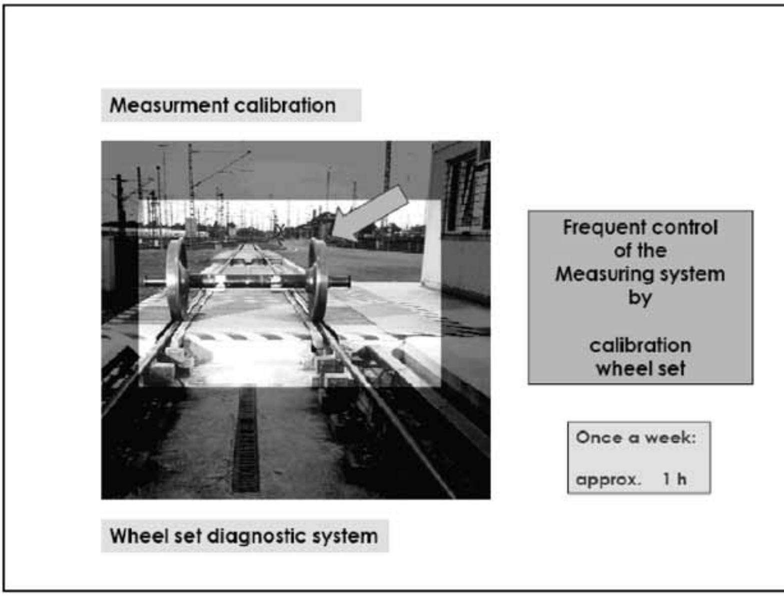

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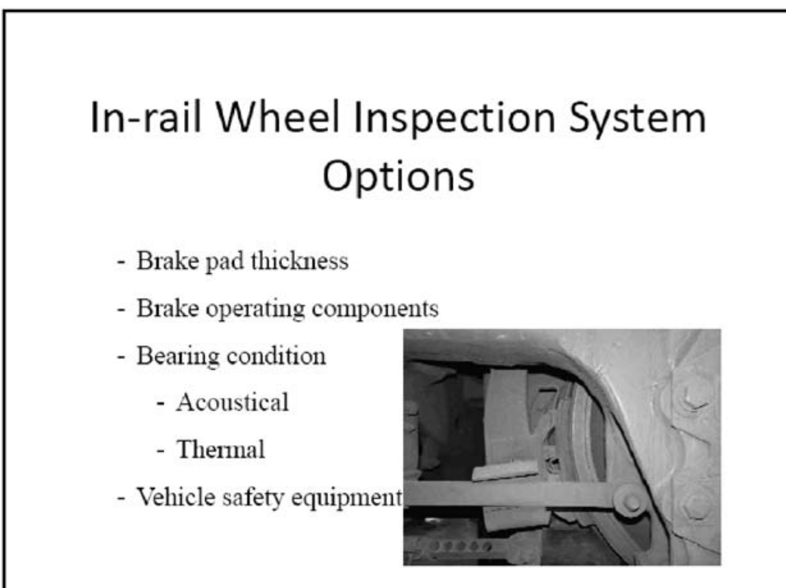

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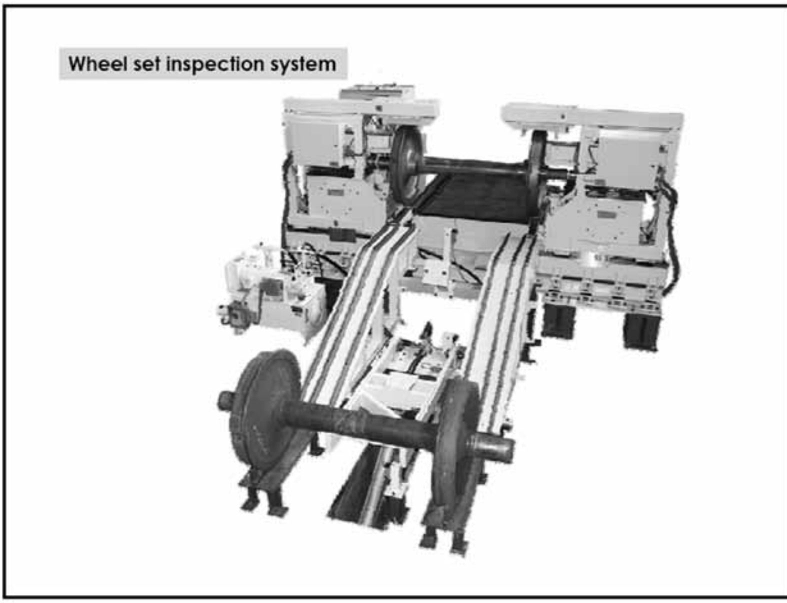

Figure 9

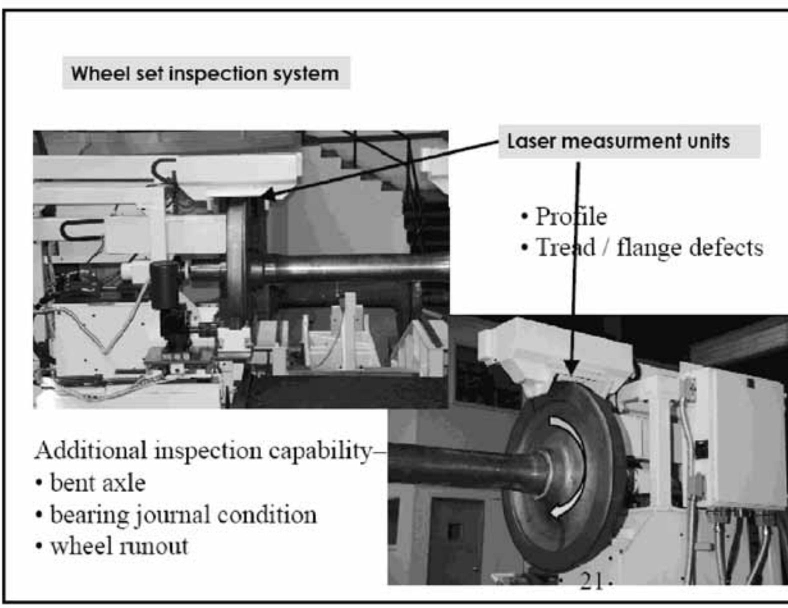

Figure 10

Report on the Committee on New Technologies

Tuesday, September 20, 2011

10:45 A.M.

Chairman

Jim Christoff
Traction Business Manager
Morgan AM&T/National
Cicero, NY

Vice Chairman

Tom Mack
VP-Sales & Business Development
Motive Power & Equipment Solutions
Greenville, SC

Commitee Members

D. Brabb	Director-Business Development	Sharma Associates	Countryside, IL
D. Brooks	Engineering Manager	ZTR Control Systems	London, Ontario
J. Clapper	Asst. Supt.-Motive Power	Wheeling & Lake Erie RR	Brewster, OH
W. Durham	Program Dir-Capital Equipment	Amtrak	Philadelphia, PA
B. Kehe	Supervisor-Maintenance	Gary Railway	Gary, IN
A. Miller	President	Vehicle Products LLC	Golden, CO
R. Nelson	Marketing Director	Cummins, Inc.	Columbus, OH
C. Nordhues	Product Manager	Invenys Rail	Omaha, NE
C. Prudian	Senior Systems Engineer	Electro Motive Diesels, Inc	LaGrange, IL
T. Shah	Product Mgr-Global Eng. Platforms	GE Rail	Erie, PA
D. Sweatt	Project Mgr-PTC Telecommunications	CSX Transportation	Jacksonville, FL
T. Volkmann	Director-Mechanical Engineering	Union Pacific RR	Omaha, NE
J. Whitmer	Electrical Design	Motive Power	Boise, ID
B. Wolff	Sales Engineer-Rail	MTU Detroit Diesel	Detroit, MI

Note: Tad Volkmann and Bruce Kehe are Past Presidents of LMOA
Cory Wyka of the Canadian National is joining the committee

PERSONAL HISTORY

Jim Christoff

Traction Business Manager
Morgan AM&T/National
Cicero, NY

Jim who was raised in Western Pennsylvania now finds himself 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 or Morgan AM&T/National) for 20 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 Traction Business Manager.

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 conducted conference calls on November 3, 2010 and January 17, 2010 courtesy of Morgan AM&T/National.

The committee held a meeting in Barstow, CA on December 1 and 2, 2010—Dinner was provided by Morgan AM&T/National and the meeting, lunch and a tour of Barstow the following day were hosted by BNSF—Many thanks to 3rd VP Brad Queen for coordinating the details.

The committee also had a meeting in Brewster, OH on March 10, 2011. Dinner was hosted by the Wheeling & Lake Erie RR as well as the meeting and lunch and shop tour the next day courtesy of Committee Member Jeff Clapper.

Positive Train Control

Prepared by
Derald Sweatt
CSX Transportation

After several train accidents, the **Federal Regulations Association** mandated that all road locomotives be equipped with **Positive Train Control** by Dec 31, 2015.

What is Positive Train Control (PTC) It's a system of mission critical, fault tolerant, vital signaling systems connected via digital radios to mobile and fixed railroad equipment. When deployed, PTC will provide interoperability between all the participating railroads. Trains from any railroad will be able to operate on the tracks of any other railroad, without ever losing contact with their own network operations center. With PTC installed on RR road locomotives, the system will prevent trains from colliding with other trains. The PTC computer system will take over the locomotive before exceeding limits or if an unsafe condition develops.

The purpose of PTC is to prevent train to train collisions, over speed derailments, work zone incursions, and movement through switches in wrong direction.

Train Control: PTC will continually monitor trains, exchanging information with Train Management Computers (TMC) and gathering precise speed and position information from GPS/TMC. PTC will have a copy of train orders, number of cars, weight, route and track characteristics along the route, including speed restrictions, curves, grades and crossings. Track authority (permission to occupy and move on a sector of track) will be continuously updated as train dispatchers and train control computers at the network operation center issue and modify train orders and operate signals.

Block Sections: With the above information from train control, PTC will monitor and enforce compliance with train orders and signals, ensuring the train operates only on the block sections it is authorized to occupy and move on.

Track Circuits: In addition to information provided from track circuits on the tracks, PTC will provide dispatchers and train control computers precise, real time position of the train on the track. In "dark territory", where there are no track circuits, PTC will be the only real-time train location information source.

Signals: The aspect of all signals on the tracks will be extended through the TMC to an onboard computer display showing all signals ahead of the train, including those that are not physically visible due to terrain, curves or visual distance. If a signal is not observed, PTC will immediately apply corrective action programmed for that event, from slowing down the train to a safe speed to the application of full emergency brakes to stop the train in the shortest possible distance. At the same time it will visually and audibly warn the engineer and report the event to the dispatcher and the train control computers.

Switches: PTC will query and monitor the status of track switches ahead and behind the train. This status will be reported to the engineer, the dispatcher and the train management computers. **Interlocking Systems**: The PTC System will work with the dispatcher, train control computers and TMC to continuously monitor and identify potential conflicts between signals and switches, train orders issued to the train, and train orders other trains are using, authorized speed and maximum speed possible on that sector of track. If any conflicts or potential conflicts would be detected, PTC will immediately apply corrective action as programmed for that event, slowing down or stopping the train, and notifying the engineer, dispatcher and train control computers.

PTC consists of several components and systems. The back office system has to be accurate with information such as timetables, dispatcher bulletins, track, switches and signals. This information is in the railroads back office server system and must be kept up to date.

On- Board the locomotive there is a Train Management Computer (TMC) and Cab Display Unit (CDU). Both components are provided by Wabtec. The TMC and CDU work together. The TMC, known as the brains of the system, communicates to the CDU. The CDU communicates with the Engineer. The interactive screen has soft keys where the Engineer can acknowledge new or modified authorities electronically. See Figure 1 below

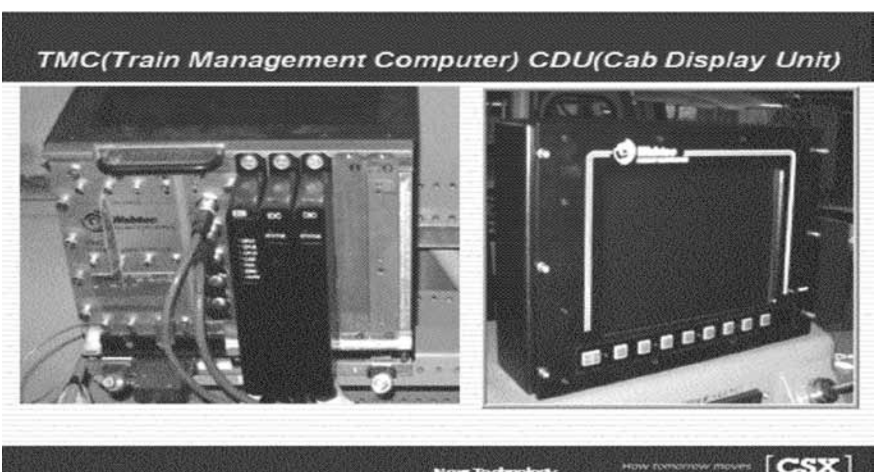

Fig. 1


NOW OFFERING...
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The Engineer will log in to the CDU prior to movement. Once logged in, the system will do a test providing the engineer with a complete system status. In Figure 2 below, you will see a good test and a failed test. Engineer is required to complete a successful test prior to departure.

Notice the interactive keys at the bottom of the screen for navigation.

Another component on-board the locomotive is the communications box. The Railroads are using a variety of options to provide this important component of the PTC system. The communications box provides several methods for PTC messages to traverse to the back office of the railroads. CSX has 802.11 WiFi, two cellular and a 220 Mhz radio for transmission of PTC messages. Figure 3 below shows CSX's communication box.

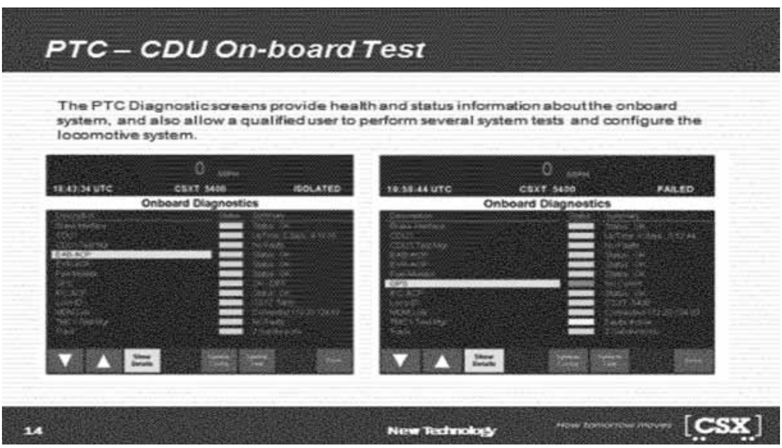


Fig. 2

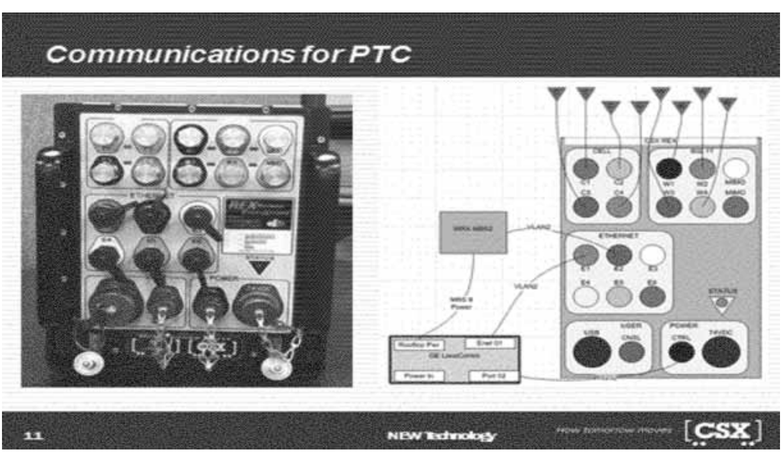
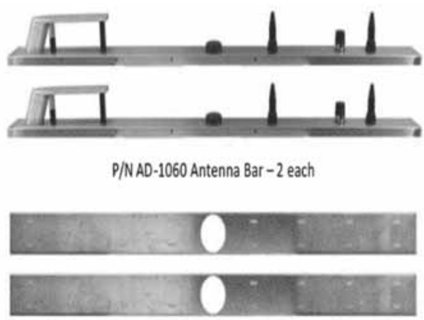


Fig. 3

The communications box is connected to an antenna array located on top of the roof of the locomotive. Each RR installing PTC can choose how the antennas will be installed. The common part to all railroads is how the messages are being sent. Priority 1 is Wifi 802.11; Priority 2 is through cell. When all communications paths are not available the 220 Mhz radio is used.

See figure below of the CSX Antenna's



The 220 MHz radio is the last resort for sending a PTC message. The skate looking antenna is the 220 Mhz radio antenna. The objective is to not have a single point of failure. If all communications paths are down, the system is configured to where PTC still can operate by sending messages through the 220 MHz radio.

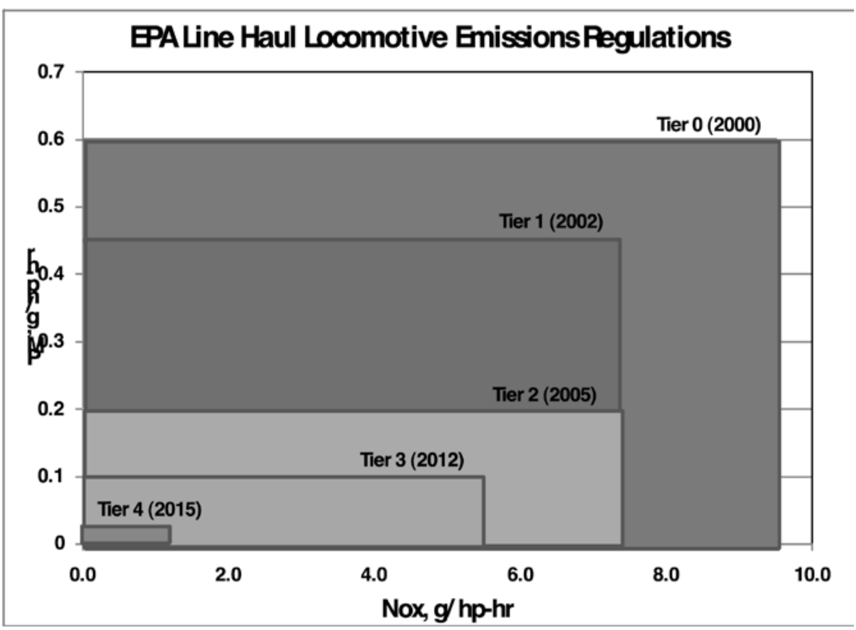
Wayside Equipment and Fault Equipment Detectors: All wayside/trackside equipment will be continuously monitored by PTC, which will automatically query equipment ahead and behind the train. PTC will issue alerts in cases such as when an automatic crossing gate is not working or a hot box detector reports some axles slightly above a certain temperature level. It will also apply corrective action in cases such as when a track integrity monitor reports a possible track breakage due to floods or extreme heat, or a hot box detector reports an axle in the train with a temperature exceeding safe operating levels, or a flood warning sensor detects the presence of water on the tracks.

PTC is a very detailed design. All parts of the system have to work together. The track, switches, grade, milepost, signal systems, back office and on-board devices have to work together. With PTC, if component changes are made, it's very important that the replacement equipment undergoes an approved series of tests to verify its compatibility with the system.

EPA Tier 4 Locomotive Development Status Update

Prepared by
Bruce Wolff MTU Detroit Diesel, Inc.
Randy Nelson Cummins Inc.

In January 2012 Tier 3 locomotive emissions standards take effect. This will be the fourth regulatory change since 2000 resulting in NO_x and PM emissions reductions by more than 75% since the late 1970s. Base engine technical improvements such as turbo charging, charge air cooling, and higher cylinder pressure capability, coupled with significant advances in fuel systems and piston bowl design have seemingly made reaching these lower levels somewhat uneventful. Development engineers have optimized virtually every engine component for thermal efficiency gains which for the most part have been able to offset the inefficiencies resulting from methods that were required to lower emissions. This is critical considering a locomotive will burn well over a million dollars of fuel per year in typical line haul service.



Through Tier 3, levels have been achieved primarily via "in-cylinder" technologies however, in most cases the practical limits of those technologies appear to have been reached. Quality improvements in design, materials, machining, and assembly have laid the foundation for increased durability and life to overhaul, but this has been countered by complex control systems that facilitate pushing engines to extremes with somewhat compromised reliability.

Upcoming Tier 4 emissions levels will require additional reductions of 75% in NO_x and 70% in particulate matter which on a percentage basis is equivalent to all previous emissions reductions combined. The goal of the engine developers is to achieve these extremely low emissions while maintaining acceptable reliability and total operating costs. 2015 is only three years away so there is keen interest in knowing what new technologies are being employed, the impact to operations and scheduled maintenance, where manufacturers are in their development cycles, and how the new engines are performing.

The LMOA New Technologies Committee assembled the following OEM Tier 4 status updates.

GE Transportation

GE launched the Evolution Series in 2005 which met Tier 2 requirements while delivering improved fuel efficiency. Since then they have been conducting a vast array of research around progressive emissions control ranging from advanced catalyst chemistries, hydrocarbon reductants and innovative combustion technologies. After the Tier 4 regulations were confirmed in 2008 GE was able to focus on evaluating the various technology options developed against regulatory & customer requirements. GE has selected a series of technologies that, in concert, will meet the stringent Tier 4 emissions standards without the use of urea and without requiring a significant infrastructure investment by the railroads.

- 2008 - technology validation began on a single-cylinder engine.
- 2009 - full engine testing at the development lab in Erie, Pennsylvania.
- 2012 - a prototype Tier 4 Evolution Series locomotive will be completed and will undergo exhaustive testing on a test track and local short line routes.
- 2013 - pre-production locomotives will be will be put in extended field tests.
- Jan. 1, 2015 - GE will be ready with Tier 4 compliant Evolution Series locomotives.

The GE team is optimistic that they will once again be able to break the emissions – fuel paradigm and deliver a new Tier 4 compliant Evolution Series locomotive that reduces NO_x & particulate matter and does not degrade fuel efficiency.

Electro-Motive Diesel

EMD did not respond to Tier 4 information requests. Research of public sources suggests that they are aggressively pursuing a Tier 4 solution for the 710 series engine. They express that inherent advantages of the 2-stroke design will promote lower NO_x and lessen the need for SCR aftertreatment. EMD is committed to delivering a non-urea system to avoid the increased costs associated with operations and infrastructure. Further enhancements to the fuel system and power-cylinder have achieved substantial reductions in oil consumption and exhaust particulate which will greatly ease the requirements of an exhaust PM reduction system.

There is no publicly documented development schedule, but EMD confirms that they have demonstrated Tier 4 levels in test facilities and are committed to a full engine development and validation program to release a reliable product on time.

Progress Rail

The Progress Rail PR30C is the first locomotive greater than 3000 hp to be packaged with urea-SCR aftertreatment. The PR30Cs are built off of SD40-2 chassis fit with a Tier 2 3,005 hp Caterpillar 3516C-HD V16 engine. A Caterpillar Clean Emissions Module (CCEM) is fit directly over the engine, a Diesel Emissions Fluid (DEF) tank is mounted cross wise behind the fuel tanks, and a dosing cabinet housing a pump and a control module is installed in the front of the rear compartment. The 250 gallon DEF tank is sized to allow one fill for every three fuel refills. The Dosing system, tank, and supply lines are heated to prevent freezing. This conversion alters the external appearance of the locomotive. In addition to the addition of the large exhaust treatment box, the radiator section is replaced with one similar in appearance to that of an EMD SD70ACe.

Five PR30C locomotives revenue freight service in California and Arizona in July 2010 and have accumulated well over 15,000 hours. The engine after-treatment system has demonstrated 0.90 g/bhp-hr NOx and 0.03 g/bhp-hr PM and achieved a 5% fuel economy benefit over a standard Tier 2 3516.

MTU

The Series 4000 will remain as MTU's future engine for line haul and heavy switcher locomotives. At InnoTrans 2010 in Berlin, MTU introduced the latest-generation Series 4000 R84, the first locomotive engine to comply with the upcoming Stage IIIB emission regulations in Europe.

The Series 4000 R84 incorporates both new technologies and concepts that have proven themselves in earlier Series 4000 engines. It maintains the Miller cycle valve timing that was introduced on the Series 4000 R43, as well as continuing the evolution of the high-pressure common rail fuel injection system that has been a hallmark of the Series 4000 since its introduction almost fifteen years ago.

Chief among the new technologies introduced on the Series 4000 R84 are controlled two-stage turbocharging, charge air cooling after each turbocharger stage, and cooled exhaust gas recirculation (EGR). A diesel particulate filter (DPF) completes the emission

reduction strategy. MTU engineers are further investigating the development of these technologies to achieve Tier 4 certification in time for the 2015 effective date of these regulations.

For smaller industrial switcher locomotives, in 2012 MTU is releasing its Tier 4i certified 12V2000 and 16V2000. As with the Series 4000 R84, the Tier 4i Series 2000 adds controlled two-stage turbocharging, charge air cooling after each turbocharger stage, and cooled EGR. In contrast with the Series 4000, the Tier 4i Series 2000 uses high-pressure common rail fuel injection for the first time in Series 2000 engines for industrial and rail applications.

Two key achievements with the Tier 4i Series 2000 are that it meets the Tier 4i limits without any aftertreatment, and that its fuel consumption has been reduced by 10% compared with the existing Tier 2 Series 2000. The same basic engine will be used for Tier 4 Final, with the addition of only a diesel oxidation catalyst (DOC) as aftertreatment. The Tier 4 Final Series 2000 is scheduled for commercial production in 2014.

Cummins

In early 2011 Cummins released its QSK Tier 3 locomotive engines which span from 750–2700 hp. The Tier 3 QSK engines feature a field proven electronic common rail fuel system, charge air after-cooling, and piston bowl designed to meet Tier 3 switcher and line haul emissions without sacrificing fuel economy and reliability. The 700 hp QSK19 has been employed in gen-set switcher applications and Cummins feels that the updated 750 hp Tier 3 model with improved fuel consumption will continue to perform well and greatly reduce operation costs over standard switchers.

Cummins will release the 600 hp Tier 4 QSX15 in early 2012. The new QSX15 will be certified for use in single, double, and triple gen-set switcher configurations up to 1,800 hp. To meet Tier 4, the QSX15 base engine has been re-engineered and up fit with a variable geometry turbo-charger, cooled EGR, a common rail fuel system, and coupled with a particulate filter. The QSX15 will meet Tier 4 emissions without the need for urea infrastructure.

Cummins will release Tier 4 compliant QSK engines in 2015, maintaining all current Tier 3 ratings. These engines will optimize in-cylinder combustion to reduce PM and add urea-SCR technology to the exhaust reduce NO_x emissions. The Tier 4 base engine coupled with exhaust after-treatment will perform as a fully integrated system. SCR technology combined with higher fuel system pressure and optimized injectors and pitons allows balance of the engine to remain unchanged from Tier 3. This approach will retain Tier 3 performance and durability, and deliver a 5-10% decrease in fuel consumption.

The following are excerpts from Tier 4 Diesel Emission Reduction Strategies which was presented by Bruce Wolf at the North American Rail Summit in Montreal Quebec, October 2010.

Engine-Based Emission Reduction

Up to and including the current Tier 3 standards, engine manufacturers have met emission limits by implementing changes within the engine itself. The following sections describe a sample of such engine-based technologies.

High-Pressure Common Rail Fuel Injection

Combustion in a diesel engine takes place when fuel is injected at high pressure into the hot, dense air that has been compressed by the piston in the cylinder. Traditionally, the fuel has been pressurized for injection by individual cam-driven pumps for each cylinder. This results in the injection pressure gradually building up and falling off during the injection event. Lower fuel pressures at the beginning and end of injection can cause incomplete atomization of the fuel spray, forming large droplets that lead to oxygen-poor regions in combustion. This increases PM, CO and HC emissions.

A technology that has been successfully implemented in several engines is high-pressure common rail injection. In this system, a single high pressure pump pressurizes fuel to maintain the optimum injection pressure for all cylinders. This fuel is then delivered to the cylinders by a common pipe, or "common rail", that connects all the injector nozzles to the high pressure fuel pump. This system ensures that full fuel pressure is available from the beginning of injection right through to the end, resulting in improved atomization and more complete combustion. In addition, electronic control of the injector nozzles allows the possibility of injecting a small amount of fuel before the main injection, to reduce noise, as well as post-injection of fuel to help further reduce emissions. The latter can be used in conjunction with possible aftertreatment devices (to be discussed later).

In-Cylinder Combustion Development

As well as increased fuel injection pressure, engine manufacturers have made great improvements in the combustion process inside the cylinder to reduce emissions, increase power and reduce fuel consumption. These improvements have included:

- Optimizing the piston crown / bowl design to achieve a more complete combustion event by controlling the interaction between combustion plume and the cooler piston surface,
- Injector tip design to produce better fuel atomization and targeted dispersion with reference to the piston
- Electronic fuel injection control to optimize injection timing and pressure based on engine speed and load, and
- Valve and head design to minimize restriction to intake air (on a four-cycle engine) and exhaust flow.

Unfortunately, some of these changes can lead to reduction of NO_x emissions at the cost of increasing PM, or vice versa.

Turbocharging and Aftercooling

Turbocharging increases the amount of air entering the cylinder. This leads to increased power by increasing the amount of fuel that can be burned in each combustion cycle. However, the air heats up as it is compressed by the turbocharger, leading to increased NO_x emissions.

The increased air temperature can be mitigated by cooling the intake air after it leaves the turbocharger, and before it enters the cylinder. Charge air coolers have been incorporated which use the engine coolant, a separate low-temperature coolant circuit, or air-to-air cooling using ambient air drawn from outside the locomotive, to cool the compressed air. Cooling the intake air combines the benefits of high-pressure air for increased power, with lower intake air temperature for reduced NOx emissions.

Another development is multiple-stage turbocharging, with charge air cooling after each stage of turbocharging. Used in, for example, MTU's next generation of engines for surface mining, this system could also be applied to locomotive engines.

Miller Cycle

The Miller Cycle is a modification of valve timing on a four-cycle engine to reduce peak cylinder temperatures. This leads in turn to a reduction of NO_x emissions.

In the Miller Cycle, the intake valve is left open until partway through the intake stroke, expelling some of the intake air and reducing the temperature rise during compression. Effective supercharging is required to maintain the ability to produce torque at low engine speeds.

Examples of locomotive engines using variations on the Miller Cycle include EMD's two-cycle engines, including the current 710ECO, and MTU's Series 4000 R43. In the two-cycle engine, the intake ports in the cylinder wall remain uncovered until partway through the compression stroke. In MTU's Series 4000 R43, the intake valve is closed early, rather than being left open partway through the compression stroke.

Exhaust Gas Recirculation

Exhaust gas recirculation (EGR) is another technique used to reduce NOx emissions by reducing peak cylinder temperatures. With EGR, a controlled amount of exhaust gas from one or more "donor" cylinders are diverted from the exhaust stream, cooled in an EGR cooler, and mixed with the intake air before entering the cylinders. The higher specific heat capacity of the water and carbon dioxide in the exhaust gas limits the temperature rise during combustion.

There are a few drawbacks to EGR. Presence of exhaust gas in the cylinder leads to increased PM emissions, often requiring a diesel particulate filter (see below). An EGR-equipped engine can have less power and lower fuel efficiency than an equivalent non-EGR engine. And finally, the presence of sulfur in diesel fuel causes sulfuric acid to form when the exhaust is cooled, leading to corrosion and premature failure of the EGR cooler. This last problem

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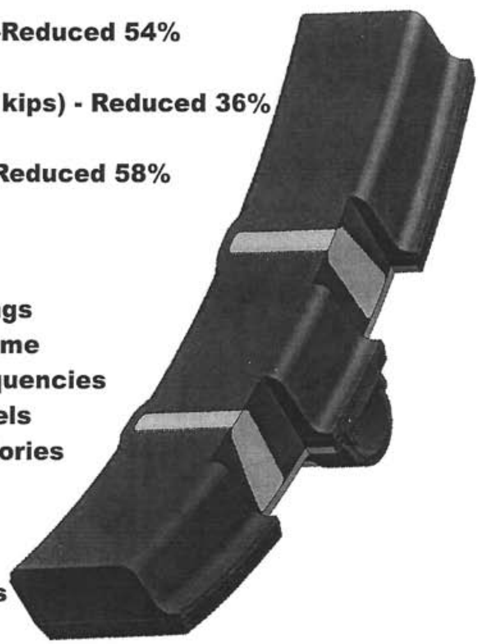

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has largely been prevented through the requirement for only ULSD (Ultra-Low Sulfur Diesel, with no more than 15 parts per million sulfur content) to be used for locomotives by the time the Tier 4 standards come into effect in 2015.

Aftertreatment-Based Emission Reduction

The Tier 4 standards are intended to reduce locomotive engine emissions below what can be achieved strictly by engine-based emission reduction technologies. In order to meet these standards, some form of aftertreatment is likely to be required. The term aftertreatment describes any device in the exhaust stream after the engine, whose purpose is to remove or neutralize pollutants in the exhaust stream.

In general, the cleaner the exhaust leaving the engine, the less aftertreatment is required. This can reduce the volume needed to house the aftertreatment in the tight confines of a locomotive. However, effective aftertreatment can allow the engine to operate in a more fuel efficient - but more polluting - configuration. Choosing the right balance between on-engine exhaust reduction and exhaust aftertreatment is a challenge for engine and locomotive manufacturers.

Diesel Oxidation Catalyst

A diesel oxidation catalyst (DOC) is a passive catalyst chamber inserted into the exhaust stream. It can be used downstream of the turbocharger, or in some engines, in the exhaust manifold between the cylinder heads and the turbocharger. As exhaust passes over the catalyst, CO and HC react with remaining oxygen to form CO2 and H2O. DOC can be very effective at reducing CO and HC. It also has a small effect at reducing PM, but is generally not effective at reducing NO_x.

DOC can be used to condition the exhaust to enhance the function of further downstream aftertreatment. Because the oxidation reactions increase the exhaust temperature, controlled amounts of fuel can be injected into the exhaust upstream of the DOC (or added through post-injection in an electronically-controlled common-rail fuel system) for the specific purpose of raising the exhaust temperature to a level that maximizes the reaction rate in other aftertreatment devices further along the exhaust system.

Diesel Particulate Filter

As its name implies, a diesel particulate filter (DPF) acts as a filter to remove particulate matter from the exhaust stream. Based on its design, a DPF can remove anywhere from 50% to 85% or more of the PM from the exhaust. However, the higher PM removal comes with an increased backpressure, leading to increased fuel consumption in the engine.

As the PM builds up in the DPF the backpressure increases. If allowed to accumulate, the backpressure would soon reach a level where the engine could no longer operate. In order to keep the backpressure within limits, the DPF must be “regenerated” by burning off the PM and turning it into CO_2.

To regenerate, the DPF must reach a relatively high temperature and remain there for several minutes (depending on the amount of PM to be burned off). The use of a catalyst "washcoat" on the filter medium can reduce the temperature needed for regeneration. If the engine's load profile is high enough - for example, a locomotive in line-haul service - the engine's exhaust temperature is often high enough to cause DPF regeneration. On the other hand, an engine whose exhaust temperature is mostly too cold for regeneration - for example, a switcher - must use other means to raise the exhaust temperature. This could involve injecting diesel fuel upstream of a DOC. However, if the exhaust is too cold, even this will not be effective, as the liquid fuel would pass through the DOC without reacting. In this case, a fuel-fired burner upstream of the DPF, or an electric heating element within the DPF, may be required.

Generally, a DPF that can regenerate strictly from the high temperature of the exhaust is called a "passive DPF", while a DPF with a burner or electric heater is an "active DPF". The choice of the type and size of DPF depends not only on the emission characteristics of the engine, but also on a good understanding of how the engine will be used and what exhaust temperature can be expected.

A DPF can be plugged not only by PM, but also by ash coming from engine lubricating oil burned in the cylinder. Minimizing oil consumption and selecting a low-ash oil can help prolong the filter element life. Even so, periodic removal and cleaning of the filter element will be required. Depending on many factors, this cleaning interval may be semi-annual, annual or biennial.

Selective Catalytic Reduction

While HC, CO and ultimately PM are removed through an oxidation reaction, a reduction reaction is needed to convert NO_x back to harmless nitrogen (N_2) gas. In the oxygen-poor exhaust from a spark-ignition engine, this can be accomplished by a passive "three-way" catalyst. However, in the relatively oxygen-rich exhaust of a diesel engine, another strategy is used: Selective catalytic reduction (SCR).

In SCR, an additional fluid is added to the exhaust as a "reductant". This reductant is then mixed with the exhaust, before entering the SCR's catalyst chamber. There, the reductant reacts with the NO_x to convert it to N_2. In existing mobile diesel engine applications, an aqueous solution of urea (commonly known as diesel emission fluid, or DEF, or in Europe as "AdBlue") is used as the reductant. While mixing with the hot exhaust, the DEF breaks down into ammonia, which in turn reacts in the SCR chamber to reduce the NO_x. The amount of DEF injected must be carefully controlled based on the engine's operation (load, speed, temperature, etc.) to maximize the reduction of NO_x, and to minimize the release of unreacted ammonia from the SCR. This "ammonia slip" is also prevented by using a "slip catalyst" to convert any remaining ammonia into harmless N2 and H_2O.

The use of DEF in SCR requires procuring, storing, dispensing and carrying onboard the locomotive another fluid besides those already used. Typically, an SCR-equipped locomotive can expect to use between 5% and 10% as much DEF as it does diesel fuel. An alternative being developed uses hydrocarbons such as diesel fuel as the reductant, rather than DEF. This avoids the infrastructure needed to support a separate fluid, though it increases the consumption of diesel fuel aboard the locomotive.

As with some other catalyst-based systems, SCR can be "poisoned" by sulfur in the fuel. This means that sulfur compounds in the exhaust attach permanently to the catalyst, eliminating its ability to reduce NO_x. This is another reason why only ULSD (Ultra-Low Sulfur Diesel) can be used in most if not all locomotives designed to meet the Tier 4 emission standards.

Constitution and By-Laws Locomotion 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 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 the 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 on 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 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, he may continue to serve as an executive officer and be allowed to elevate through the ranks as naturally as 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 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 distributed, monitoring membership levels and reporting same at 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 Nominating Committee, and General Executive Committee without vote.

D. Furnishing security bond in amount of $5000 of behalf of his/her assistants directly handling Association funds. Association will beat 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 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 its attendees for mutual benefits to the railroad industry. It is understood that the expression of opinion, or statements by attendees in the meetings, and the recording of papers containing the same, shall not be considered as representatives 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 proceeding and business transactions of this Association shall be governed by Robert 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.