

LMOA

Locomotive Maintenance Officers Association

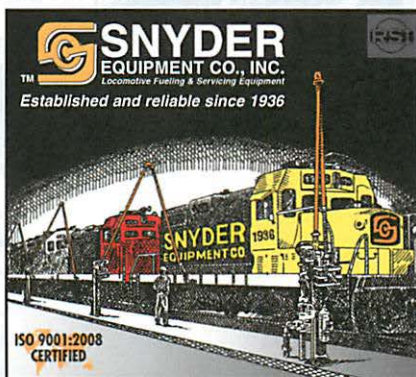
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2014 LMOA MVP RECIPIENTS

The executive board of LMOA wishes to congratulate the following individuals who were selected as the Most Valuable People of their respective committees in 2014

NAME	COMMITTEE
David Brooks, formerly of ZTR Control Systems	New Technologies Committee
Shane Sledge, Norfolk Southern	Diesel Electrical Maintenance Committee
Corey Ruch, BNSF Railway	Fuel, Lubricants & Environmental Committee
Eric Armstrong, Eric Armstrong & Associates	Diesel Material Control Committee
Tom Casper, PowerRail Distribution	Diesel Mechanical Committee

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

LMOA EXECUTIVE COMMITTEE

The Executive Board of LMOA wishes to express their sincere appreciation to the Burlington Northern Santa Fe Railway (BNSF) for hosting the LMOA Joint Technical Committee meetings in Fort Worth, Texas on May 6 and May 7, 2015 at the BNSF Network Operations Center (NOC). Special thanks go to LMOA Past President Brad Queen for coordinating and facilitating the meetings and to Nancy Gandy for making all of the preliminary arrangements and devoting so much time to ensure the success of the meetings.

We also want to extend our sincere appreciation to Daniel McCaslin, BNSF Senior Manager Dispatcher Practices and Rules, for giving a tour of the Operations Center to members of the various LMOA technical committees. Thank you Daniel.

A special thank you also goes out to our 1st Vice President Stuart Olson who set up the hotel accommodations and other preliminary arrangements.

Our sincere gratitude is extended to Paul Foster and the PowerRail Distribution family for hosting lunch on May 6th and to Mark Ritchey of Curry Rail Services for hosting a box lunch on May 7th. Your support of the organization is extremely appreciated.

We also want to give a shout out to Megger Instruments for allowing LMOA committee members to tour their facility in Dallas, Texas on May 6th. The tour was very educational and informative.

**The Executive Board of the Locomotive
Maintenance Officers Association would like
to express their deep and sincere gratitude to LMOA
3rd VP Dwight Beebe of Temple Engineering for
sponsoring an Executive Committee meeting
luncheon at the Palais des Congr s in Montreal,
Quebec, Canada on Tuesday, September 23, 2014.**

**Thanks Dwight for your long and continued
support of the LMOA .**



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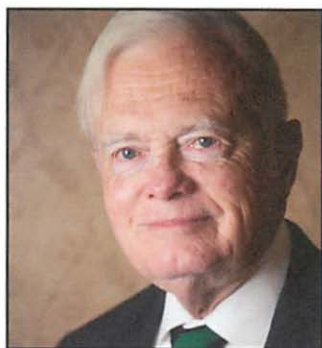
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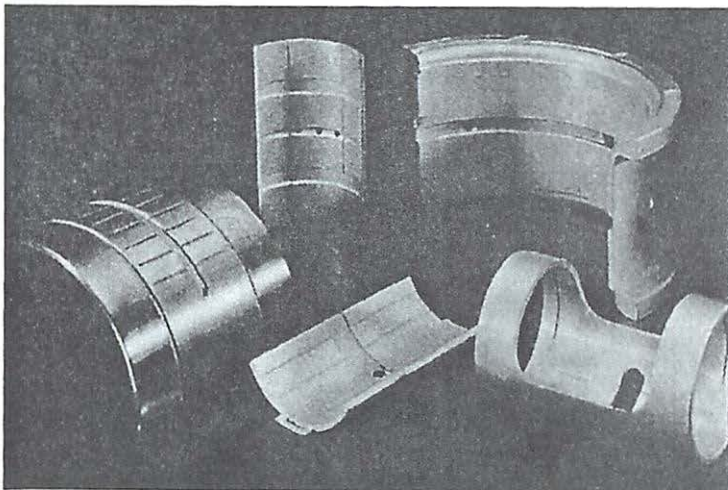


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Omaha, NE 68179



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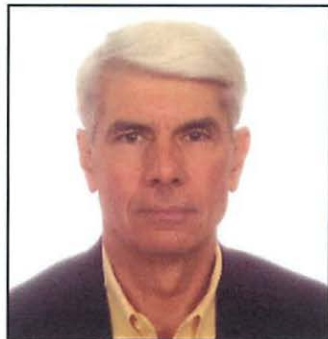
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2014 State of the Union Address

President Dave Rutkowski

Monday, September 22, 2014

1:15 PM

Good afternoon ladies and gentlemen, members of the executive committee, Mr. Secretary, and fellow LMOA members. Welcome to the 2014 RSI/CMA and Canadian Rail Summit in beautiful downtown Montreal, Quebec.

The LMOA organization is seventy-five years old this year and we are still going strong. We all deserve a round of applause for keeping this great organization alive and well.

I'd like to take a moment to reflect back on what was going on in the industry 75 years ago. The year is 1939, a year that really emphasized forward-thinking and looking to the future.

The 1939 World's Fair in New York was the first exposition to focus on the future, with an opening slogan of "Dawn of a New Day", and it allowed all visitors to take a look at "the world of tomorrow".

As for the railroad industry, it was the Dawn of a New Day because in 1939, EMD introduced the "FT" locomotive and the SW1.

The "F" stood for 1400 horsepower and the "T" stood for twin, as it came standard in a two unit set. Between 1939 and 1945, 555 "A" cab-equipped locomotives

were built and 541 "B" cabless locomotives were built.

These units convinced many U.S. railroads that the diesel electric locomotives were the future. Also introduced a DL-109 with a patented 3 window design and Baldwin introduced the VO-1000 switcher with a 1000 horsepower, 8 cylinder engine.

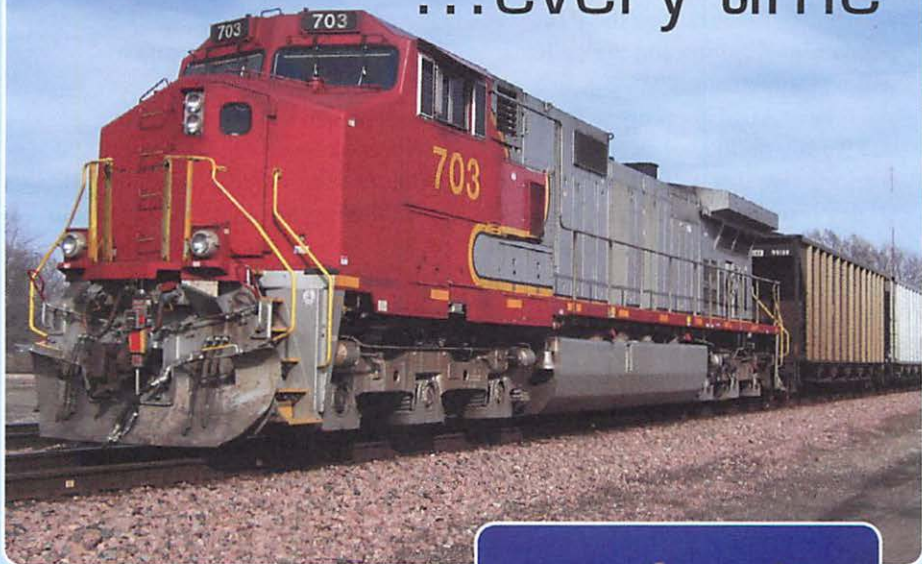
Also in September 1939, Henry Flagler introduced the Florida East Coast passenger train from Jacksonville to Miami, Florida.

Seventy-five years later here we are in 2014 and we've come a long way. Our locomotives are state of the art, more powerful, more fuel efficient than ever and they require less maintenance, like the EMD SD70Ace units with 4300 horsepower and GE with AC4400's which is a 4400 horsepower locomotive.

We also have entered into an environmentally friendly era. Many manufacturers are producing Gen Set locomotives and the industry is exploring Natural Gas (LNG) and Dual Fuel locomotives.

Looking further into our future, we can expect more changes in our industry. New locomotives will need to comply with EPA Tier 4 emissions standards. We will deal with the

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FRA Emergency Order 28 (EO28) that specifically deals with securing unattended locomotives; Positive Train Control will come into effect on December 31, 2015.

Many in the industry have said we need an extension on the PTC regulations deadline and the systems will be problematic.

I have ACSES on my railroad and we run on the northeast corridor. We deal with daily tests, 60 day tests, record keeping, hours of service employees resulting in less productivity for locomotive maintenance, transponder failures, revisions and it goes on and on.

At this time I would like to play a video that Norfolk Southern has created explaining the monumental challenges and hurdles we face with PTC.

Editor's Note: President Rutkowski played video for LMOA members in attendance

So, we have faced similar challenges in the past. In 1928, Mr. C. E. Horsley from the Illinois Central Railroad stated the following in his speech at the International Railway General Foreman's Association meeting at the Sherman Hotel in Chicago, Illinois: "For the past several years, and at the present time, the subject of Federal Inspection of our locomotives has been, and is, one of the greatest problems confronting our Roundhouse Foremen, General Foremen, and Master Mechanics."

Most, if not all, of us today do not consider federal inspections

of our locomotives to be one of the greatest problems confronting us. These inspections may fall into the category of being a pain in our collective backsides, but dealing with them is now just considered "part of the job".

Going back a few years to 1911, the Interstate Commerce Commission's act to eliminate defects on locomotives, tenders and appurtenances was passed. At first the thinking was that this law would retard railroad movement. However, Mr. Horsley believed that this was one of the best laws ever passed for a Mechanical Department's benefit.

Although the challenges we face with PTC are far greater than those we have faced in the past, I suggest that if PTC is here to stay, we may need to reflect back on how we, as an organization and as an industry, have dealt with legislated mandates and look forward to the future where PTC will be dealt with as just "part of the job" because of the efforts of this organization and the industry as a whole.

We can also be assured that some new legislation will be passed that will replace PTC as the focus of future LMOA meetings and technical papers.

In closing, I think this has been a great year with only better things to come. This past May we held our joint technical committee meetings in Scranton, PA at the Radisson Hotel, which was originally the historic Erie-Lackawanna Railroad Station. It was a great venue and a terrific

meeting with over 60 participants. Thanks to PowerRail Distribution for sponsoring the meetings and for all they do supporting the LMOA website. I want to thank my wonderful and loving wife, Katarina, for all her support throughout my career.

I want to thank the executive committee, the chairmen of each committee and their respective members, and our Secretary-Treasurer, Ron Pondel, for all the help I received this year. As always, Ron has stepped up to the plate and hit another grand slam in 2014. Thank you Ron for making my Presidency a smooth ride.

It was a pleasure serving as your President and I want to thank all of you for your continuing efforts on behalf of the locomotive industry.

Acceptance speech

Bob Harvilla

Tuesday, September 23, 2014

9:00 AM

Good Morning

The first thing I would like to do is thank Dave Rutkowski for his leadership and hard work this year as our President. I think we should give Dave a round of applause for a job well done.

The Locomotive Maintenance Officers Association was formed in 1939, which means we are celebrating our 75th year in existence. This is quite an achievement, and caused me to think about some of the things the LMOA has faced, and some of the accomplishments of our fine organization over the last 75 years.

The LMOA was formed for the express purpose of providing a forum and an avenue for railroad professionals to meet and discuss issues and opportunities to improve the reliability and value of locomotives. The LMOA gives railroaders and railroad suppliers the venue to share problems, solutions, and best practices for the betterment of our industry.

Think about what was happening in 1939. Europe was already ablaze in war, and our countries were about to find themselves plunged into World War II fighting for our freedom and our very way of life. Railroads were at the very heart of this fight. Providing not only raw and finished

goods to feed the war machine, but also providing the primary source of domestic troop movement. Of course reliable locomotives were critical to this effort. I don't think it's too much of a stretch to imagine that the founding Fathers and earliest members of the LMOA were instrumental in helping our countries to prevail. It makes me very proud to be a member of the LMOA.

The LMOA has helped locomotive maintainers overcome many obstacles over the years.

In the 1940's and 50's Mechanical Department personnel that had spent their entire career maintaining steam locomotives suddenly found themselves maintaining fleets of diesel electric locomotives. It must have been a daunting task, but the LMOA was there to help.

Changes to locomotives over the years have presented many challenges, such as turbo charged engines, computerization, EPA requirements, and in just the last few years Positive Train Control. The one constant was that the LMOA was always there to help.

The LMOA is about hard work and value added. We are about the value added to our Industry, by helping to improve locomotive

reliability we help our Industry stay competitive with trucks and other modes of transportation. We are about value added to our companies, for Railroaders the information and best practice learned from LMOA involvement helps to improve locomotive reliability and availability which is key to Railroad profitability. Suppliers use their LMOA experience to learn about new opportunities and develop relationships with customers to the betterment of their companies.

Presently the LMOA is on very solid footing. We have a dedicated and experienced Executive Committee, strong Technical Committee leadership, and generally well stocked committee rosters. Most importantly we have solid backing from the Railroad Mechanical Depts., and the CMO's. and I would like to encourage the CMO's to continue to view us as an asset and a tool to be used for locomotive maintenance issues.

I have no doubt that the LMOA will continue to be relevant in the future, and I wish I could be there in 2089 when the new president of the LMOA gives her acceptance speech and she talks about all the things the LMOA will have accomplished in the next 75 years.

I would like to thank Ron Pondel for all he does for the LMOA. We wouldn't be the outstanding organization we are today without his efforts. Thank you Ron.

I would also like to thank my employers over the years for supporting my involvement in the

LMOA. Certainly none more than my present employer, and I would like to thank Paul Foster for all he does for the LMOA both out front and behind the scenes.

And I would like to thank my lovely wife Barb. I know for certain I would not be anywhere near here without her love and support over the years. Thank you dear.

She also knows how to keep me humble. Not long ago I was working on these notes, and I said "I hope I can deliver a good speech". She looked at me and said "just keep it short and everybody will be happy."

As I said the LMOA is about hard work. We have done some great things in the past, and I'm sure we will do great things in the future, and right now we have much to do in the present. So let's get back to work.

Thank You

Report on the Committee on Diesel Electrical Maintenance

Monday, October 5, 2015 at 10:00 A.M.



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Tom Nudds

Manager-Training & Development
ZTR Control Systems, London, Ontario

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PERSONAL HISTORY

Tom Nudds

Training and Development Manager
ZTR Control Systems

Tom was born in London Ontario and attended Fanshawe College there. He joined General Motors Diesel (EMD London) in 1971 and was at GMD for 17 years. His work experience includes Locomotive and Titan electrical assembly, Locomotive Test, Armoured Vehicle Test, Production Supervisor, Quality Assurance, Receiving Inspection Supervisor and Locomotive Test Supervisor. In 1988, Tom joined four other former GMD employees to start a company called Trac Rail which became ZTR Control Systems. His position currently is Training and Development Manager at ZTR.

Tom lives in London with his wife Mary Lou, a Bouvier Des Flandres and two Siamese Cats. He has two children and four grandchildren. Tom enjoys his motorcycle, photography and IPSC shooting sports.

The Diesel Electrical Maintenance Committee would like to extend their sincere appreciation and gratitude to the Norfolk Southern for hosting the committee's meeting in February 2015 in Chattanooga, TN.

The committee would also like to sincerely thank Bach Simpson and ZTR for hosting the summer meeting held in London, Ontario in July 2015.

These meetings could not be held without the support of companies such as Norfolk Southern, Bach Simpson and ZTR.

Modular Hardware & Software

*Prepared by:
Amarjit Soora, ZTR*

The past many years have seen a proliferation of electronic and microprocessor based systems added to locomotives. The driving factors for this phenomenon are varied and as diverse as the railroads themselves.

- Because of microprocessor based technologies, locomotives and their operators are working more safely.
- Microprocessor technologies are being used to replace low reliability legacy systems and at the same time, enhancing performance of the locomotive to its designed maximum.
- Microprocessor technology is used to reduce fuel consumption and the locomotives' negative impact on the environment.
- These same technologies collect data that can be used to understand how locomotives actually work and are being utilized. They can be used to monitor operating characteristics of not only the individual locomotive, but the collective fleet as well. Connectivity with back office and other locomotives can be used to improve fleet efficiency and the railroad's operations and performance.
- Many times, microprocessor technology is the only effective way of complying with legislation, both at the state and federal levels.

Whatever your driving factor, be it safety, reliability or any of the many reasons we just touched on, the traditional approach to using microprocessors is to define the problem and design a system that precisely solves that problem. Systems installed on locomotives are inherently application specific. They are often single purpose. They are not designed to be integrated into or with other systems – either on the locomotive or within the railroad's offices. Enhancements and/or expansion to the system can be difficult and costly. In some cases, it will be impossible. Yet the nature of our business is one of striving for continuous improvement. What happens when the specification, the problem and/or the business environment changes?

There is precedence. When computers first emerged, they too were designed as complete systems. You purchased a predefined product with a certain size power supply, certain amount of RAM and permanent memory and computing power. The operating software was predefined for you and the application software was either limited or had to be custom designed for you. These computers were intended to appeal to certain industries or segments of our population. This

embryonic stage of computer technology was successful. They created an environment that allowed their users to achieve more, to be more efficient and to handle expansion faster and with more confidence. However, this also created the conditions where many users demanded more performance specific to their own requirements

Computers became modular. Companies were able to purchase a computer with the absolute minimum requirements. These included the CPU and mother board, the power supply, memory, hard storage and a video card. The major advancement here was that any one of these devices could be replaced with similar components more suited to the company's requirements. The sweeping game changer however was the expansion slots built into the motherboard. With this development, the user could now add more memory, faster video cards and new radical technology such as discrete input and output cards, modems, Ethernet and a multitude of other serial communication interfaces.

How can our industry benefit from this precedence?

If we look at typical locomotive control systems, we can expect to find the traction control system, the discrete logic control system, event recorder, vigilance and alerter systems, electronic air brakes, one or several operator displays, automated engine shutdown and start systems, and engine speed or injection controllers. Historically, many of these microprocessor based systems and sub-systems are designed as silos. They operate in

isolation of other systems. These systems may be designed and applied by different suppliers.

What if we started with basic building blocks using the concept of the PC? Let's design a control system with a CPU, generic discrete inputs and outputs as well as analog inputs and outputs. What if we added expansion capability that allowed adding radical capabilities like Ethernet, video and more I/O? What if, just like modern computers, we designed application specific modules that not only perform application specific tasks, but does so while communicating and sharing expensive and valuable information and physical integration into the locomotive?

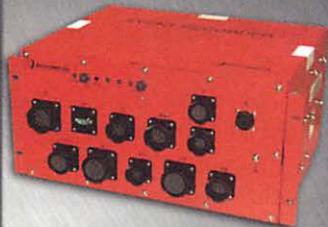
From an application standpoint, this can be a fundamental change to how a railroad approaches enhancements to its fleet. Locomotives, especially older ones, may have a myriad of enhancement opportunities. The most pressing are those that are legislated and/or safety related. These requirements are followed closely by opportunities that impact the railroad's profitability, such as locomotive reliability, performance improvement and fuel consumption. Corporate realities such as volume, growth, cash flow and ROI, both actual and targeted, influence how resources and cash are allocated to any given project. Project managers can be put in a position where they need to choose between a smaller project that solves an immediate problem, knowing that future enhancements and expansion will be cumbersome, and a larger project that meets the long term



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needs of the railroad, but that cannot be adopted due to fiscal and resource realities of the railroad.

If the project manager is confident that he/she is investing in a smaller system that will solve the immediate need and yet, economically and effectively, offer expansion and enhancements as required, the decision becomes easier to make, easier to promote and easier to adopt. An example of this includes:

- Designing an automatic shutdown and restart system
 - o Later adding a vigilance system, taking advantage of the AESS' existing inputs (i.e. throttle, direction, etc.)
 - o Later adding a communication interface to the locomotive's LIG.
 - o Etc.

There are other benefits. Systems designed to solve a problem on one locomotive model can be fundamentally transferred to another model, solving the same problem even though the physical requirements of that locomotive are different. Examples include:

- Designing a traction control system for a four axle locomotive
 - o Later porting the technology effectively and efficiently to a six axle locomotive.
 - o Later porting the technologies from a GETS locomotive to an EMD locomotive (or vice versa).
- Designing an excitation controller for a DC generator
 - o Later porting the technology effectively and efficiently to

an AC generator equipped locomotive

- o Later porting the technologies from an EMD locomotive to a GETS locomotive (or vice versa)

We expect many beneficial spin-offs with this new approach.

The logistics of stocking spare parts for locomotive control systems are expected to be simpler as they all share the same CPU and basic interface modules.

Repairs to locomotive microprocessor based controls are expected to be more efficient as one is no longer repairing the entire control system. Repairs are now confined to a specific module.

Exposure to obsolescence will be reduced. If modular components are designed with generic specifications, advancements in technology can be adopted with little or no impact on legacy systems. Components from different generations of technology can be interchangeable.

When adding functionality with the modular approach, the diagnostics for the whole new system can be updated at the same time.

We expect instant integration to existing information management systems and operators. This occurs because expansion will utilize the locomotive's existing HMI (Human Machine Interface). It will use and be compatible with existing operator interfaces such as laptops. If the original system has remote connectivity, the enhancement will naturally integrate into the existing connectivity.



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Finally and potentially the most significant benefit, is the reduced stress on the shareholders. Since the fundamentals of the basic system are always constant, there is less training expense and simpler logistics with your maintenance personnel, locomotive operators, the operations department and the back office integration staff.

And in our business, less stress is always welcome.

Idle Reduction on GE Locomotives

Prepared by:
Shane Sledge, Norfolk Southern

Locomotive engines cannot use antifreeze in their cooling systems. Unlike car or truck engines, the anti-freeze damages the engine components. Therefore, in the past, to prevent freezing during cold weather, a locomotive engine must either be working or idling. A freeze-damaged locomotive engine can cost hundreds of thousands of dollars to repair (http://www.gwrr.com/about_us/community_and_environment/gwi_green/

auxiliary_power_units_apus).

This paper will review two major options for anti-idling, and then discuss how one of the options, Auto Engine Start Stop (AESS) systems are implemented on later model GE locomotives.

Back in the dawn of diesel locomotive time, diesel fuel was \$0.50/gallon and nobody cared about emissions. Locomotive engines were designed to run forever and never stop. With a water cooled engine, they couldn't

GADK Locomotive Group

Fuel Consumption

	Notch											DR	Low k/hr
	k/hr	1	2	3	4	5	6	7	8	9	10		
SW1000/01	3	5	6.1	13.4	22.2	31	39.9	49.7	60.2	-	-	-	-
SW900	3.1	5.2	6.4	13.9	23.7	32.9	41.1	51.6	62.9	-	-	-	-
SW1200	3.3	5.1	6.3	13.8	23.1	29.6	41.3	54.4	68.9	-	-	-	-
SW1500	3.8	6.5	11.5	25.2	38.6	52.5	62.1	79.6	92.6	-	-	-	-
MP15DC	3.8	5.8	13.6	24.1	35.8	48.3	61.9	75.1	87.9	-	-	-	-
MP15AC	3.8	5.8	13.6	24.1	35.8	48.3	61.9	75.1	87.9	-	-	-	-
GP15-1	3.8	5.8	13.6	24.1	35.8	48.3	61.9	75.1	87.9	-	-	-	-
GP9	3.5	4.4	13.4	23.6	36.8	56	67.7	82.2	108.1	-	-	-	-
GP10	3.5	8	15	25	39.7	54.5	70	88	108	-	-	-	-
GP8B	4.6	7	16	31.4	46.8	63.8	83.1	102.8	122.4	15	3.8	-	-
GP/SD19-3	4.6	7	16	31.4	46.8	63.8	83.1	102.8	122.4	15	3.8	-	-
GP40/-3	5.5	7.4	24.9	41.4	57.2	79	108.5	145.8	167.7	21	4.3	-	-
GP40-3	5.2	9.3	25.4	44.1	60.5	79.7	100.2	133	164.4	18.4	4.1	-	-
GP30	3.5	7.2	18.9	31	44.9	61.1	75.2	102.1	124.9	-	-	-	-
GP25	5	11	20.9	34.9	51.2	72.1	96.2	124.3	143.6	-	-	-	4
GP19-2	4	6	19	32.2	44.8	59.3	78.5	107.5	128.8	16	-	-	-
SD30	2.9	15.1	23.9	51.9	79.3	96.2	125.7	162.5	178.2	-	-	-	-
SD40-3	5.5	9.1	24.9	41.4	57.2	79	108.5	145.2	167.7	21	4.3	-	-
SD45	6	9.8	28.1	47.8	67.5	91.7	127	171.5	194	25	4.7	-	-
SD40	3	12	23	48	66.6	88	135	160	183	11	-	-	-
SD70M	3	11.7	23	46.6	64.1	87.3	130.7	164.5	189	5.7	-	-	-
B40-B	3.4	16.1	22.7	47.3	72	99.8	129.5	162	193	3.9	-	-	-
C40-B	3.4	16.1	22.7	47.3	72	99.8	129.5	162	193	3.9	-	-	-
C44-B	3.4	11.8	26.8	54.6	78.9	109.7	140.5	171.6	211.2	3.4	-	-	-

Gallons / Hr.

freeze without being damaged. The two stroke engine burned oil at 1/100 the rate of fuel use, they were dirty, producing high amounts of particulates, NOx, and sulfur. These engines became the workhorses of the industry. It was standard industry practice to idle locomotives for days, even weeks, at a time.

Today we live in different times. Fuel is much more expensive, so idle reduction results in significant savings. We have become aware of the damaging effects of pollutants, both on human health, and the health of the rest of the planet. As a result there are increasing demands across the industry to reduce idling of locomotives.

There are a number of different ways to reduce locomotive idling, while still keeping the locomotive engine warm enough to allow the engine to start smoothly. The two most popular methods are Auto Engine Start Systems (AESS) and Auxiliary Power Units (APUs).

The Auxiliary Power Unit, or APU, is a small diesel engine that automatically operates via computer control. To prevent freezing of the main engine, whenever the main locomotive engine is shut down and ambient temperatures are close to or below freezing, heat from the small engine is transferred to the larger engine. The APU keeps the main engine warm, reducing idling, and the resulting fuel consumption and emissions.

A typical locomotive main engine may burn up to five gallons of diesel fuel per hour while idling. An APU consumes as little as one gallon. This results in significant savings.

Short line railway group, G&W, monitored data for a 15-month period from one of its Canada Region locomotives equipped with an APU. Fuel savings averaged more than 20 gallons per day. In addition, over a typical year, the APU can significantly reduce emissions. Emissions reductions from one locomotive with an APU installed can be more than 80 tons of nitrogen oxides, 12 tons of carbon monoxide and three tons of particulate matter (http://www.gwrr.com/about_us/community_and_environment/gwi_green/auxiliary_power_units_apus).

Auto Engine Start Systems (AESS) is another computerized option. The idea behind an AESS is to provide a computerized system to monitor environmental conditions, to sense the operating state of the locomotive, and to start up or shut down the locomotive as required. The purpose of the system is to prevent damage to the locomotive during hazardous cold weather conditions and to reduce fuel consumption on locomotives that remain in a prolonged idle state. (http://www.elconinc.net/pdf/auto_start_stop_specs.pdf)

With an AESS system, the locomotive engine is shut down after set idle time. Typically operator intervention not required. Fuel use, emissions, and noise levels are avoided during shut-down. However, no cab comfort provided while engine is off (Lynda Gaines -<http://www.transportation.anl.gov/pdfs/RR/290.pdf>).

AESS systems typically monitor water temperature, brake pressure, and battery charge. The engine restarts if any parameter out-of-range.

From an operational savings perspective, AESS systems are most effective in warmer climates. When the temperature drops below 40oF/4oC, the engines will run constantly regardless of whether an AESS system exists. At that point, the APU or other external engine heating options become more cost effective (Lynda Gaines - <http://www.transportation.anl.gov/pdfs/RR/290.pdf>).

There are specific recommendations from the AAR with respect to how AESS systems should be implemented (AAR S-5502).

How these requirements and recommendations are implemented vary from manufacturer to manufacturer, both on the OEM and the aftermarket side.

Here are the basic conditions for shutting down the locomotive in an AESS state:

- Reverser centered
- Engine in idle
- Ec switch not in jog
- Ind. or Auto brake applied
- Speed ind. At 0 Mph
- Not in self load
- Oil temp. between 160 and 230 oF
- Battery regulation between 3 and 150 amps
- Battery voltage between 69 and 74 volts
- No more than 8 auto shutdowns in 24 hrs
- Air compressor at 0 Rpm's (the numbers listed above may be different depending upon customer desires).

Before the unit will shutdown there will be an alarm bell that will sound to warn of the shutdown. There will also be a message displayed on the computer screen that will indicate a shutdown is about to occur.

An AESS shutdown can also be suspended by the crew by pressing the SASS button located on the back panel. The shutdown will be suspended for up to 120 minutes. This message will also be displayed on the computer screen.

Here are the basic conditions for an AESS start up:

- Engine in Auto Stop state
- Throwing reverser with GFB up
- Battery voltage drops below 63 volts
- Release of Ind or Auto brake
- Main reservoir drops below 105 PSI
- Rolling locomotive
- Ambient Air Temp. less than 40 degrees (the numbers listed above may be different depending upon customer desires).

Before the unit will start up there will be an alarm bell that will sound to warn of the startup. There will also be a message displayed on the computer screen that will indicate a startup is about to occur.

An AESS can also be prevented by holding the SASS button in for a few seconds. Once this is done, the unit will have to be manually restarted.

Also, if at any time the EFCO is depressed this will nullify the AESS system then requiring a manual restart.

In conclusion, with soaring fuel prices and EPA emission restrictions, AESS is an ideal tool. With the AESS system active, the locomotives will idle less often therefore saving fuel and lowering the emissions output.

The Ghost in the Machine: EMI on Your Locomotive

Prepared by:

*Brandon Locklear, CSX, Joe Whitmer, DMVW RR and
Peter Scholtens, TMV Control Systems*

Imagine sitting in a Cadillac convertible in the early eighties, drafting behind a transport truck. You're feeling good because the cylinder deactivation in the so-called variable displacement system in V-8 engine is saving you fuel, reducing the amount of fuel going to the engine. Suddenly, the car jumped forward as the 4 cylinders that had not been receiving fuel were suddenly fully supplied. Cursing the new technology, you slam on the brakes to keep from running into the rear of the truck.¹

On another day in the nineties you happen to be chatting with a Canadian friend who is an engineer for VIA Rail, the passenger rail service in Canada. He tells you that, for some unknown reason, VIA's LRC (*Light, Rapid, Comfortable* or *Léger, Rapide, et Comfortable*) locomotives, on their route from Toronto, ON, to Montreal, QC, would coast to a stop near Belleville, ON.² After inspecting everything and finding nothing wrong, the engineer would restart the unit and the consist would proceed on its way.

These are both examples of Electro-magnetic Interference (EMI). EMI, at its most basic, is any undesirable electromagnetic emission or any electrical or electronic disturbance, man-made or natural, which causes

an undesirable response in electrical equipment.³ There are numerous examples that we are familiar with from ordinary life. For instance, the buzz or reduction in volume that you experience on your AM radio when driving underneath high-tension power lines is caused by electromagnetic interference. The flickering of an analog TV screen and the scratchiness heard over TV and radio speakers during an electrical storm are caused by electromagnetic interference.

At times, the existence of EMI can seem very mysterious, hence the title of this paper, "The Ghost In the Machine".⁴ This paper will focus on three main topics: first, a brief historical review of the issue, second, an analysis of the categories and possible causes of EMI, and third, a small collection of case studies of EMI on locomotives.

Historical Review

EMI, and its corollary, Electromagnetic Compatibility (EMC) is a relatively recent field of study in electrical engineering. While there are instances of EMI recorded in the 19th century (for instance, the Carrington event, a solar storm in 1859, created havoc with telegraph systems⁵), it wasn't till the second half of the 20th

century, when the use of radio, electrical, and computer systems became common, that EMI issues arose on such a regular basis.

Some of the more famous historical events where EMI was an issue took place at this time.⁶ For instance, on July 29, 1967, a Zuni rocket was accidentally fired from an F-4 Phantom on the deck of the U.S.S. Forrestal, an aircraft carrier serving in the Vietnam War. The resulting explosions started a fire that ultimately killed 132 crewmen and injured 62 more. The accidental firing is believed to have been triggered by a combination of the powerful fields at deck level from the ship's radar and an incorrectly fitted shielded cable connector.⁷

In another incident, on May 4th, 1982, during the Falkland Islands War, the H.M.S. Sheffield's search radar was turned off due to electromagnetic interference problems with the ship's satellite communication system.⁸ This disabled the ship's anti-missile defense systems and enabled an Exocet missile to hit the ship, resulting in the loss of the ship and 20 lives.⁹

Finally, in 1987, while flying past a radio broadcast tower in West Germany, a U.S. Army Sikorsky UH-60 Blackhawk helicopter experienced an uncommanded stabilator movement. Subsequent investigation showed that the stabilator system was affected by EMI. In fact, there were numerous instances of Blackhawk helicopters flying too near radio transmitters crashed killing or injuring all on board. The Navy version of the Blackhawk, the SB-60 Seahawk was hardened against

the severe EM environments of ships and did not experience the same EMI problems as the Blackhawk.¹⁰

Subsequently, since the advent of cellular phone technology, there have been numerous instances of wireless communications affecting instrumentation and equipment in airplanes, hospitals (including operating rooms and patient care facilities). It is a little disconcerting to realize that your cell phone could be the cause of your parent's medicine being delivered improperly from a pump in their hospital room because the medical device manufacturer did not consider the impact of EMI. As a result, federal regulatory agencies in the USA have released a number of directives with respect to the impact of radiation. These have been issued with respect to both aviation and medical devices.¹¹

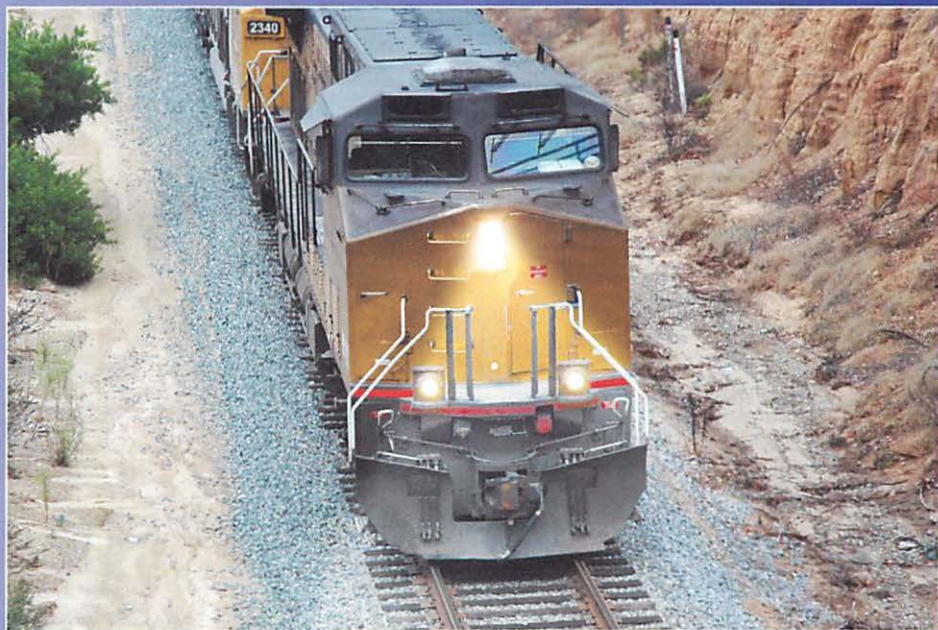
As for the rail industry, as wireless devices, along with the radio waves that they generate, proliferate across the landscape, awareness of these issues will become increasingly important. In addition, manufacturers of electrical equipment do not always consider the impact of the EMI that their equipment generates on other equipment in the vicinity. Overall, this is and will continue to be an issue for anyone involved with locomotive electrical systems and the purchase and installation of aftermarket electronic components. For this reason, anyone involved with operating and maintaining locomotives should have, at the very least, some understanding of EMI, its causes, and possible solutions to eliminate or reduce its effects.



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EMI: Categorization and Causes

To elaborate on the earlier definition that EMI is unwanted signal on a receiver, EMI is a disturbance caused by an electromagnetic field which prevents the proper performance of an electrical device. It can come from man-made or natural sources. However, most EMI that causes trouble on locomotives is caused by stray magnetic or electrical fields generated by machinery or electrical equipment.¹²

There are two aspects to consider with respect to EMI and installing locomotive electronics, (1) emissions, and (2) susceptibility (or immunity). Emissions refer to how much EMI is produced by a piece of equipment.¹³ Susceptibility (and its converse, immunity) is how sensitive (or insensitive)

a system is to unwanted EMI. Ideally designers of locomotive electronics are considering both aspects, working to reduce emission from their equipment, increasing the immunity of their equipment, while considering the susceptibility of the equipment installed nearby and reducing the level of EMI produced by their equipment.¹⁴

EMI is divided into two categories of interference:

Continuous Interference: This type of EMI generally arises from a source such as a circuit that is emitting a continuous signal. On a locomotive this can be in the form of an AC wave from equipment such as companion alternator, an inverter, or even an AC traction motor. In fact, there have

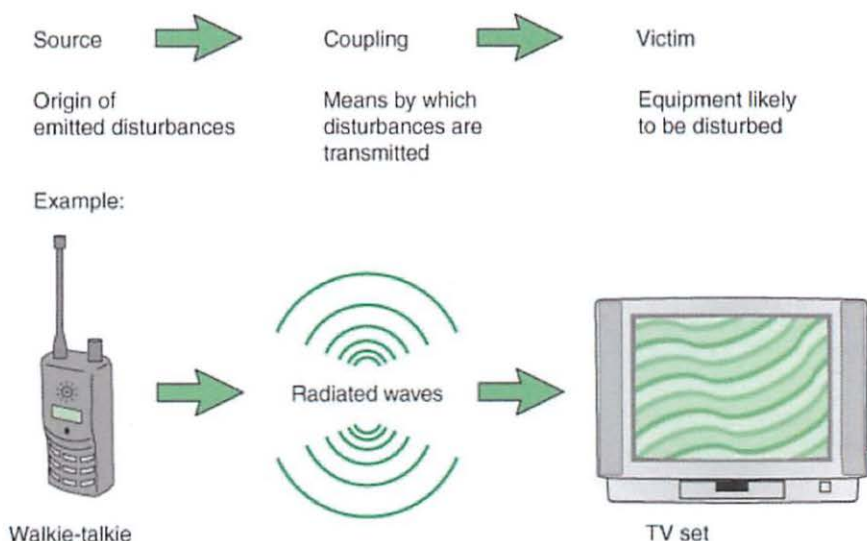


Figure 1: A summary of the EMI phenomenon
 (Source: http://www.electrical-installation.org/en/wiki/Coupling_mechanisms_and_counter-measures)

been situations noted where the cab signalling has reported false information because of interference from AC motors.¹⁵ Loading of these AC circuits will also increase the disturbance effect created.

Impulse interference: Intermittent, fast burst interference often caused by a singular electrical event (like a lightning strike). Sharp changes in currents can cause this, particularly in switches and contactors controlling current to traction motors.

Further, EMI can be split into two other categories, man-made, which is generated from electronic systems and circuits, and naturally occurring EMI. With locomotives we are most strongly interested in the man-made form because of the number of onboard systems and the radiation they can emit. However, as some examples have highlighted, we need to be aware of external sources that can be troublesome. These may be high powered microwave or radio sources along the right of way.

Finally, coupling, or the transmission of EMI, is the method through which this interference is transferred from source to victim circuit.

EMI takes place in many different electrical environments. The different sources of disturbances are:

Radio-frequency emissions:

- wireless communication systems (radio, TV, CB, radio telephones, remote controls)
- Radar

Electrical equipment:

- High-power industrial equipment (induction furnaces, welding machines, stator control systems)
- Office equipment (computers and electronic circuits, photocopy machines, large monitors)
- Discharge lamps (neon, fluorescent, flash, etc.)
- Electromechanical components (relays, contactors, solenoids, current interruption devices)

Power systems

- Power transmission and distribution systems
- Electrical transportation systems

Lightning

- Electrostatic discharges (ESD)
- Electromagnetic nuclear pulses (EMNP)

As you can see, aside from lightning and nuclear magnetic pulses, these are all commonly found on board your nearest locomotive, and even lightning is a definite possibility to consider when running into problems.

The potential victims include:

- Radio and television receivers, radar, wireless communication systems
- Analogue systems (sensors, measurement acquisition, amplifiers, monitors)
- Digital systems (computers, computer communications, peripheral equipment)

Again, each of these types of systems are commonly found on board a locomotive. The combination of these two factors makes the locomotive environment an ideal place to find incidents of EMI.

So what is it specifically that causes EMI? It is an electrical phenomenon called coupling. While coupling is useful and helpful in many situations, unwanted coupling causes EMI.

EMI can couple (or travel) 4 different ways. The different types of coupling are:

- Common-mode impedance (galvanic) coupling
- Capacitive coupling
- Inductive coupling
- Radiated coupling (cable to cable, field to cable, antenna to antenna)

Each of the types of EMI are quite different, and attempts to mitigate one type can create situations where another type is more likely to take place.

The following is a more detailed examination of the different types of coupling that can cause EMI.¹⁷

Common-mode Impedance Coupling

Common-mode impedance coupling takes place when two or more devices are interconnected by the power supply and communication cables (see Figure 3). When external currents, either natural or unnatural, flow via these common-mode impedances, an undesirable voltage appears between points A and B (which are supposed to be equipotential). Low-level or fast electronic circuits are particularly susceptible to this stray voltage.

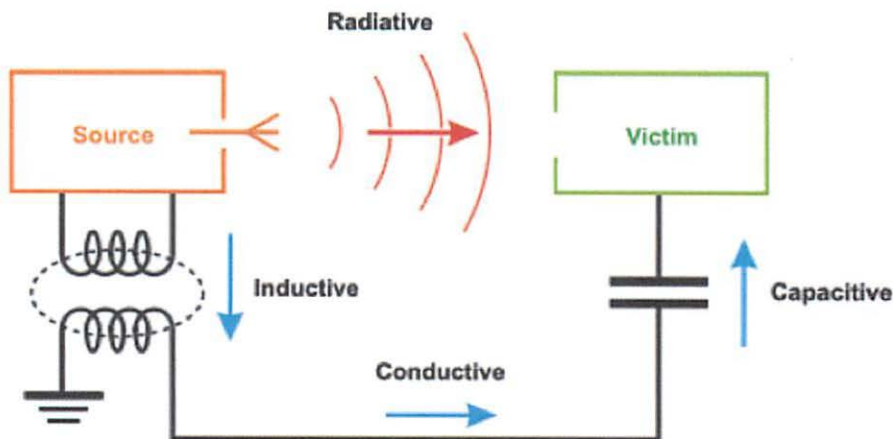


Figure 2: Illustration of the 4 types of coupling

(Source: Source: http://en.wikipedia.org/wiki/Electromagnetic_compatibility)

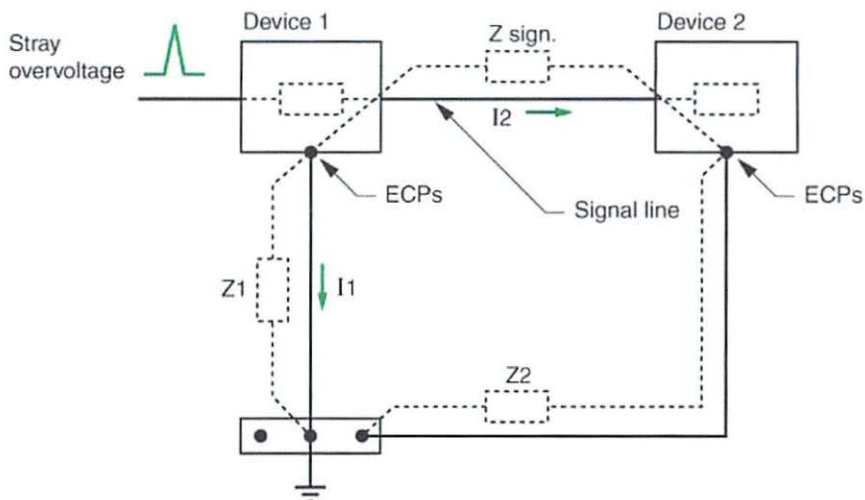


Figure 3: The stray overvoltage flows to the earth via Z_1 . The potential of device 1 increases to $Z_1 I_1$. The difference in potential with device 2 (initial potential = 0) results in the appearance of current I_2 . (Source: http://www.electrical-installation.org/enwiki/Coupling_mechanisms_and_counter-measures)

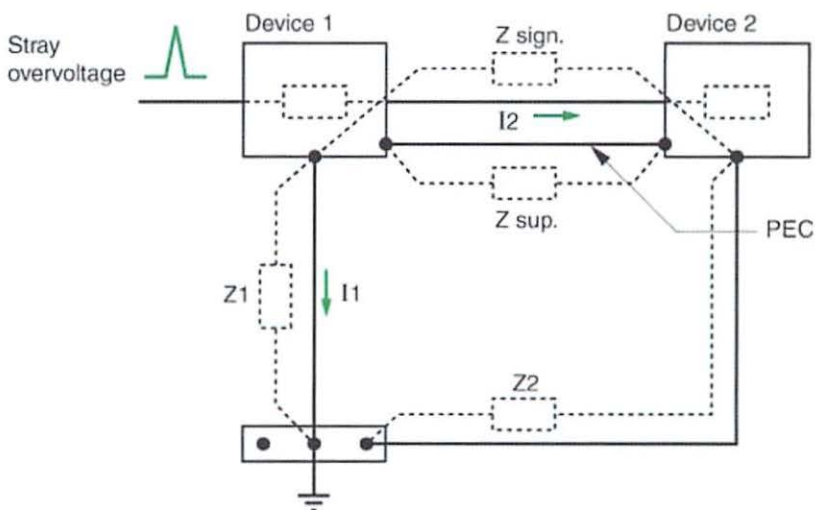


Figure 4: If the impedance of the parallel earthing conductor PEC (Z_{sup}) is very low compared to Z_{sign} , most of the disturbing current flows via the PEC, i.e. not via the signal line as in the previous case. The difference in potential between devices 1 and 2 becomes very low and the disturbance acceptable are likely quite fascinating to the average electrical engineer, fortunately for the rest of us, mitigation of the EMI created by the four types of coupling is quite similar. (Source: http://www.electrical-installation.org/enwiki/File:Fig_R24.jpg)

Counter-measures to common-mode impedance involve making the impedance as low as possible. Methods to reduce common-mode impedance includes:

- Using short cables or flat braids which, for equal sizes, have a lower impedance than round cables
- Installing functional equipotential bonding between devices.

Capacitive Coupling

Capacitive coupling is the transfer of energy within an electrical network by means of the capacitance between circuit nodes.¹⁸ The level of disturbance depends on the voltage variations and the value of the coupling capacitance between the disturber and the victim.

Capacitive coupling increases with:

- The frequency
- The proximity of the disturber to the victim and the length of the parallel cables
- The height of the cables with respect to a ground referencing plane
- The input impedance of the victim circuit (circuits with a high input impedance are more vulnerable)
- The insulation of the victim cable, particularly for tightly coupled pairs

Countermeasures to capacitive coupling include:

- Limiting the length of parallel runs of disturbers and victims to the strict minimum

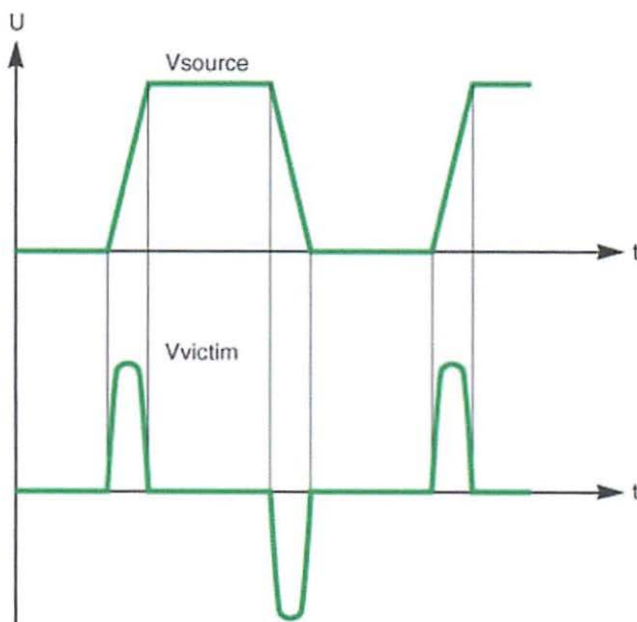


Figure 5: Typical result of capacitive coupling (capacitive cross-talk).
(Source: http://www.electrical-installation.org/enwiki/File:Fig_R25.jpg)

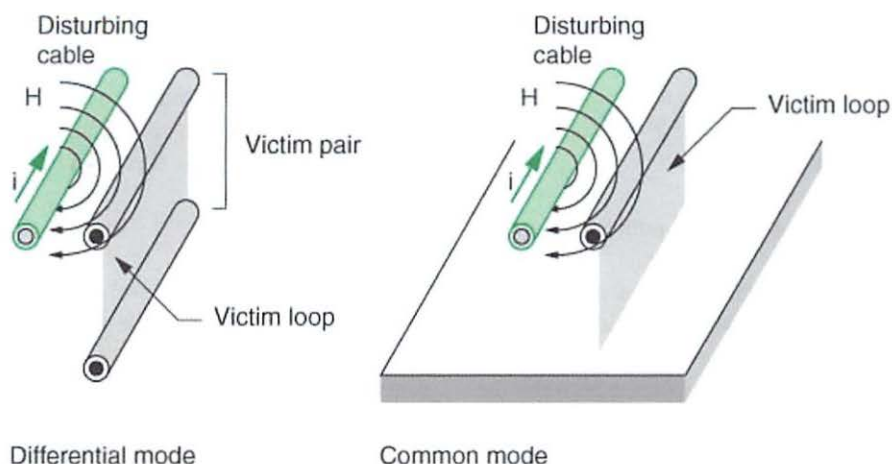


Figure 6: Examples of inductive coupling, where H is the magnetic field created by the current i (Source: http://www.electrical-installation.org/enwiki/File:Fig_R28.jpg).

- Increasing the distance between the disturber and the victim
- For two-wire connections, running the two wires as close together as possible
- Positioning a PEC bonded at both ends and between the disturber and the victim
- Using two or four-wire cables rather than individual conductors
- Using symmetrical transmission systems on correctly implemented, symmetrical wiring systems
- Shielding the disturbing cables, the victim cables or both (the shielding must be bonded)
- Increasing the signal rise time where possible

Inductive Coupling

Inductive coupling occurs when energy is coupled from one circuit to another through a magnetic field. Since

currents are the sources of magnetic fields, this is most likely to happen when the impedance of the source circuit is low.¹⁹

The level of disturbance depends on the current variations and the mutual coupling inductance.

- Inductive coupling increases with:
 - The frequency
 - The proximity of the disturber to the victim
 - The length of the parallel cables,
 - The height of the cables with respect to a ground referencing plane,
 - And the load impedance of the disturbing circuit.

Examples of inductive coupling include:

- Nearby cables subjected to rapid current variations
- Short-circuits

- Fault currents
- Lightning strikes
- Stator control systems
- Welding machines
- Inductors

Countermeasures to inductive coupling include:

- Limiting the length of parallel runs of disturbers and victims to the strict minimum
- Increasing the distance between the disturber and the victim
- For two-wire connections, running the two wires as close together as possible
- Using multi-core or touching single-core cables, preferably in a triangular layout
- Positioning a PEC bonded at both ends and between the disturber and the victim
- Using symmetrical transmission systems on correctly implemented, symmetrical wiring systems
- Shielding the disturbing cables, the victim cables or both (the shielding

must be bonded)

- Increasing the signal rise time where possible (series-connected resistors or PTC resistors on the disturbing cable, ferrite rings on the disturbing and/or victim cable)

Radiated Coupling

Radiated coupling results when electromagnetic energy is emitted from a source and induces voltages and currents in another circuit. No conducted path is required, which distinguishes it from common-impedance coupling. Radiated coupling is the only coupling mechanism where the source and victim circuits are separated by many wavelengths.²⁰

The power of the radiating source and the effectiveness of the emitting and receiving antenna both have an impact on the level of disturbance. An electromagnetic field, comprised of both an electrical field (E field) and the magnetic field (H field), are coupled in wiring systems via the wires and loops.

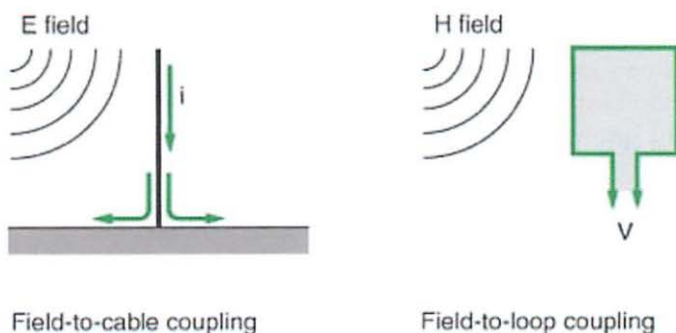


Figure 7: When a cable is subjected to a variable electrical field, a current is generated in the cable. Similarly, when a variable magnetic field flows through a loop, it creates a counter electromotive force that produces a voltage between the two ends of the loop. (Source: http://www.electrical-installation.org/emwiki/Radiated_coupling)

Examples of radiative coupling include:

- Radio-transmission equipment (walkie-talkies, radio and TV transmitters, mobile services)
- Radar
- Automobile ignition systems
- Arc-welding machines
- Induction furnaces
- Power switching systems
- Electrostatic discharges (ESD)
- Lighting

Countermeasures include:

- Reducing the antenna effect of the victim by reducing the height (h) of the cable with respect to the ground referencing plane
- Placing the cable in an uninterrupted, bonded metal cableway (tube, trunking, cable tray)
- Using shielded cables that are correctly installed and bonded
- Adding PECs
- Placing filters or ferrite rings on the victim cable
- Reducing the surface of the victim loop by reducing the height (h) and the length of the cable
- Using the Faraday cage principle

In general, it is crucial to follow these guidelines when constructing control systems or adding new equipment as it will increase the reliability of the entire locomotive electrical system.

- The use of shielded multiple conductor cable for small signal circuits is beneficial.
- A cable with a foil jacket that encases the conductors for the length of the cable resists the induction of outside interference by absorbing most of the energy.

- If a multi-conductor cable is not available, the circuit conductors should be run as parallel as possible.
- Proper grounding procedures of signal cables need to be followed as well. Shields should normally be only grounded at the controller end of the cable.
- Adding electronic filters can help prevent EMI, and can make equipment less susceptible
- Shields grounded at both ends can sometimes be a problem. If there is a potential difference, say corrosion in body and frame connections in the locomotive, then circulating currents could develop in the shield circuit, negating the benefit of having the shield in place.

Ghosts on the Rails

As mentioned earlier, a locomotive's electrical environment is a prime environment to find every type of electromagnetic interference except nuclear magnetic impulses. While the basic design and layout of a diesel electric locomotive has not changed for over 70 years, the last 40 years has brought a proliferation of low voltage electrical equipment that, unless wired and shielded properly, will impact and be impacted by other electrical equipment on the locomotive.

Because of these issues, standard authorities, both here in North America, and overseas in Europe, have released directives giving advice and guidance on how to build locomotive electronics. For example, IEC 60571, sections 12.2.7-10 give instructions on testing for, among others, supply

Wire Potential Category Groupings	
Category	Description
0	Circuits of extremely high potential (i.e. catenary, or DC Link) typically 1500 volts. Also AC locomotive traction systems and AC locomotive ground relays.
1	Circuits of high potential and high current levels (Generator, traction motor, and battery trunk lines to be routed through cleats).
2	Circuits of AC Voltage & High Current DC Voltage (Conductors Larger than #12 AWG, excluding Traction Circuits).
3	Locomotive control logic wiring (typically 74 VDC, including all electro mechanical Devices).
4	Low voltage and energy control and signal lines (Shielded multi-conductor cabled, and signals 24 V and below).
5	High energy un-fused conductors. (Isolated routing identified by alpha sub-category as needed.)
5A	BTP and BTN leads
5B	AL and ALL leads
5C	AG leads
6	Radio antenna cabling (Susceptible to EMI when receiving, and radiates a significant field while transmitting).

Figure 8: The main category groups of locomotive wiring
 (Source: TS-00051 – Classification, Separation, Termination & Installation of Wiring and Cabling, *Motive Power* – used with permission)

overvoltage, surges, transient bursts, and radiation emissions.²¹

The Association of American Railroads' *Manual of Standards and Recommended Practices, Section K-V, Electronics Environmental Requirements and System Management* (2012), Paragraph 4, describes in detail the emissions and susceptibility limits of locomotive electronics and the tests to be performed to ensure compliance.

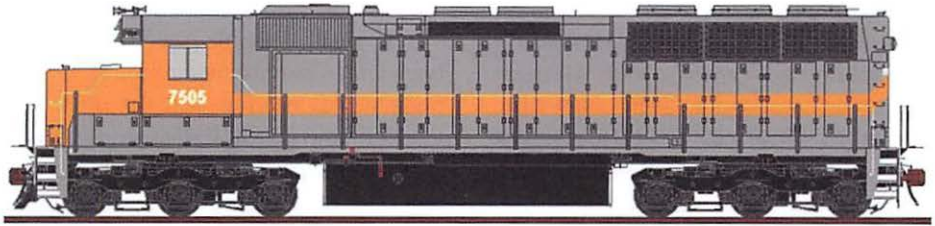
However, even assuming that all equipment has been tested effectively, the following installation guidelines should be maintained. All locomotive wiring can be separated in to different categories (See Figure 8). Category

separation is important when laying out harnesses and even when adding in control systems. Categories need to be utilized and considered in all locomotive design and aftermarket installations. It is important to emphasize again: even if equipment has been suitably designed and tested for compliance, proper wiring guidelines must be followed to minimize EMI.

A best effort needs to be made to make sure these identified categories are separated using troughs, separator blocks, or even routing. It is however, understandable that there are some situations where parallel runs will be created by necessity. In these situations

Potential Sources:
 -Main Alternator
 -Auxiliary Alternator
 -TM Cabling
 -Fan Cabling

Potential Victims:
 -Speed Inputs
 -Current Inputs
 -Temperature Inputs
 -Serial Communication



*Figure 9: EMI sources and victims on board a locomotive
 (Illustrator: Joe Whitmer, DMVWRR)*

where parallel runs are necessary, minimize the effective common run distance and separate as much is practical.

The key to eliminating EMI issues is to understand the type of coupling that exists and develop ways to mitigate the effect of the coupling. Thus, reducing the effects of EMI and improving performance.

Sources and victims of EMI need to be identified in the locomotive realm. Once these two areas can be identified, then steps can be taken to mitigate any issues before they become a problem. We can name some of the sources here, but with ever changing complexity and new technology being applied, we can only refer to a few.

Examples of sources include traction and auxiliary alternators, inverters for air conditioners, traction motors, or other equipment requiring alternating current. The cables carrying these varying currents from generation to consumption can radiate EMI. With the

large amount of radio equipment, RF from antennas and associated cabling can be a culprit. It should be noted here that with RF equipment that terminations are important to prevent excessive radiation.

Victims are most notably micro-processor based. With their small signal feedback circuits, usually less than 5-volts, they can be quite susceptible to EMI leakage from overpowering circuits in close proximity.

EMI can be very difficult to fight in the locomotive world. As can be seen in Figure 9, there are many types of sources and victims to be considered, and yet there is no set scheme that is the same from one locomotive model to the next. It would be great if you could have a defined common pattern to where equipment would be mounted and wiring routed. But, as we know, this is not realistic. Definite locations and routing could be pinpointed for the particular locomotive in the figure,

which would not necessarily work for another. Routing and separation need to be considered as a major part of the initial design or upgrade in a locomotive.

The following case studies will help give some guidance to locomotive electricians and others responsible for installing equipment about situations that can arise, and potential solutions to consider. Finally, they will also highlight how important experience and training are when dealing with EMI issues.

Case Study 1: Radio Problems on CSX GP38 / GP40 locomotives²²

The problem:

Units with new AC units suffered from impaired VHF voice radio performance, particularly when the locomotives were in the Huntington, VA shop. Radio problem abated somewhat when the AC units were shut down.

Three types of tests were conducted:

1) Receiver desense test using iso-tee.

This test is typically used to measure the "noise floor" at fixed radio sites. The test provides a comparison between receiver sensitivity under perfect conditions and degraded (actual) conditions.

2) Direct spectrum analyzer measurement using the locomotive rooftop antenna.

A calibrated spectrum analyzer is used to measure the received signal strength of a band of radio spectrum. The measurement is displayed on a

two-axis graph of amplitude versus frequency.

3) Direct spectrum analyzer measurement using a portable "sniffer" antenna.

A small portable spectrum analyzer with a portable antenna is used to find physical locations with the greatest level of radio signal. Rather than using a fixed antenna, the portable antenna and test set is used to compare measurements in a given area.

Diagnosis:

The test environment proved to be challenging. The local ambient radio noise floor at the Huntington, VA yard was 10 times more extreme than typical ambient radio environments. Without any electrical devices operating on either of the parked locomotives, the radio receivers were degraded by at least 10 dB. In contrast, a locomotive parked in the Waycross, GA yard is typically degraded by about 1-2 dB by the ambient radio environment.

Three factors seemed to play a role in this noisy environment:

1. The electrical substation that was located 20 feet from the test locomotives
2. The 2 electrical load banks that were within 100 feet
3. The hilltop radio transmitter site which was located about ¼ mile from the test locomotives.

The radio transmitters on the hilltop probably represented the majority of the radio noise. The problems are

likely caused by radiative coupling.

Solution:

There were 4 potential solutions identified.

A. Filtering

This solution is the most attractive. The manufacturer may be able to modify their hardware design to include filtering the output (110 vac) stage before it leaves the enclosure.

B. Shielding

The 110 vac wiring from the inverter to the rooftop air conditioner could be housed in aluminum conduit in order to shield emissions in the VHF radio band. Alternatively, it may be possible to use shielded cable to achieve the same effect.

C. Using air conditioners that run directly on 74 vdc without an inverter.

The supplier does provide cab fans that run directly on 74 vdc using brushless DC motors. These types of motors do not generate the strong interference that DC motors using brushes create. Unfortunately, they do not yet have an air conditioner compressor motor that will run directly on 74 vdc.

D. Using an air conditioner with an integrated inverter inside a shielded metal enclosure.

The supplier does offer a locomotive air conditioner that integrates the 72 vdc-to-110 vac inverter directly into the chassis for the rooftop air conditioner. The downside is that the inverter is located even closer to the

rooftop VHF antenna and thus may even worsen the problem.

Case Study 2: Actuator control Unit (ACU) Issues on CSX SD40-3 Units²³

The Problem:

Com losses and resets on a Q-Tron QES-III ACU. These issues led to erratic locomotive behaviour, including loading issues, engine shutting down, and airbrakes going into emergency.

Cause:

A series of different issues, but particularly a lack of category separation, led to these issues. The ACU serial communication cable was routed through the same conduit as the AC fan power cable, contributing a significant amount of noise to the data cable. In addition, the magnet valves did not have any filtering devices applied.

Solutions:

1. Add a free-wheeling diode on mag valves (sand mag valves, air start mag valves)
 2. Ensure ACU grounding strap properly applied
 3. Re-route ACU to ECU cable in a separate conduit to isolate it from other low voltage wiring
 4. Update all ACU cabling to give it more robust shielding capabilities
- Once these solutions were applied, the issues were resolved.

Case Study 3: Indiana Central SD75 Voltage Regulator Breaker Trip²⁴

Problem:

After quad (4-year) inspection and maintenance of the air brake system, the overvoltage circuit breaker on the front end of the voltage regulator would trip out while the locomotive was out on the road. The locomotive would return to the shop. While in the shop, everything on the voltage regulator circuit would check out and the locomotive would be released back into service. Typically within 2-3 days, the problem would arise again.

Cause:

Inductive coupling from the collapsing magnetic field in the magnet valve created a voltage spike that would pass up through the circuit and trip the breaker on the front side of the voltage regulator. After further research, it was discovered that the magnet valve that was used to activate the pneumatic blowdown device had been replaced, but the TranZorb device²⁵ that was on the original magnet valve had not been transferred over to the new magnet valve. (This magnet valve is wired in on the auxiliary generator side of the battery assembly.)

Solution:

Once the TranZorb device was replaced, the issue was resolved.

Conclusion

This paper about electromagnetic interference, is, in summary, a historical review of EMI, a detailed examination

of its nature and causes, and finally, three case studies of examples of EMI on locomotives. It is the hope of the authors that the information will be helpful to our colleagues in the industry as they continue to work faithfully in keeping locomotives operational so that trains can run safely and on time across the continent.

We wish to thank our colleagues and friends in the LMOA, and particularly the Electrical Committee, for their interest, ideas, and helpful comments, while we put together this paper and the presentation that it supports.

Endnotes

1. Thanks to John Hedrick, Southwestern Research Institute, for sharing this example. The activation of the additional cylinders was caused by interference of local CB radio operators with the engine's microprocessor. More information about the variable displacement system is available at https://en.wikipedia.org/wiki/Variable_displacement.
2. Example provided by J.P. Ouellet, Ronsco/Allrail. The exact problem was never identified, but the recent installation of microwave towers in the area was suspected to be the cause. The issue was resolved by "shielding everything in sight".
3. <http://www.jmkfilters.com/faq.htm>
4. With apologies to Arthur Koestler, author of the 1967 book about philosophical psychology, titled *The Ghost in the Machine* (https://en.wikipedia.org/wiki/The_Ghost_in_the_Machine).
5. ?
6. See <http://www.cvel.clemson.edu/emc/info/news.html> for a longer list of historical events and issues.
7. [https://en.wikipedia.org/wiki/USS_Forrestal_\(CV-59\)#1967_fire](https://en.wikipedia.org/wiki/USS_Forrestal_(CV-59)#1967_fire)
8. [https://en.wikipedia.org/wiki/HMS_Sheffield_\(D80\)](https://en.wikipedia.org/wiki/HMS_Sheffield_(D80))

9. For the detailed MOD report, see http://webarchive.nationalarchives.gov.uk/20121026065214/http://www.mod.uk/NR/rdonlyres/9D8947AC-D8DC-4BE7-8DCC-C9C623539BCF/0/boi_hms_sheffield.pdf
10. For more details, see <http://catless.ncl.ac.uk/Risks/5.56.html#subj1>
11. <http://www.cvel.clemson.edu/emc/info/news.html>
12. <http://www.herzan.com/applications/noise-source/emi.html>
13. https://en.wikipedia.org/wiki/Electromagnetic_compatibility
14. <http://www.iec.ch/emc/explained/emissions.htm>
15. Personal conversation with Derick Vander Klippe, TMV Control Systems.
16. For more info about nuclear magnetic pulses, see https://en.wikipedia.org/wiki/Nuclear_electromagnetic_pulse.
17. For an excellent, in depth examination of coupling mechanisms and counter-measures, see http://www.electrical-installation.org/enwiki/Coupling_mechanisms_and_counter-measures.
18. https://en.wikipedia.org/wiki/Capacitive_coupling
19. <http://learnemc.com/magnetic-field-coupling>
20. <http://learnemc.com/electromagnetic-radiation>
21. IEC 60571 refers to IEC 62236-3-2 for detailed testing specifications.
22. Glubis, Steve. *Subject: Huntington, WV Locomotive Air Conditioning RFI Test*
23. Example provided by Brandon Locklear, CSX, with further elaboration by Joe Whitmer (DMVWRR).
24. Example provided by Steve Alessandrini (CN), with further elaboration by Joe Whitmer (DMVWRR) and Eugen Greco (VIA Rail).
25. TranZorb (also spelled transorb) is the trade name for a TVS (transient voltage suppression) diode. A TVS diode operates by shunting excess current when the induced voltage exceeds the avalanche breakdown potential (See https://en.wikipedia.org/wiki/Transient-voltage-suppression_diode for more information).

Report on the Committee on Shop Safety, Processes and Equipment

Monday, October 5, 2015 at 11:00 A.M.



Chairman

Bill Peterman

Director-Rail Operations
B.P. Railway Services
Baie D'Urfe, Quebec

Vice Chairman

Tom Stefanski

President
Tom's Locomotive and Cars
Romeoville, IL

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R. Collen	Product Manager	Simmons Machine Tool	Corp. Albany, NY
C. Fette	President	TESCO	Erie, PA
L. Gelo	Dir Facility Cap Design & Maint	CSX Transportation	Jacksonville, FL
M. Maddox		Temple Engineering	Harvey, IL
D. Rodriguez	Loco Shop Supt-Mech & Value Engineering	BNSF Railway	Barstow, CA
D. Rutkowski	Chief Mechanical Officer	Providence & Worcester	Worcester, MA
(Past President)			

Note: Larry Gelo was a previous member of this committee when he was with Macton Corporation
Todd Dodgin of the BNSF is a guest speaker

Technology for Railway Wheelsets



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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 Director—Rail Operations of B.P. Railway Services, 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 Safety, Processes and Equipment Committee for several years. Bill lives in Montreal and is married with 5 children and finally has 3 grandchildren.

The Shop Safety, Processes and Equipment Committee would like to express their sincere gratitude and appreciation to the Providence & Worcester Railroad and LMOA Past President Dave Rutkowski for hosting the committee's meetings in Worcester, MA on March 18 and 19, 2015.

The P&W hosted a dinner for the committee on March 18th and then graciously invited the committee members to attend the New England Rail Forum & Expo on March 19th which was very interesting and informative.

Thank you to the Providence & Worcester RR and Dave Rutkowski.

Video Borescope for Locomotive Maintenance Officers

Prepared by:

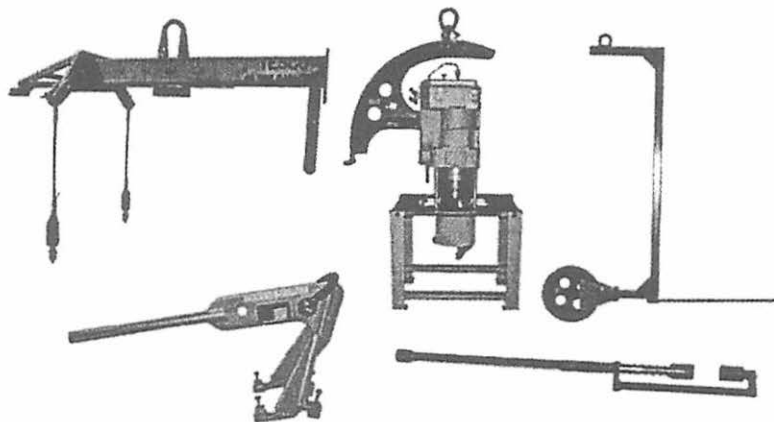
Tom Stefanski, Tom's Locomotives and Cars, and Duncan White, RF System Lab

This paper will cover the following subject matter

- Video Borescope Benefits
 - Failure Analysis
 - Preventive Maintenance
 - Inspect Machinery without disassembly
 - Take Pictures of inside machinery
 - Share the pictures
 - Take videos of insides of machinery
 - Share the videos
- Common Videoscope Inspections
 - See list below of locomotive components that can be inspected using video borescopes
- A Look Back at Older Remote Visual Inspection Technology
 - Lens and mirror based scopes go back decades
 - Fiberscopes using fiber optics for images and lighting
 - Non-articulating scopes are not able to move the camera at the tip of the probe. Some are semi-rigid to help aim the camera.
 - Scope on a Coil – typically used for sewers. Can extend hundreds of feet
- Portable videoscope – packed with technology for technicians in industries such as rail, aviation, power generation, oil & gas, manufacturing, casting and more
- Multi part Videoscope – A predecessor to the truly portable video scope. Multi part scopes may have external components such as batteries, control levers, monitors and/or lighting. Can be unwieldy to work with
- Medical endoscope – helped drive current industrial videoscope technology
- Rigid eyepiece borescope – probe does not bend or articulate. Good for looking straight at something
- Consumer borescopes – Available at big box retailers, auto parts stores, and hardware stores. Typically not a good fit for heavy machinery.
- Anatomy of a Video Borescope (figure 1)
 - Full Color Displays/Monitors
 - Variable lengths on the probe or “insertion tube”
 - Joystick to control moving camera tip, or “Etch-A-Sketch” style

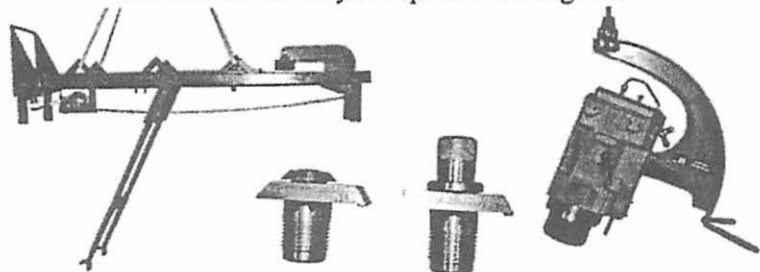


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- o Lighting adjustment buttons for LED
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 - o Start/stop buttons to take videos
 - o Battery compartments
 - o USB connection ports
 - o Control panels for to dial in Gain, review images, annotate photos, switch languages, switch to metric etc.
- Inspection Applications for Locomotive Maintenance Officers
 - o See list below
 - Other Inspection Applications for Rail
 - o Weld inspections under tankcar jackets
 - Ensure the Videoscope works for your Applications
 - o The top companies will let you borrow a borescope to test, or they will visit with a sales representative for an on-site demonstration.

Listed below are some of the benefits of Video Borescope Inspections

- Increase Machine Reliability
- Valuable Asset for Preventive Maintenance Programs
- Troubleshooting
- Greatly Reduces Teardown and Reassembly

There are many locomotive components that can be inspected using video borescope as follows:

- Combustion Chambers
- Piping
- Electric Motors
- Valves
- Generators
- Heat Exchangers
- Condenser Tubes
- Seals
- Compressors
- Pumps
- Meter Tubes
- Vessels

Some examples of older remote visual inspection technology are pictured in figure 2. Video borescoping can be used for many locomotive applications such as power assemblies, lines, exhaust valves, spray tips on fuel injectors, lower bore of engine assemblies and turbo charger turbine blades.

Concluding Remark:

Video borescope technology has come a long way since its inception. Today, technology has allowed us to combine LED lighting, camera tip articulation, image capture and portability in a single handheld unit. With outer diameters of 2mm and larger, the articulating video borescope is key in investigating locomotive maintenance issues without having to disassemble the entire component. This will save your company time and money.

Remote Visual Inspection Tools



Fiberscope



Non-articulating
videoscope



Scope on a Coil



Portable
Videoscope



Multi part
Videoscope



Medical
Endoscope



Rigid Eyepiece
Borescope



Consumer
Borescope

Video Borescope Anatomy



Modern and User Friendly Compared to the old Fiberscopes

4-Way Joystick Articulation

Pistol Grip Design

Built-In 3.5" LCD Monitor

2.8mm, 3.9mm, or 6.9mm Diameter

Image, Video, and Audio Capture

Variable LED Illumination

Removable Micro SD Card

USB Connectivity

Lengths Range From 1.0 to 5.0 Meters



Locomotive Inspections

- Power Assemblies
- Lines
- Exhaust Valves
- Spray Tips on Fuel Injectors
- Lower Bore of engine Assemblies
- Turbo Charger Turbine Blades





Power Assembly - Valve Inspections



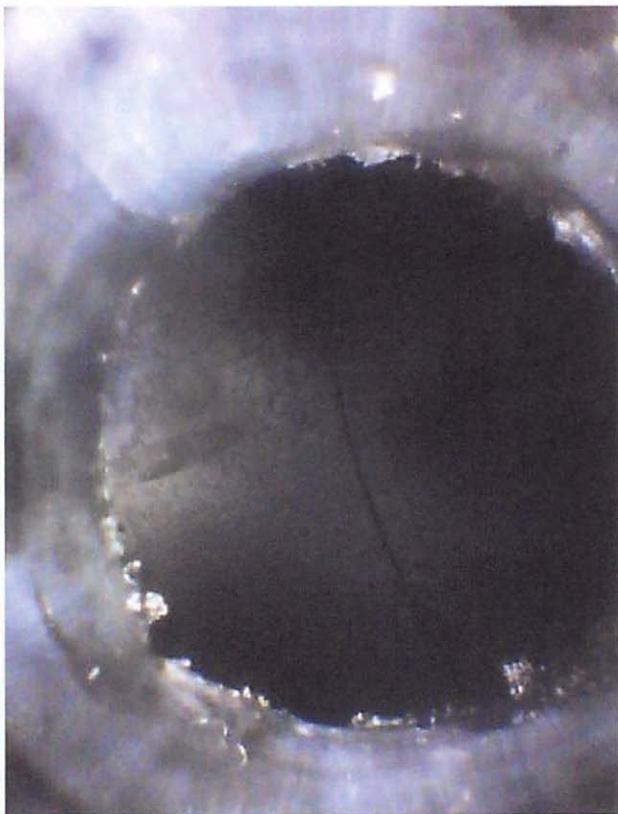


Valve Inspections – Eroded Valve



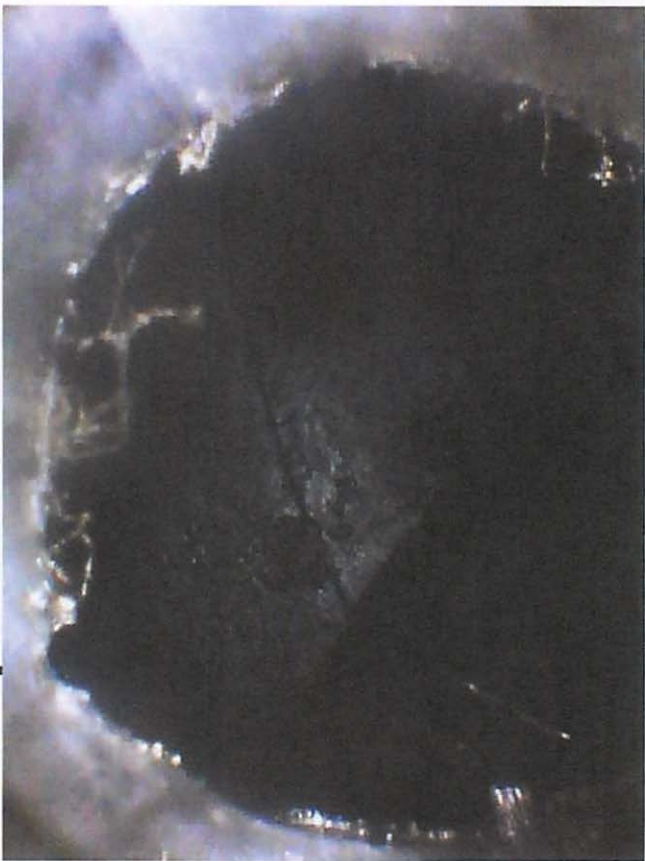


Power Assembly Inspections – Crack





Valve Inspection – Cracked & Eroded



Other Applications in Rail

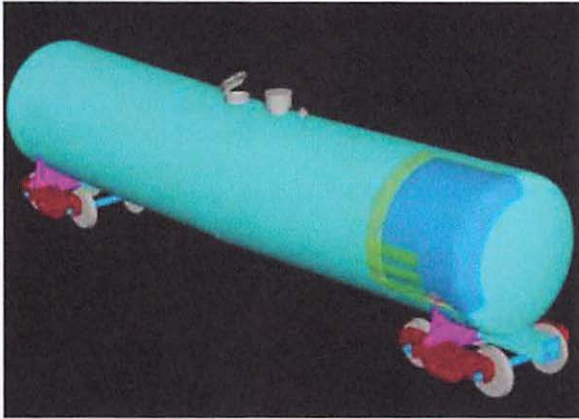


Image from UTLX.com

- Tankcar Weld Inspections Under the jacket





Corrosion Inspection Examples



Surface Corrosion
Should Have Borescoped
This Area Long Ago



**Combustion
Chamber**



Intake Port
Badly corroded



PC Pump

- Pumps
- Vessels
- Valves
- Piping

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Pump Inspection



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Some Corrosion, but Still Operable



Bore Hole
Access port for 4mm borescope



Pump Mounting Shaft



Pump Heat Sink
Made visible with video borescope

Test the Equipment Before You Buy



Test the videoscope on your applications.

Some companies will ship you a demo unit to try at your facility. Other companies may require that a sales rep visits your facility for a demonstration. Either way you should try before you buy.

Mechanical Department- 3 Main Safety Focus Areas

Prepared by:

Todd R Dodgin, BNSF Railway

Safety Vision

We believe every accident is preventable. Our vision is that BNSF will operate free of accidents and injuries.

Mechanical Safety Focus Area

The Mechanical team's 3 Main Focus Areas to achieve our vision by continuous improvement in reducing accidents and injuries;

- **Rules Compliance,**
- **Supervisor-with-Employee Safety Contacts, and**
- **Peer-to-Peer Safety Interaction and Support**

This simplified safety message communicates clearly our safety focus and everyone understands what we need to do to improve our safety.

Rules Compliance

Rules compliance is the foundation to our success in safety. We work in a safe but unforgiving working environment and must have 100% rules compliance 100% of the time. Compliance with all rules is important. The rules associated with our "Safety Absolutes" have the greatest potential for loss of life or life altering injury

Mechanical Safety Absolutes include: (see figures 1 and 2)

- **Blue Signal Protection**
- **Lockout/Tag out**
- **Jacking Equipment**
- **Vehicle Operations**
- **Fall Protection**
- **Crane Operations and Rigging**
- **Locomotive & Car Movement**

Supervisor with Employee Safety Contacts

The purpose of this enhanced process is for supervisors, working together with their employees to evaluate work practices, processes, and procedures for opportunities to reduce or eliminate unnecessary risk and prevent potential injuries. This process is also intended to promote positive interaction and relationships between supervisors and their employees. Each supervisor performs a minimum of two quality documented Employee Safety Contacts per week.

Peer to Peer Safety Interaction & Support

The Mechanical Team has always stressed the importance of intervening if you see a co-worker performing an at-risk behavior. Beginning in 2013, the Approaching Others About Safety Initiative was rolled out to describe how to approach others and why it is

Rules Compliance – Safety Absolutes



Blue Signal Protection



Lockout/Tag out



Jacking Equipment



Vehicle Operation

Figure 1

Rules Compliance – *Safety Absolutes*



Fall Protection



Crane Operation & Rigging



Locomotive/Car Movement

Figure 2

critical that we do so. This is a system-wide effort to train approximately 37,000 BNSF Operations employees annually.

Approaching Others About Safety Initiative:

Approaching Others About Safety is ...

The willingness to speak up about safety and risk exposure, recognizing people who are working safely as well as expressing concerns when co-workers put themselves at risk.

Our desire is for the BNSF team to consistently demonstrate the following:

- Pause work for discussions
- Identify exposures
- Positive interactions with people who are working safely
- Be willing to talk to someone that is at risk
- Be open to accepting feedback

Exposures-Approaching Others About Safety

Line of fire/release of energy- Does the person place his/her body in a position to avoid being hit, cut, struck or sprayed if something shifts, moves, releases or travels unexpectedly? (figure 3)

Pinch point- Does the person keep fingers and toes out from between objects that could crush or smash them if the objects shifted, closed or came together unexpectedly? (figure 4)

Ascending/descending- When climbing and going from one level to another, does the person use three-point contact, avoid jumping from one level

to another, use hand rails on stairs, and look before stepping? (figure 5)

Walking/path of travel- Does the person look in his/her path of travel before moving, scan the path as he/she is travelling, use designated pathways when walking and take the safest route available? (figure 6)

Life-saving processes- For the task being performed, do we follow and use the most critical procedures and talk with others in the area about these critical procedures? (figure 7)

Risk Identification

Three-Level Inspection to Identify Risk to Exposure: (figure 8)

- Ground to knee level (figure 9)
- Knee to head level (figure 10)
- Head level and above (figure 11)

Conclusion

Our Mechanical team is committed to continuous improvement in reducing accidents and injuries through our 3 Main Focus Areas:

- **Rules Compliance,**
- **Supervisor-with-Employee Safety Contacts, and**
- **Peer-to-Peer Safety Interaction and Support**

Exposure – Line of Fire Release of Energy



Does the person place his/her body in a position to avoid being hit, cut, struck or sprayed if something shifts, moves, releases or travels unexpectedly?



Figure 3

Exposure – Pinch Points

Does the person keep fingers and toes out from between objects that could crush or smash them if the objects shifted, closed or came together unexpectedly?



Figure 4

Exposure - Ascending/Descending

When climbing and going from one level to another, does the person use three-point contact, avoid jumping from one level to another, use hand rails on stairs, and look before stepping?

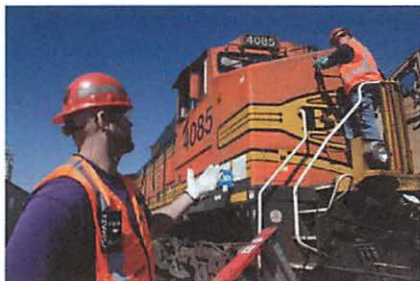


Figure 5

Exposure - Walking/Path of Travel



Does the person look in his/her path of travel before moving, scan the path as he/she is traveling, use designated pathways when walking and take the safest route available?



Figure 6

Exposure –Life Saving Processes



For the task being performed, do we follow and use the most critical procedures and talk with others in the area about these critical procedures?

Figure 7

Three-Level Inspection



Figure 8

Ground to knee level



Figure 9

Knee to head level

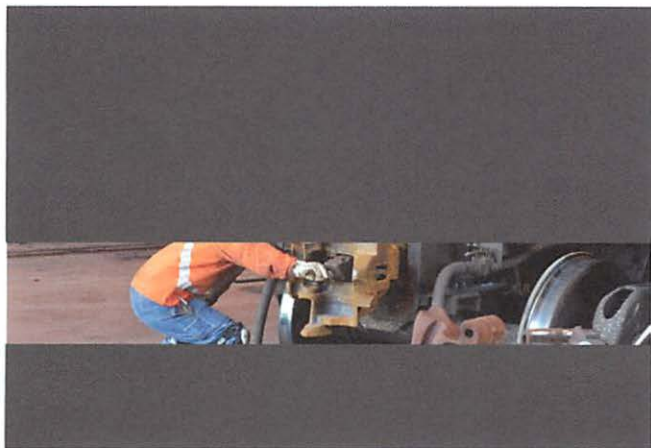


Figure 10

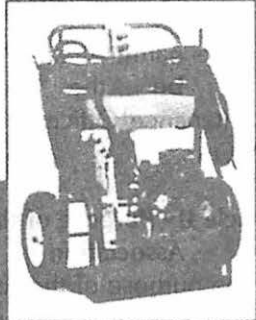
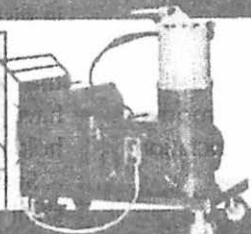
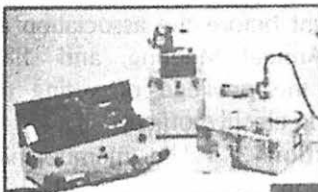
Head level and above



Figure 11

T

TIME-SAVING Tools and Machines for Locomotive Maintenance, Parts Reclamation, and Testing



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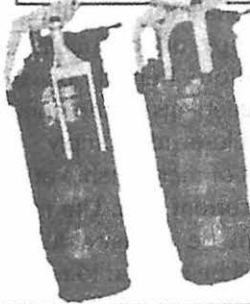
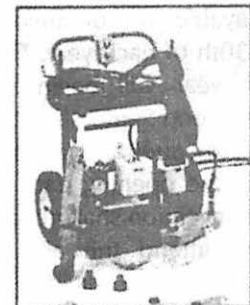
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Report on the Committee on New Technologies

Monday, October 5, 2015, 1:30 P.M.



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Tom Mack

CTO

VeRail Technologies, Reno, NV/Cincinnati, OH

Vice Chairman

Jeff Clapper

Supt-Motive Power

Wheeling & Lake Erie Rwy, Brewster, OH

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B. Wolff	Sales Engineer-Rail	MTU	Detroit, MI
C. Wyka	Senior Reliability Specialist	Canadian National Rail	Edmonton, Alberta

PERSONAL HISTORY

Tom Mack

Tom Mack has served as Chief Technology Officer of VeRail Technologies, Inc. since September 2013. VeRail's focus is bringing leading edge natural gas locomotives and technologies to railroads around the world.

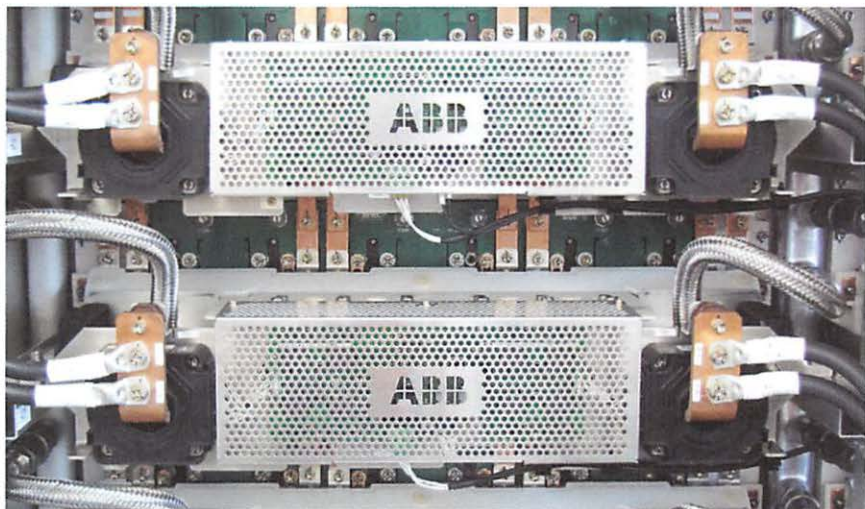
Prior to VeRail, Tom served as Vice President of Sales and Business Development for Motive Power & Equipment Solutions, Inc. (dba/MP&ES) of Greenville, SC. Prior to MP&ES he founded Alternative Hybrid Locomotive Technologies (AHL-TECH) in November 2005. Tom assembled a team of innovators from the locomotive, biofuels, software, and energy storage industries to design the world's first ethanol hybrid locomotive. While the AHL-TECH hybrid never became reality, the designs incorporated into the locomotive and the computer models developed, along with the experience gathered from the project, have given Tom a unique insight into alternative fuels use in locomotives, locomotive new technologies, and the locomotive market.

In addition to LMOA, Tom serves on the Mechanical Committee for the American Short Line and Regional Railroad Association (ASLRRA), is a member of the FRA's Natural Gas Locomotive Research Task Force, and as a supplier representative has been invited to meetings of the AAR Natural Gas Fuel Tender Technical Advisory Group (AAR NGFT TAG). He also served on the SAE TC-7 Biodiesel in Rail committee.

Tom currently resides in Cincinnati, Ohio with his wife, Mary.

The New Technologies Committee would like to sincerely thank CSX Corporation and Yousef Abdel-Moty for hosting and supporting the committee's meeting in Jacksonville, Florida on November 2014.

The LMOA committees would not be able to conduct their internal meetings without the support of companies such as the CSX.



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Second life for DC locomotives

Prepared by:

David Caron, ABB and Steven Beal, National Railway Equipment Co.

Main Topics:

- INTRODUCTION
- TARGET LOCOMOTIVE
- DC TO AC CONVERSION
 - o AC TRACTION MOTORS
 - o GEAR
 - o AC TRACTION CONVERTER
 - o SYSTEM EFFICIENCY
- INDEPENDENT SINGLE AXLES CONTROL – DC TRACTION
 - o IAC TRACTION SYSTEM
 - o HOW IAC WORKS
 - o DC TO IAC CONVERSION
 - o IAC PERFORMANCE
- CONCLUSION

INTRODUCTION

Locomotive operators and owners all have the same challenges, which include moving more merchandise for less money, improving locomotive availability and reducing maintenance costs. Today, with the advancement in power electronic technology, there are options available in the market to optimize locomotive performance. Whatever the technology chosen, it will all come down to having a valid business case.

Today's technology is helping the new generation of locomotive design engineers (part of the "Nintendo generation") to simplify operation and

protect the vital mechanical and electrical components. For example: in order to protect the equipment while delivering maximum tractive effort and optimal performance, new traction controllers prevent engineer mistakes by continuously monitoring the engine temperature, RPM, accessible power, traction motor current and voltage, etc. thereby reducing expensive failures and improving availability.

Additionally, as a society, we have the responsibility to manage our day to day energy consumption in order to protect the environment. We need to consider a locomotive as a large power generator in which every kilowatt should be carefully managed and used in an appropriate manner. New technologies can help us to better achieve this improved efficiency.

These new technical solutions are not just available for new locomotives. The aging locomotive fleets can also benefit from these advantages and could lead to immediate positive impacts such as major costs savings and a greener environment for railroaders of future generations.

For the purpose of discussion, throughout this paper we will be using an SD40-2 locomotive as our reference example. However, each technology

presented is fully applicable to other types of locomotives and not limited to this specific model.

TARGET LOCOMOTIVE

The North American fleet of DC locomotives is aging while locomotive demand is increasing. The targeted fleet that will benefit greatly from energy efficient improvement is the typical 20 to 35 year old DC locomotive fleet that has never been through a major overhaul. The main objective is to give a second life to an old locomotive by delivering

performance equivalent to the latest models, at a fraction of the cost of a new locomotive. However, in order to have a real business case for such technological improvement, the conversion cost should be limited and not exceed the threshold that could force the operator to upgrade the engine to the latest emission standards (e.g. Tier 4). In addition, it is quite demanding to upgrade the entire traction system. This is why the conversion should be performed at the same time as a major overhaul where new wiring and equipment will be installed on board.

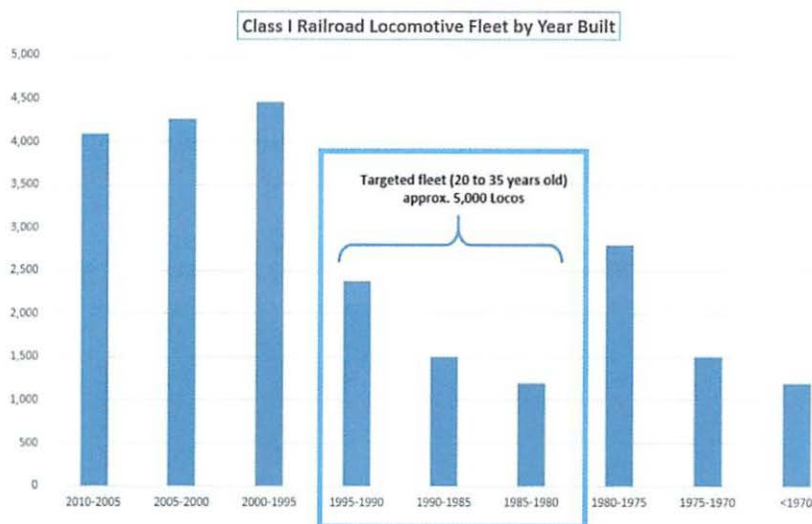


Figure 1 – Class I Locomotive Fleet by Year Built

Source: Estimate based on U.S. Department of Transportation
National Transportation Statistics - 2013

DC TO AC CONVERSION

AC technology has been proven for years in the industry, with major Class 1 operators having already demonstrated its benefits. The premium cost of acquiring an AC locomotive is

quickly recovered depending on the target operational objectives. A positive Return on Investment (ROI) is driven by 37% to 39% traction adhesion, high continuous torque and lower maintenance.

Top 7 Freight Fleet Overview AC vs DC		
	AC	DC
UP	42%	58%
BNSF	37%	63%
CSX	32%	68%
NS	6%	94%
CN	2%	98%
CP	50%	50%
KCS	51%	49%
For a total of 28,155 Locomotives		

Figure 2 – Fleet Overview
 Source: Locomotive 2013 by Greg McDonnell

AC TRACTION MOTORS

AC traction motors are an improvement over DC motors where maintenance is concerned. AC motors are designed and built without carbon brushes, which means there is no electrical contact between the rotor and stator. They do not require electrical contactors and switch gear, which

eliminates a potential point of failure and ensures lower maintenance requirements, therefore decreasing the system Life Cycle Cost (LCC). DC’s carbon brushes are consumable products which require regular replacement and maintenance, while AC traction motors are not subject to these attentions.

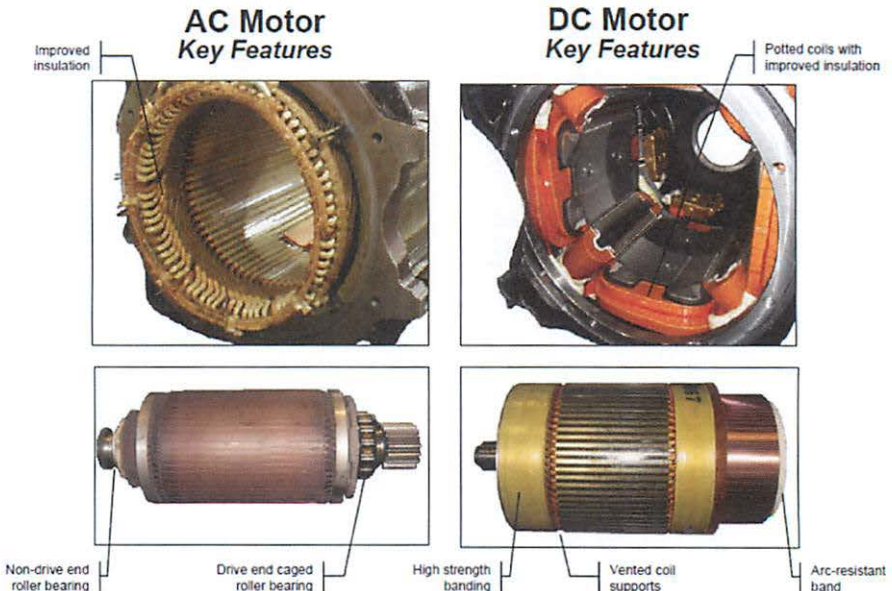


Figure 3 – AC vs DC Traction Motor
 Picture Source: EMD 2010 Certified Rebuilt Traction Motors flyer

The SD40-2 can deliver a tractive effort in the range of 27% of the locomotive weight (105,300 pounds of starting tractive effort for a 390,000 pound SD40-2). However, per EMD published data, this same SD40-2 only produces 83,243 pounds of tractive effort 99% of the time at a continuous speed of 11.1 MPH. This is considered its 99% "All Weather Adhesion" level but is only a 21% tractive effort level. Hence they are excellent candidates to be upgraded to an AC Traction System. This is done by replacing the DC D77 brass axle bearing mounted traction motor with a modern "Form-Fit" equivalent AC traction motor using a roller-bearing U-Tube mounting system. Since the gear ratio of the existing DC motor is not optimized for an AC application, it becomes important to perform an analysis of the desired performance and upgrade the pinion and bull gear accordingly. Also of note is that due to the high torque created by

an AC traction motor, North American locomotive OEMs have decided to introduce helical-cut gears on new AC traction locomotives instead of straight-cut gears as found on DC traction locomotives. An explanation for this follows.

GEARS

Straight-cut gears have teeth that are just that...straight! They are easy to manufacture but are very noisy and don't handle high torque requirements as well as helical-cut gears. Helical gears cut the noise by using helix-shaped teeth that engage more gradually. But because of this, they also produce a thrust force along the axis of the shaft on which they spin. This demands special attention of the traction motor design. Helical gears also have higher frictional losses than straight-cuts, thus it becomes critical to select appropriate lubricants to prevent tooth wear and loss of power.

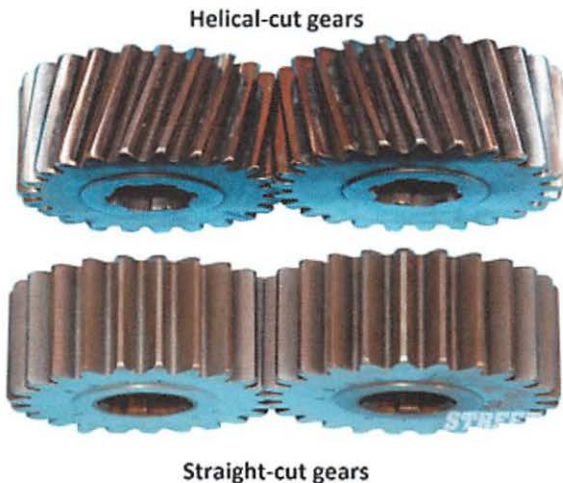


Figure 4 – Gear Configuration

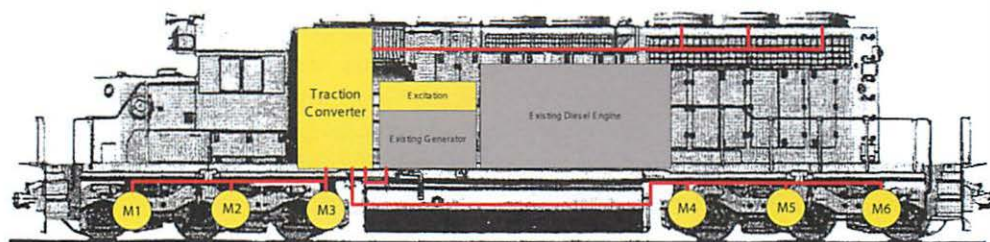


Figure 5 – SD40-2 AC Version layout example

AC TRACTION CONVERTER

A primary objective of conversion to AC traction is to reuse a maximum number of existing components. The original EMD 645 diesel engine mounted with an AR10 alternator is a perfect combination. Using the DC power created by the AR10, the AC traction converter is fed directly from the AR10. The AC traction converter then provides single axle control where each traction motor is driven independently. This type of configuration is a tangible improvement compared to the actual bogie control configuration. Each axle is independently controlled and during wheel slip power to only the specific slipping axle will be adjusted to eliminate the slip. This process happens a few hundred times per second. Using independent axle control the AC traction converter is designed to maximize tractive effort by forcing all wheels to slightly slip and release to deliver optimal adhesion for the current track and weather conditions (“Best Weather condition”). An added benefit of AC propulsion is that full tractive effort is available in all notches of the diesel

engine and not just at maximum RPM (Notch 8). Theoretically, it is possible to have full locomotive tractive effort in Notch 1, giving AC propulsion an advantage over DC propulsion in terms of fuel savings and control. Thanks to the progress in power electronics, a form fit solution is now possible.

The traction converter is the master device in an AC Traction System. Without a converter, the traction motor is not able to be powered and managed properly. The latest generation of traction converters are Insulated-Gate Bipolar Transistor (IGBT) based. Because the IGBT creates heat due to its switching frequency, cooling is very important to achieve high performance. There are different types of cooling methods available which include convection cooled, forced air cooled and liquid cooled technologies. Liquid cooled solutions offer the most compact configuration where the temperature of the system is monitored and adjusted in real time. Liquid cooled converters also offer the largest power density for the size of the equipment and are best suited for the heavy duty environment.



Figure 6 - IGBT Device

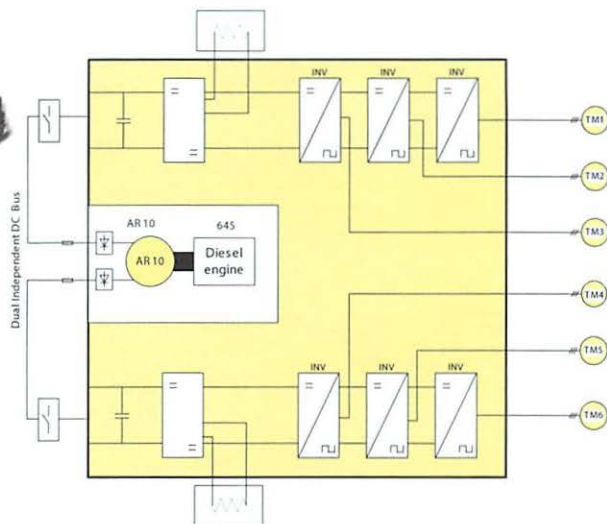


Figure 7 - Typical AC Traction Converter electrical layout. The solution with a converter, replaces the countless electromechanical switches and relays

The traction converter cabinet is designed to accommodate all of the inverters needed to power the traction motors. A Voltage Limiting Unit (VLU) is part of the overall product design to ensure a constant DC voltage throughout the entire system. During dynamic braking, the VLU sends the extra power generated by the traction motors to the brake resistor. Dynamic braking doesn't require any reconfiguration of the propulsion circuit - it is achieved inside the converter. Power is even used for auxiliary devices such as traction motor blowers or radiator fans.

SYSTEM EFFICIENCY

The traction converter is in fact a power management system which, in a very efficient way, handles the power supplied from the main generator by controlling losses, thus actually increasing the total efficiency of the locomotive. AC traction offers an average total traction power transmission efficiency of around 87%, compared to only around 82% for DC traction. This 5% power transmission improvement provides direct savings to the operator and is a big part of improving the business case for AC implementation. For a 3,000 horsepower locomotive, it can be thought of as the equivalent of upgrading to a 3,150 horsepower locomotive.

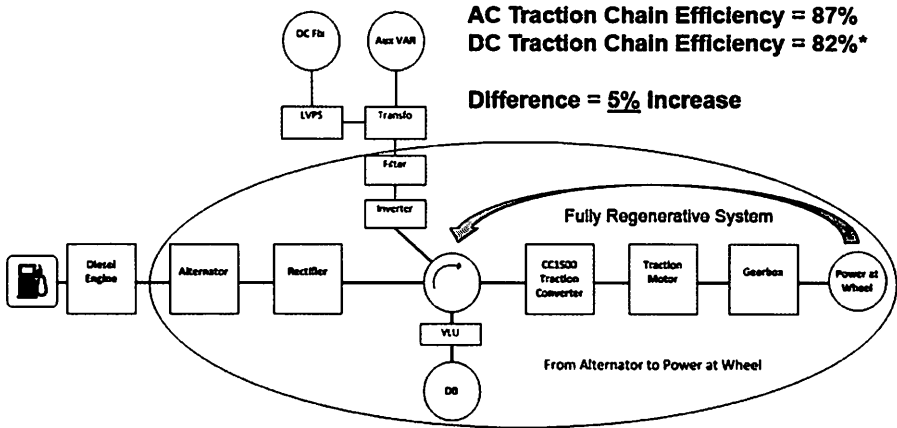


Figure 8 - Traction chain efficiency diagram

Source: * AREMA chapter2 - Railway industry Overview @2003 - Section 2.6.1

During dynamic braking, the AC traction motor associated with the converter acts as a generator. This extra power will first be used internally for powering cooling fans, battery charging or any other auxiliary power needed (as included in the converter design). For example, the extra power could be used to power electrically driven traction motor blowers or an electrically driven air compressor. Any additional power that remains will be sent directly to the dynamic braking resistors via the VLU. Therefore, an AC traction system is regenerative. In some specific business cases, it could be possible to introduce energy storage devices such as batteries or super-capacitors. The stored energy could be reused during acceleration which again would lead to additional savings. However, carrying the extra weight of the energy storage device may not be profitable in some cases. Any of such configurations should be

carefully evaluated according to the specific mission profile.

Because the AC traction motor is offering more power within the same footprint, it is also possible to retrofit the SD40-2 with only four AC traction motors (four powered axles on a six-axle locomotive) instead of six DC traction motors and get the same performance. Advanced features are also possible, such as "Track Cleaning". This feature creates a temporary slip on the first axle set which will clean the track and provide the maximum adhesion for the following axles. This is a temporary power sacrifice that could potentially help significantly increase tractive effort in specific operating conditions.

INDEPENDENT SINGLE AXLES CONTROL – DC TRACTION

Although DC technology is being replaced by AC technology on new Tier 3 and Tier 4 locomotives, the majority of locomotives operating in North America remain DC traction units. Microprocessor control retrofits of older locomotives and within new builds have been an effective means of improving productivity of legacy DC traction locomotives, resulting in higher performance and increased adhesion. However, a large performance gap exists between the best conventional DC traction system and a modern AC traction system. On a conventional DC traction locomotive, all motors are powered from a single common generator supply. If any single wheel slips, power must be reduced to all motors in order to regain traction. This inherent characteristic limits the performance potential of a DC locomotive during high adhesion operation. Additionally, the characteristic of a series wound DC traction motor results in a rapid speed increase during wheel slip. This can damage both the traction motor and the rail without rapid correction.

IAC TRACTION SYSTEM

As with AC traction, modern technology permits the use of solid-state components to independently control DC motors from a common generator supply. Independent Axle Control (IAC) does just that. Using a DC “chopper” module, IAC allows a microprocessor control system to control power and torque to each individual DC traction motor, maximizing

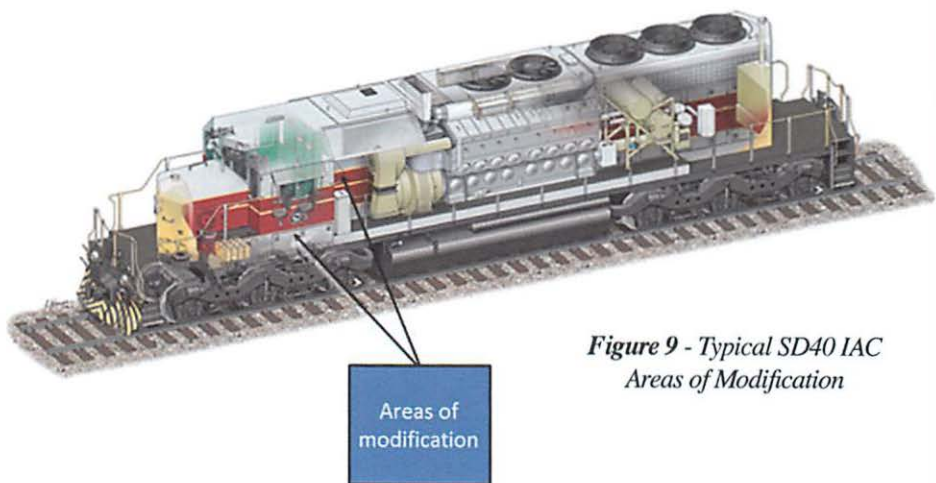
the performance on a per-axle basis. A power reduction to all motors is no longer required if one wheel slips. Precise motor control is possible, further increasing the degree of wheel creep control, and significantly increasing locomotive adhesion performance into a range typically associated with AC traction.

HOW IAC WORKS

IAC works very similarly to AC traction. The microprocessor control system regulates generator excitation to maintain a fixed DC link voltage for each throttle notch. Each chopper modulates the applied DC voltage to its one associated traction motor from the DC link, independently controlling the level of current to each individual traction motor.

IAC monitors the voltage and current to each traction motor as primary feedback. Thus speed sensors for each axle are not required for the system to operate. IAC control algorithms will always attempt to maximize tractive effort within power limits for each throttle notch.

With IAC, the locomotive can supply nearly 10,000 amps to the combined traction motors with less than 2,000 amps supplied by the generator (pulsed “current multiplication”). This means that the generator can work at its most efficient operating point whether in stall conditions or high speed, significantly improving transmission efficiency at lower track speed/high tractive effort where generator losses are highest.



*Figure 9 - Typical SD40 IAC
Areas of Modification*

DC TO IAC CONVERSION

To convert a DC locomotive to an IAC locomotive very few changes are required. A microprocessor control system must be fitted. This can be a basic system with minimally invasive wiring changes or it can be a fully featured microprocessor system. The existing generator and traction motor circuits can be retained. All contactors and switchgear can be kept as-is. The existing trucks can be retained. The existing DC traction motors can be retained and do not need to be rebuilt or modified. A new MEC/HVC (Main Electric Cabinet and High Voltage Cabinet) is not necessary, but can be supplied to simplify the conversion process. A "bolt-on" IAC chopper package is possible with many unit types. The primary physical change required is fitment of the IAC chopper assembly and a minor cabling modification to insert the choppers in the circuit between the generator and

motor circuits. IAC boils down to a system designed to work with all existing major locomotive components, maximizing performance with minimal changes. In highly utilized, maximum locomotive adhesion applications, IAC will provide a fast return on investment along with lower long term locomotive maintenance.

IAC PERFORMANCE

With IAC, adhesion levels for a DC traction locomotive increase to over 33% (NREX 4321 with flexi-coil trucks). Higher adhesion can be achieved under ideal conditions and with modern truck and suspension designs. At these adhesion levels, the limiting factor in peak tractive effort is often the traction motors themselves. Larger motors or a higher gear ratio can allow higher starting tractive effort when the motors are holding back performance.

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Locomotive type	Adhesion	Continuous Tractive Effort (lbs)	Performance Limiting Factor
SD40-IAC	33%	128,700	Motor current limit
SD40-3	27%	105,300	Adhesion
SD40-2	21%	81,900	Adhesion
SD9	15%	58,500	Adhesion

Figure 10 - Relative performance of IAC vs. conventional locomotives

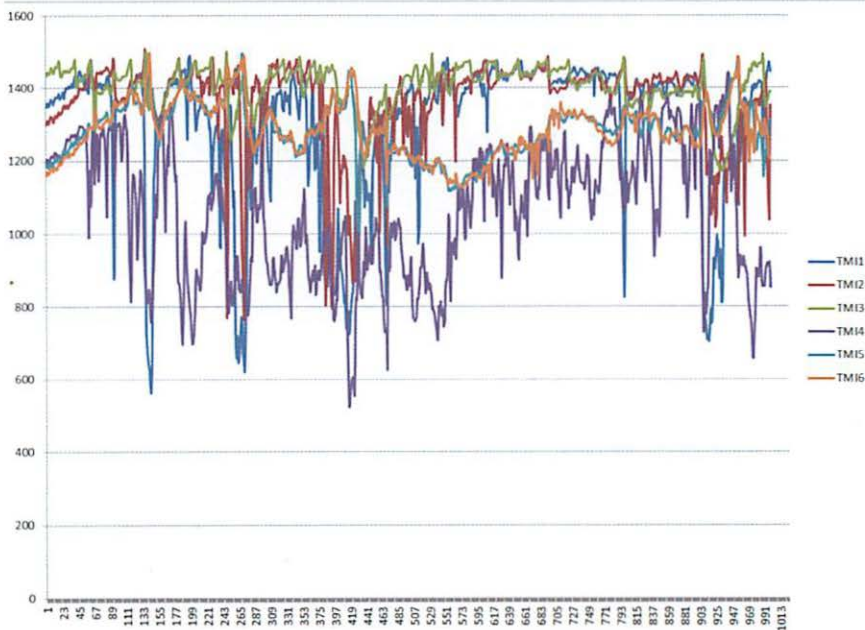


Figure 11 - SD40 IAC in Operation, Motor Currents 1 thru 6 at 100ms

As with AC traction, IAC allows DC traction locomotives to focus slip corrections to only the axles affected, leaving the remaining axles to either maintain or (if capacity is available) increase output. Figure 11 illustrates traction motor current for each of 6 axles in an IAC converted SD40

running in low speed, heavy haul service.

Higher adhesion is possible with IAC in all conditions. When crossing a switch or a road crossing, full power can be maintained while making individual slip corrections. In poor conditions, an IAC equipped locomotive will

always outperform a conventional DC traction system. This translates to more work getting done more reliably, rain or shine.

CONCLUSION

When it's time to give a second life to your old locomotive, it is also the right time to evaluate your traction control options. Different applications may drive different solutions and therefore different results. The quicker you act, the better your business case and ROI.

Natural Gas – Dual Fuel Locomotives Developments and Field Demonstrations

Prepared by:

Walter H. Klaric, Electro-Motive Diesel

Market Incentive Update – The relative fuel costs of Natural Gas (NG) compared to diesel fuel incentivizes the rail industry to pursue the expanded use of Natural Gas as a transportation fuel.

With the increased use of hydraulic fracking and horizontal drilling in shale rock structures, the reported inventories of natural gas have increased dramatically over the last six years. Natural gas contained within shale structures has yielded massive increases to the natural gas supply to the domestic market place. Correspondingly, this has resulted in significant reductions in the pricing for natural gas relative to liquid petroleum fuels, like gasoline and diesel fuel. Current long term projections regarding natural gas inventories and pricing indicate significant cost advantages for utilizing natural gas as a transportation fuel. At present, international market influences on the pricing of natural gas are still minimal, as compared to liquid petroleum fuels. Most projections suggest the North America railroads can benefit from low cost NG for decades to come, as they invest increasingly in NG infrastructure and NG fueled locomotives for their next generation locomotive fleets.

While natural gas spot price movements have been volatile, with highs

above \$13.00 per MMBtu in 2003, 2005 and again in 2008, for the last six years, the average price of natural gas has remained below \$5.00 per MMBtu, with spot prices dropping below \$2.75 per MMBtu in early 2015. The increased domestic supply has resulted in the downward pressure on NG pricing, approximately a 75% reduction in the price of natural gas from the peak prices experienced in the last decade. Market forces continue to put downward pressure on natural gas prices.

While there are additional costs to the railroads for NG over the spot prices, i.e. for processing, liquefaction, storage, transportation and taxes, when comparing the end user costs, there are significant fuel cost savings to the railroads, estimated to be on the order of \$1.50 per diesel gallon equivalent (DGE).

Based on the Association of American Railroads (AAR), locomotive medium duty cycle projection of ~350,000 gallons of diesel consumed per year for a high horsepower heavy haul road locomotive, there are substantial dollars to be saved by converting existing diesel powered locomotives to dual fuel, diesel and natural gas configurations. Every railroad's fuel usage will vary, but not only

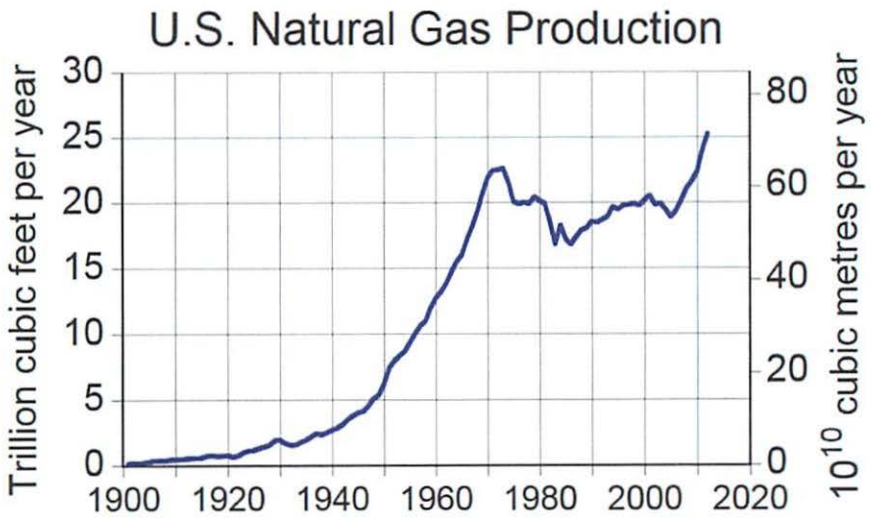


Figure 1 - U.S. Natural Gas Marketed Production 1900 to 2012, source US EIA

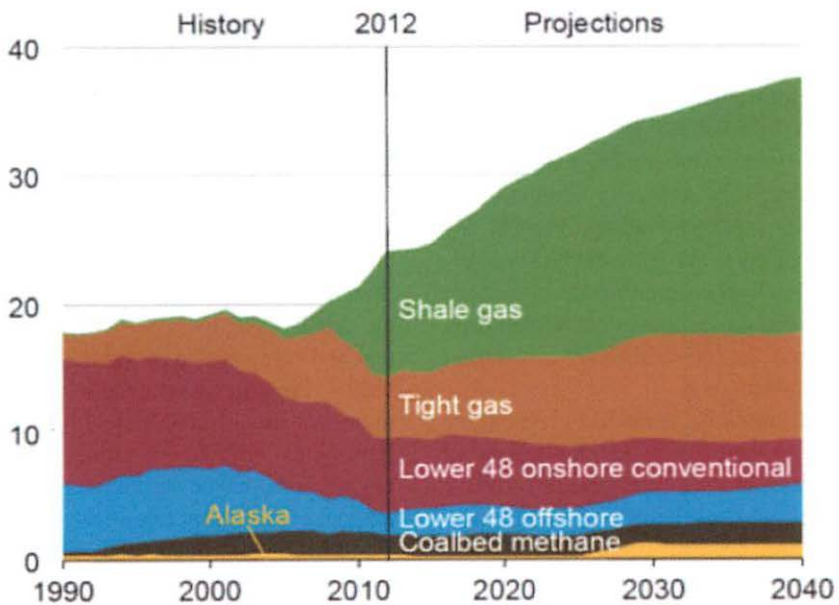


Figure 2 - U.S. Natural Gas Production Segments, source US EIA

will the shift toward natural gas reduce operating costs to the railroads, it will also improve the competitive advantage for the movement of freight by rail as compared to other forms of freight transportation. Each railroad will have to do their own value analyses to justify the investments required for infrastructure, NG fuel tenders and dual fuel locomotive retrofits.

As the North American railroads, the locomotive original equipment manufacturers (OEMs) and suppliers to the industry better understood that long term cost advantages of operating locomotives on natural gas, efforts were increased to develop products. The locomotive OEMs initial efforts have focused on low pressure, dual fuel, diesel and natural gas configurations.

Dual Fuel Configuration Development

While natural gas fueled engines have been commercially available for decades, they typically required significant power de-rating. Present day technology is allowing the NG and diesel dual fuel configurations to achieve full rated diesel equivalent horsepower, without the de-rating seen on earlier configurations.

In previous generation NG engine designs, because of the limitations of mechanical fuel injectors, fixed valve timing and mechanical governor control, and because these engines were typically designed and tuned for 100% diesel operation, natural gas conversions resulted in significant reductions of the engine horsepower output rating, compared to the equivalent

displacement diesel engine and per dollar invested.

In fact, Electro-Motive Diesel (EMD) began offering dual fuel engines, diesel and natural gas configurations in 1954 on stationary power electrical generator sets. Here again, with these previous generation designs, the dual fuel engines were de-rated 40-50% on a brake horsepower or kilowatt hour basis, as compared to operating the engine on straight diesel fuel. These non-rail offerings were sold through the 1985 time frame.

Current day dual fuel engines consuming diesel and natural gas employ state of the art technology utilizing high speed, electronic control modules and electronic, solenoid actuated fuel injectors. These allow for double sets of fuel injectors, or fuel control valves, for each engine cylinder. This has provided tremendous flexibility to optimize natural gas consumption without taking a reduction in the brake horsepower output of the diesel engine. Computers can now be utilized to map engine performance to adjust for variations in ambient temperature, altitude, air density and even the energy content and composition of the fuels being used. Present diesel engine designs are now being offered in dual fuel configurations without de-rating of the engine horsepower output, locomotive response time or tractive effort.

EMD has developed Dynamic Gas Blending® retrofit/upgrade kits for the existing SD70ACe (AC traction system) and SD70M-2 (DC traction system) locomotive fleets, fitted with the EMD 16-710 Tier 3 engines. This

DGB® kit includes highly reliable, high speed Cat® electronic controllers, and integrates communication and control with the existing locomotive control computers. The resident locomotive computers, EM2000®, EMDEC® and FIRE®, continue to provide control and protection of all other locomotive functionality. By coordinating control between NG and diesel fuel consumption, the performance of this configuration is almost transparent to the train operators. From a locomotive performance and train handling standpoint, the operating crews can rarely distinguish whether they are operating a dual fuel locomotive, or a diesel only unit.

The voice of the railroads has been clear, with a significant initial investment required to implement changes toward the expanded use of natural gas, there is a strong desire to have designs that can revert back to full diesel power, now commonly known as Diesel Only Mode (DOM). This transition needs to be seamless to the train operating crews and allow the railroads the flexibility to switch from dual fuel to diesel only mode, as operations demand. OEMs have effectively achieved this goal. Engine response times, horsepower outputs and locomotive pulling power have been demonstrated during dual fuel field test demonstrations and during revenue operations as compared to their diesel only locomotive counterparts. These newly re-configured dual fuel locomotives are moving the same freight ton-miles with a measureable reduction in total fuel costs.

Because of the wide variations in NG and diesel fuel pricing that can

occur on a month-to-month basis, because costs can vary based on proximity to refineries and/or NG liquefaction plants, and because costs can vary on state-by-state basis or from one region of the country to another, these pricing variation can significantly impact fuel costs. This report will not attempt to target a specific dollar cost reduction. However, other reports have indicated a 25-50% reduction in fuel cost can be achieved on a dual fuel DGB locomotive when operated with >60% diesel displacement, on an average duty cycle basis.

EMD Developmental & Demonstration Test Programs

Following experimental engine test cell developmental testing and proof of concept testing on the 16-710 engine, the EMDX70 locomotive was up fitted with the DGB retrofit kit for further in-house locomotive developmental, validation and durability testing. From the onset, the goal was to achieve and develop a Tier 3 emissions compliant dual fuel retrofit kit that would achieve greater than 60% diesel displacement, i.e. to reduce the average duty cycle diesel fuel consumption by substituting NG as the other fuel.

The NG/diesel, dual fuel configurations to-date consist primarily of intake port NG injection and intake manifold fumigation using diesel fuel in the compression ignition process. Diesel fuel injection is used to initiate combustion. The EMD 16-cylinder 710 engine utilizes solenoid operated NG valves, one at each cylinder, to



Figure 3 - EMDX 70 - DGB Proof of Concept Locomotive

deliver gaseous natural gas (GNG) into the combustion chambers.

These special valves have very rapid response times to accurately control the on, off, duration and quantity of the NG delivered for each injection event. It is imperative the timing of the NG event be optimized to maximize the NG substitution rate at each engine operating speed and brake horsepower output level, to maximize combustion efficiency and minimize exhaust emissions.

EMD, in concert with Progress Rail Services Corporation and parent company Caterpillar Inc., has conducted intensive analytical analyses of the fluid dynamics of the intake, compression and exhaust cycles, as well as the combustion process to optimize the NG dual fuel combustion

efficiency of the 16-710 two-cycle engine. The combustion chamber configuration has been very successful at maximizing NG substitution rates as compared to earlier designs, improving combustion efficiency and controlling the potential for “knock” or pre-ignition.

Following proof of concept testing on the EMDX70 locomotive, the first EMD DGB retrofits were made on existing, customer SD70ACe locomotives for field demonstration trials. Existing legacy LNG fuel tenders have been up fitted for use in a NG, dual fuel consist. These locomotives along with the LNG tender came to EMD Engineering in 2013 to be up-fitted with the EMD DGB kit for validation and verification testing.

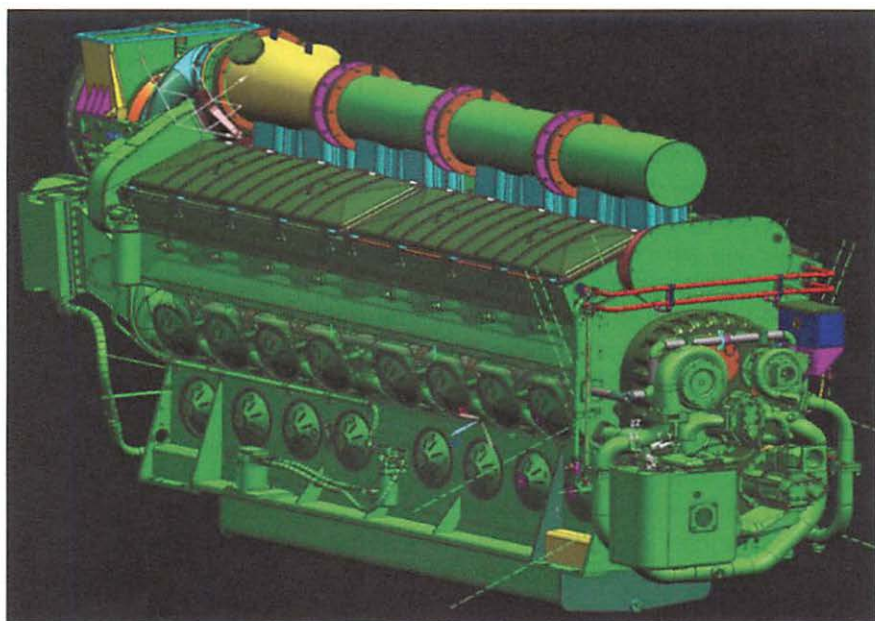


Figure 4 - EMD 710 Engine fitted with the Dual Fuel DGB Kit

Dynamic Gas Blending DGB Locomotive Configuration

The EMD DGB configuration utilizes gaseous natural gas that is delivered to the locomotive from the natural gas fuel tender (NGFT) through piping and hose connections across the coupler. The locomotive contains a NG shut-off valve, filter and pressure regulator before the NG enters the air box of the two-stroke, 16-710 engine. Internal to the engine air box, NG is distributed to each cylinder via manifold piping and solenoid actuated valves. The timing and duration of the NG valve operation must match the engine operating speed, power output level and the targeted NG substitution rates.

In support of the LNG tender, a heat exchange fluid subsystem is added to the locomotive to supply and return a propylene glycol (PG) and water mixture to the tender for use in vaporizing the LNG and warming it at a controlled rate to deliver the required gaseous NG flow rate, pressure and temperature to match the demand requirements of the engine. The engine coolant loop is used to maintain the temperature within the PG circuit. The PG circuit includes a heat exchanger, transfer pump and motor assembly, a thermostatic control valve and pressure and temperature sensors to regulate the performance of the PG circuit.

Control between the locomotive and NGFT are coordinated between

computers on-board the locomotive and a Programmable Logic Controller (PLC) on the tender. Control and electrical power are exchanged between the locomotive and tender through an additional dedicated 27-point tender communication receptacle and multiple unit (MU) plug and cable assembly, which is separate from the locomotive-to-locomotive MU control circuits. If additional electrical power is required to operate pumps and/or heaters on the NGFT, this power can be provided by a dedicated receptacle normally used for train line battery charging.

A NG detection system was added to the demonstrator locomotives with two sensors dedicated to monitor the confines of the engine compartment and another sensor located within the operator's compartment. If NG is detected, the NG delivery circuits on both the locomotive and the tender are shut-down, and the locomotive is allowed to continue operating in DOM.

Methane is flammable in air, within a 5-15% concentration range. The detection sensors can identify concentrations significantly below the lower flammability limits of NG, then shut-down the fuel supply system, log faults, and provide annunciations, as necessary. If a NG detection fault occurs, the NG supply system is locked out, and the locomotive reverts to the diesel only mode of operation. Maintenance personnel must investigate the fault and take corrective action before the NG system can be re-activated.

To supplement the external leak detection system, EMD utilizes a NG piping integrity check that is

automatically conducted when the NG supply system is initially activated. If the piping integrity check falls outside of the required acceptable range, the NG system is shut-down and locked-out until the root cause of the fault is identified and remedied.

Natural Gas Fuel Tender (NGFT) Configurations

There are primarily two types of NGFT designs being developed for the rail industry: liquefied natural gas (LNG) tenders and high pressure gaseous, compressed natural gas (CNG) tenders. Each railroad must consider the advantages and limitations that each configuration offers. In general, dual fuel engine equipped locomotives can operate from either type of NGFT as long as the required NG composition, flow rates, pressures and temperatures to the locomotive are met. Looking forward, requirements for the composition for the NG delivered to the locomotive may be necessary to meet emission requirements and avoid pre-ignition, i.e. knock. The composition of "line gas" from high volume pipe line suppliers can vary widely in methane content and may contain other undesirable non-methane components. For LNG, the percentage of methane content is typically greater than 95%, and the composition varies less, because many of the non-methane components can be removed, or reduced, during the liquefaction process. Similarly the "line gas" can be cleaned by removing non-methane impurities with additional processing.

“Line Gas” Composition

Typical Composition of Natural Gas

Methane	CH ₄	70-90%
Ethane	C ₂ H ₆	0-20%
Propane	C ₃ H ₈	
Butane	C ₄ H ₁₀	
Carbon Dioxide	CO ₂	0-8%
Oxygen	O ₂	0-0.2%
Nitrogen	N ₂	0-5%
Hydrogen sulphide	H ₂ S	0-5%
Rare gases	A, He, Ne, Xe	trace

Typical makeup of natural gas. Source: Naturalgas.org

The composition of Compressed NG (CNG) can vary significantly and can negatively impact engine efficiency, emissions and the tendency for pre-ignition.

Early in the development process, working in conjunction with the Association of American Railroads (AAR), the use of an LNG tender semi-permanently connected to a dual fuel locomotive or between two DGB locomotives, the tender was classified as part of the locomotive consist, a locomotive appurtenance. The concept design was for a high volume storage capacity of a 25-30,000 gallon LNG tender to be connected between two up-fitted dual fuel locomotives. Because the original intent was to offer retrofit DGB kits, all locomotive interfaces to the LNG tender were constrained to the rear of the locomotive.

Recognizing the need for interoperability standards, an AAR Technical

Advisory Group (TAG) was formed to develop standards for Natural Gas Fuel Tender configurations for locomotive interchange and crash worthiness requirements. Standards are required so that tender designs offered to the rail industry meet a set of requirements for the transfer of fluids between the NG tender and the locomotive, i.e. natural gas, compressed air and heat exchange fluid for vaporizing LNG into gaseous NG, as well as to define electrical power, control, communications and crashworthiness requirements.

Legacy LNG tenders were reconfigured to supply NG to locomotives from both ends of the tender, including all necessary control elements to regulate NG flow, pressure and temperature to the locomotives. From an interoperability standpoint, it has been demonstrated that both OEM's dual fuel locomotive offerings can operate

simultaneously, one from each end of a single LNG fuel tender.

When developmental and functional verification testing of communications, control, electrical power, NG delivery and Glycol heat exchange fluid interfaces between the locomotive and LNG tender were completed, the locomotives had additional instrumentation applied, to monitor operating variables during field demonstration trials.

Before beginning the revenue service phase of demonstration field testing, proposed operational plans were presented and reviewed with the Federal Railroad Administration (FRA), which included specific routes to which the DBG consist would be operated. Prior to each phase of field testing, a Letter of Concurrence was sought and received from the FRA. The DGB consists have successfully operated in some of the hottest of summer conditions, and the coldest of winter conditions. The dual fuel locomotives have achieved average diesel displacement fuel rates greater than 60%, and on occasion have exceeded 75%.

The first demonstration revenue routes were constrained to round trips of 250 to 500 mile ranges. The next phase of testing will include longer revenue runs covering multiple crew changes with round trips exceeding 2,500 miles in range. While the shorter revenue runs provided valuable information regarding real world service, dual fuel consumption rates and operating parameters experienced within the LNG tender, the longer runs will validate that experience and assist railroads in making infrastructure decisions

regarding distances between re-fueling of LNG tenders and other strategic decisions regarding LNG tender refueling. Projections indicate a DGB dual fuel consist, including a 25,000 to 30,000 gallon LNG tender, may be able to go several thousand miles before re-fueling. However, these projections are dependent on train make-up, i.e. horsepower per trailing ton and the terrain over which any particular train is traversing.

What's next...DIG® - Direct Injected Gas

EMD, through a coordinated effort with Progress Rail and Caterpillar, is developing the next generation of a natural gas engine configuration. Why something more than the DGB configuration? The answers are many. The Direct Injected Gas (DIG) configuration achieves diesel displacement rates in excess of 95% through the entire engine operating range. While the DIG configuration is more complex than DGB, current life cycle cost estimates indicate that fuel savings alone when compared to straight diesel operation may pay for the locomotive prior to its first major overhaul. One of the exciting findings on the 710-series engine when fitted with the DIG system is that fuel efficiency of the engine is improved several percentage points as compared to predecessor configurations.

The DIG system configuration is based on the technology of directly injecting natural gas into the combustion chamber near the top of the compression stroke. To accomplish this,



Figure 5- DIG Engine Test Cell Performance Testing

dual purpose, electronically controlled fuel injectors are utilized. These new fuel injectors have dual solenoids and porting for both natural gas and diesel fuel to be injected near the top of the

compression stroke, more analogous to the diesel cycle, whereas with the DGB configuration, natural gas is admitted into the combustion chamber near the bottom of the compression stroke, more closely resembling an Otto cycle. Both the DIG and DGB systems use diesel fuel injection to initiate the combustion process. With the DIG configuration, the injection of both the natural gas and diesel fuel into the combustion chamber occurs near top dead center, igniting the fuels as they enter the combustion chamber, resulting in improved combustion efficiency and reduced emissions.

Following experimental and development testing in a test cell environment, the EMDX 2012, SD70Ac locomotive has been up-fitted with the DIG fuel systems, and the proof of concept testing has successfully demonstrated full, 4500 brake horsepower,



Figure 6- EMDX 2012 – SD70Ac locomotive up-fitted with DIG®

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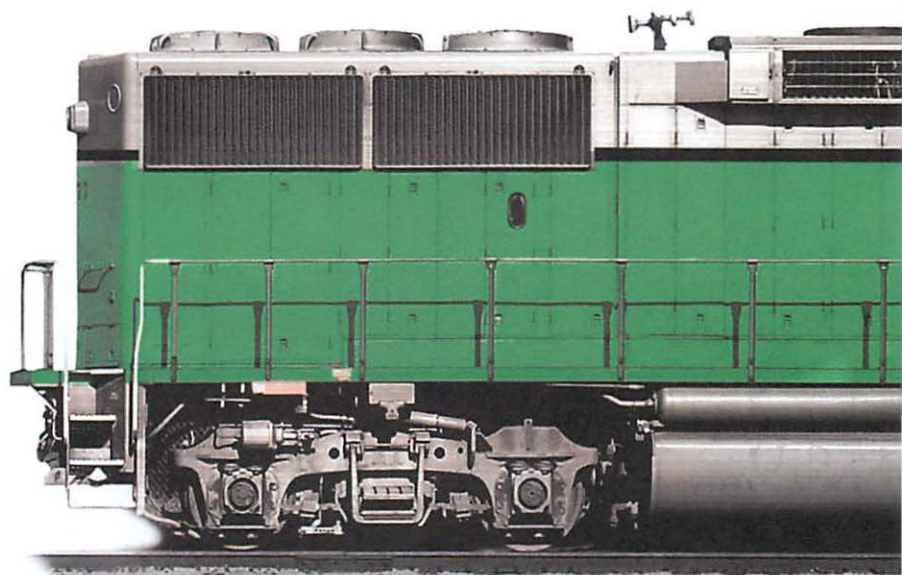


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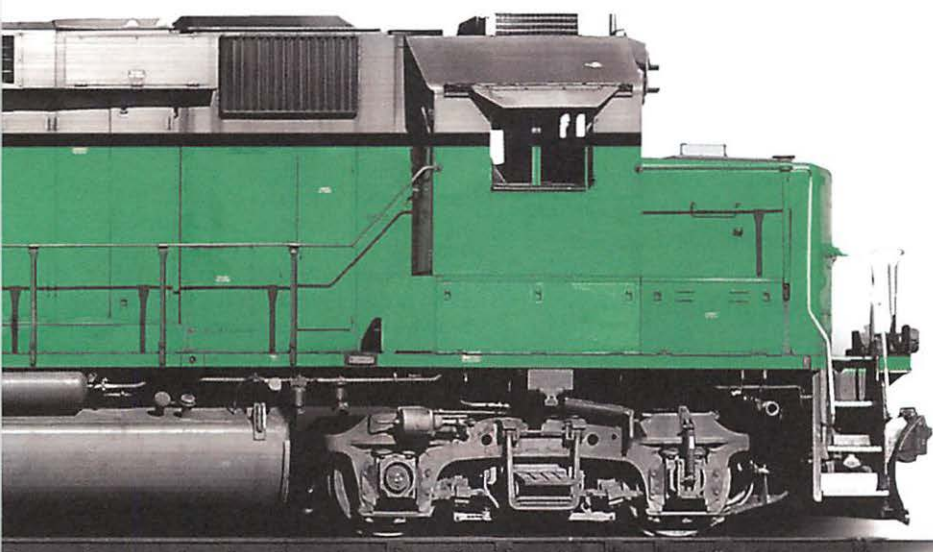
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with >95% diesel displacement. EMD is presently working with the railroads and LNG tender suppliers to develop retrofit configurations that will maximize savings for the industry while reducing emissions and the impact on the environment.

In conclusion, the long term prospects for the increased use of natural gas as a transportation fuel are excellent. While DGB applications are being utilized by the railroads to increase confidence in the utilization of natural gas as a primary fuel, the industry is recognizing technology exists to drive to the next level, DIG. With direct injected gas, the railroads will be able to maximize fuel savings while utilizing a clean burning technology, reducing the impact on the environment.

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- EPA – Locomotive Exhaust Emission Standards
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Hidden Costs of Locomotive Modernization

*Prepared by:
Viktor Gvelesiani, ZTR*

Locomotive modernization can take on many different forms – from an old relay replacement with a more modern variant to a complete remanufacture where the only remaining parts are the underframe and the truck castings. Understanding which technology components to retain, replace or add and at what cost can be quite complex: even daunting in some cases. It is not uncommon for businesses to focus on direct costs and benefits of the proposed upgrades simply because they have the most immediate impact on their financials and on their operations.

It is important to remember that the railroad industry today is not only affected by the accelerating rate of technological advancements, but also by the rate of regulatory advancements. New regulations and standards are approved and released every year and tremendous efforts are invested into these documents to ensure they are as simple, clear and easy to follow as possible: based on today's knowledge. The problem is that today's knowledge is becoming old knowledge increasingly faster. Every year, new amendments and additional explanation of the regulations are published to address the challenges brought up by the new technologies.

A locomotive modernization project could result in a very costly non-compliant (and as a result, unusable) locomotive if this complex regulatory environment is not considered and continually monitored.

This paper provides a quick overview of various potential pitfalls and benefits that should be considered by locomotive owners and operators during the planning stages of any locomotive modernization program.

EPA COMPLIANCE

In 1990, The Clean Air Act was amended, mandating the EPA to establish emission standards for non-road mobile equipment, including locomotives. The law became effective December, 1997. Compliance and enforcement of the law became effective January 1, 2000.

The specific emissions being regulated are:

- Oxides of nitrogen (NOx)
- Hydrocarbons (HC)
- Carbon Monoxide (CO)
- Particulate matter (PM)
- Smoke (opacity out of the exhaust stack)

Initially there were 3 separate sets of emission standards:

- Tier 0 – New locomotives (1973–2001)
- Tier 1 – New locomotives (2002–2004)
- Tier 2 – New locomotives built 2005 and afterwards

In recent years, new tier levels as well as additional locomotive classification (and exception) rules have been introduced. Currently the tier levels that are applied to all new locomotives based on the manufacture date as follows below:

Additionally, all new locomotives (including remanufactured locomotives) must be equipped with an EPA certified Automated Engine Shutdown and Start (AESS) system.

The above rules apply to all new locomotives. It is important to understand when a locomotive is considered to be new, as it defines its date of manufacture and therefore, the tier level of the applicable emissions standards. This especially is important when locomotives are rebuilt or upgraded because these modifications may require a change in the date of manufacture of the locomotive and consequently a

compliance with another tier level.

Section 40 of the Code of Federal Regulations, section 1033 defines locomotives to be “new” when they are originally manufactured and when they are remanufactured.

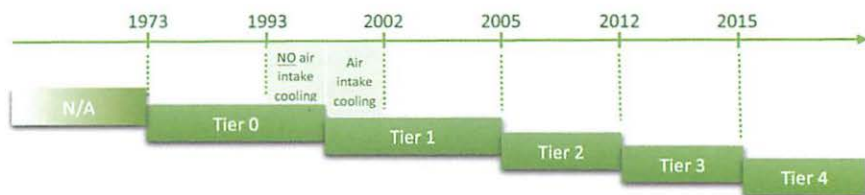
Original Manufacture of Locomotives

Original manufacture means the event of freshly manufacturing a locomotive or locomotive engine. The date of original manufacture is the date of final assembly, with the exception of special compliance provisions of 40 CFR 1033 section G.

Remanufacture of Locomotives

Remanufacture means one of the following¹:

- To replace, or inspect and qualify, each and every power assembly of a locomotive or locomotive engine, whether during a single maintenance event or cumulatively within a five-year period.
- To upgrade a locomotive or locomotive engine.
- To convert a locomotive or locomotive engine to enable it to operate using a fuel other than it was originally manufactured to use.



- To install a remanufactured engine or a freshly manufactured engine into a previously used locomotive.
- To repair a locomotive engine that does not contain power assemblies to a condition that is equivalent to or better than its original condition with respect to reliability and fuel consumption.

A remanufactured locomotive means either a locomotive powered by a remanufactured locomotive engine (see the definition of remanufacture above), a repowered locomotive (a locomotive powered by a new engine), or a refurbished locomotive.

The definitions of the terms “freshly manufactured”, “remanufactured” and “refurbished” also depend on the overall content of new parts versus the old parts used in any modernization program. This ratio is calculated based on the dollar value of used and new parts at the time of manufacture or remanufacture of locomotives and is defined as the weighted fraction of used parts:

If the weighted fraction of the locomotive that is comprised of previously used parts is greater than or equal to 25%, then the locomotive is considered to be a remanufactured locomotive and retains its original date of manufacture².

Additionally, if the weighted fraction is less than 50%, then the locomotive is also considered to be refurbished. The manufacture date also remains unchanged.

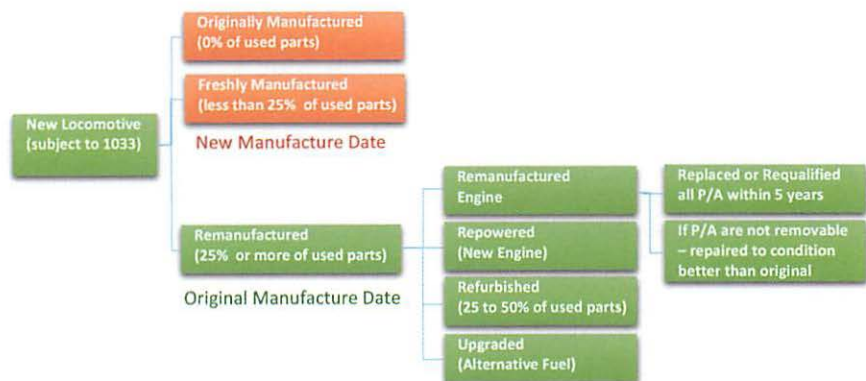
If the weighted fraction of the locomotive that is comprised of previously used parts is less than 25 percent, then the locomotive is deemed to be a freshly manufactured locomotive and the date of original manufacture is the most recent date on which the locomotive was assembled using less than 25 percent previously used parts³.

Although the general rule appears to be quite simple, a locomotive manufactured or remanufactured with less than 25% of used parts will have a new manufacture or remanufacture date and therefore will have to comply with the corresponding tier level. The complex relationship of various definitions stated above becomes very important when dealing with the special exemption cases.

Section 1033 defines a number of various exceptions and special provisions. This paper will mention only a few noteworthy examples. Reference 40 CFR 1033 section G for details.

Locomotives and engines that were originally manufactured before January 1, 1973 are not considered to become new when remanufactured unless they have been refurbished or repowered (also defined as “upgraded”). An upgraded locomotive will require a new manufacture date.

The rules for switch yard duty locomotives have also changed on January 1, 2015. Prior to that date, remanufactured Tier 0 switch locomotives that were deemed to be refurbished were subject to the Tier 0 line-haul cycle and switch cycle standards. After January 1-2015, all remanufactured Tier 3 and earlier switch locomotives that are



deemed to be refurbished are subject to the Tier 3 switch standards⁴.

A switch locomotive is a locomotive that is powered by an engine with a maximum rated power (or a combination of engines having a total rated power) of 2300 hp or less. This number also includes auxiliary engines that are permanently installed on the locomotive and can be operated while the main propulsion engine is operating.

Some locomotives (and locomotives using engines from the same engine families) originally manufactured 1986-1994 by General Electric Company that have never been equipped with separate loop aftercooling (8-40C P32ACDM, 8-40B, P42DC, 8-32B, 8-40BPH, 8-40CW, P40DC, 8-40BW, 8-32BWH, 8-40CM, C39-8, 8-41CW, B39-8E, 8-44CW) and SD70MAC and SD70IAC locomotives originally manufactured 1996-2000 by EMD can exceed otherwise applicable line-haul cycle NOX standard for high ambient temperatures and/or altitude because of limitations of the cooling system. However, the NOX emissions may exceed the otherwise applicable

standard only to the extent necessary (reference 40 CFR 1033.655 for details).

CAB AND FUEL TANK DESIGN (OR UPGRADE)

All wide-nose locomotives manufactured or remanufactured on or after January 1, 2009 must meet the requirements of 49CFR229 for Locomotive Crashworthiness Design. The requirements are stated in the AAR S-580 standard.

A narrow-nose locomotive must be designed in accordance with the provisions of AAR S-580, applicable to that type of locomotive (notwithstanding any limitation of scope contained in that standard), or in accordance with a standard or design approved by FRA as providing at least equivalent safety.

Each locomotive used in occupied service must meet the minimum anti-climber, emergency egress, emergency interior lighting, and interior configuration design requirements set forth in AAR S-580.

Locomotives with external fuel tanks must also comply with the

requirements of AAR S-5506 standard (except for section 4.4) and meet the requirements of 49 CFR 238.223. The fuel tank must meet the requirements for:

- Structural strength (minor derailment)
- Jackknifing
- Side Impact
- Penetration Resistance
- Sideswiping
- Spill control

ALERter REQUIREMENTS

Alerters are currently required on passenger locomotives pursuant to Sec. 238.237 (67 FR 19991), and are present on most freight locomotives. Section 20701 of Title 49 of the United States Code prohibits the use of a locomotive unless the entire locomotive and its appurtenances are in proper condition and safe to operate in the service to which they are placed. Under this authority, FRA has issued many violations against railroads for operating locomotives equipped with a non-functioning alerter.

Starting January 1, 2017, all controlling locomotives (not just those that are placed into service for the first time) operating at speeds of 25 mph and above must be equipped with functioning alerter.

CONCLUSIONS

Locomotive modernization implications can sometimes go beyond its direct costs and benefits. Some examples of these implications have been reviewed in this paper to demonstrate the importance of understanding of indirect effects of any modernization program before committing valuable resources to these programs.

The list of regulations and implications reviewed in this paper is by no means exhaustive. New rules, regulations and amendments are being developed to keep up with the dynamic and complex world of ever-changing railroad technology. It is understandably difficult and equally important to be aware of all of the ongoing changes and developments. Whether you have your resources dedicated to this task, or seek reliable advice from the experts in locomotive modernization, the assessment of both direct and indirect implication of these programs should become common practice.

Endnotes

1. 40 CFR 1033.901 Definitions
2. 40 CFR 1033.640.c
3. 40 CFR 1033.640.d
4. 40 CFR 1033.640.e

Report on the Committee on Diesel Mechanical Maintenance

Monday, October 5, 2015 at 3:30 P.M.



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R. Wullschleger	CMO	New York & Atlantic Rwy	Glendale, NY

Note: Eric Dillen of GE Transportation will be joining the committee



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PERSONAL HISTORY

Tom Kennedy

Tom was born in Kansas City Missouri and obtained a Bachelor of Science degree in Mechanical Engineering from the University of Kansas, Lawrence Kansas Campus. He joined Boeing Aircraft Company in Wichita Kansas in 1980 as a Systems Engineer covering the areas of reliability, maintainability, life cycle costing, and safety for multiple military projects. In 1990 Tom transitioned to the commercial side of the business where he was a Structural Design Engineer on the 737 aircraft. In 1995 Tom joined Case corporation as a reliability project engineer and became the corporate manager for reliability in 1996. In 2000 Tom joined Electromotive Diesel as the corporate reliability Manager. In 2005 Tom joined Union Pacific Railroad where he manages multiple projects and new technology in the Mechanical Department. Tom is also a member of the Society of Automotive Engineers.

Tom and his wife of 33 years, Joan, live in Omaha Nebraska. Their three sons (Zack, Mike, and Joe) also live in Omaha. Tom and Joan enjoy outdoor activities such as bicycle riding, BBQ's, and playing with their German Shepherd, Nikki.

The Diesel Mechanical Maintenance Committee would like to express their sincere gratitude to Southwest Research Institute and John Hedrick for hosting/ supporting our winter committee meeting on January 28-30, 2015 in San Antonio, Texas.

The Mechanical Committee had teleconferences for their Spring/Summer meetings this year which were set up by Union Pacific for which we want to say thank you.

The meeting and teleconferences could not be held without the support of companies such as SWRI and the UP.

Measuring the Value of Installing Solid Lube Sticks on Locomotives

*Prepared by:
Jeff Bink, JMA Railway Supply*

There were many resources referenced in the preparation of this paper/presentation and they are listed below:

- Snyder Equipment Co Test Data
 - TTCI Lube Stick Test-P.K. Agarwal
 - Railroad Industrial-Interlude Corp
 - MPL Technology Inc Test Data
 - LB Foster Rail Technology
 - National Research Canada Trans.
 - Kansas State University
3. Wheel flange wear reduction of up to 50%
 4. Rail wear reduction up to 25%
 5. Noise reduction of up to 20%
 6. Reduction of consumption of track side lubricants of 20%
 7. Measured by both mechanical and electrical force reduction

There are various types of Locomotive Flange Lube Sticks and they are listed below:

- Solid Stick Spring Loaded Flange Lubrications
- Wheel Flange Installations
- Natural Blend Formula Polymer Lubricants
- Biodegradable Polymers
- Multiple Sizes and Shapes
- On-Board Friction Modifiers

Transportation Technology Center Inc. in Pueblo, Colorado conducted various tests with the use of flange lube sticks and the following benefits were realized:

1. Energy savings in electric rolling stock of almost 5%
2. Fuel savings in diesel rolling stock of almost 5%

Locomotive flange lubrication sticks come in many shapes and sizes and have an interlocking feature (figure 1). There are many benefits for locomotive friction management with the use of lube sticks. They improve fuel economy, increase rail and track structure life, reduce lateral forces which minimize the potential for derailments, and reduce green-house gas (GHG) emissions.

The lubrication sticks are black, opaque solid. They are available with an interlocking or non-interlocking feature. The coefficient of friction range is 0.30-0.40. They do not change dimensions or melt under extreme temperatures. Decomposition begins above 250 C. They are non-flammable (ASTM D 4982-95) and are unable to sustain combustion (ASTM D635-97). They are non-toxic.

Solid Stick Friction Modifier

The use of solid stick on-board modifiers reduce short pitch corrugations, reduce rail replacement costs, reduce lateral forces by anywhere from 30 – 50% and reduce energy fuel consumption. Figure 2 contains data which illustrates the reduced wheel/flange wear due to the use of solid stick lubricators.

Gauge face lubrication and TOR (top of rail) friction control operate in tandem to reduce rail wear; one does not take the place of the other (figure 3). A chart of the life cycle of solid lube sticks is presented in figure 4. Additional photos are provided:

Figure 5 Flange lubricant applicators

Figure 6 Standard spring load applicator

Figure 7 Metro Insulation

Figure 8 Freight locomotives

Figure 9 Multiple types of applicators

Figure 10 Noise is reduced through reduced corrugation, extending grinding opening back to 5-9 Months

Figure 11 Track curve wear chart

Figure 12 Chemical deposits of lube stick

Figure 13 Flange wear goals

Figure 14 Wheel applicator

Figure 15 Freight applicator

Conclusion

Solid sticks systems can be customized to meet individual requirements. Through testing this technology continues to advance. Installation of these systems is relatively easy on any locomotive or car. Many benefits are derived such as reduced friction and noise, reduction of friction of wheel flange and rail. Additionally, it takes less energy to move train loads with these systems and it increases fuel economy, rail life cycle and less GHG (Greenhouse Gas) emissions.

Locomotive Flange Lubricant Sticks



Figure 1

Locomotive Wheel Flange Wear

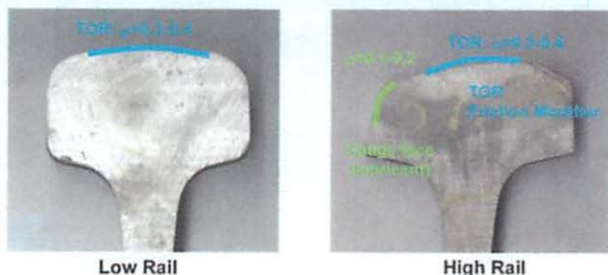
	Wear Rate (mm/kkm) (Trials with Control Vehicles)		Wear Rate (mm/kkm) (Trials without Controls)
	Metros	Freight	Metros/High Speed Trains
Control Vehicles	0.017 – 0.100	0.043 – 0.071	N/A
Test Vehicles	0.004 – 0.018	0.009 – 0.024	0.005 – 0.012

- Typical Flange Wear Target: 0.01 – 0.02 mm/kkm
(0.0006 – 0.0012 inches/1000 miles)

Figure 2

Friction Management

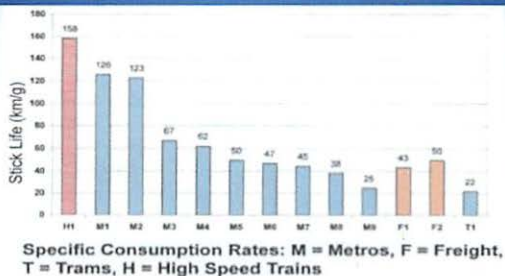
Recommended Friction Targets



- Gauge face lubrication and TOR friction control operate in tandem to reduce rail wear – one does not take the place of the other

Figure 3

Life Cycle of Solid Lube Stick



- Typical Applicator: 20 – 34 kkm (12k – 21k miles)

Figure 4

Flange Lubricant Applicators

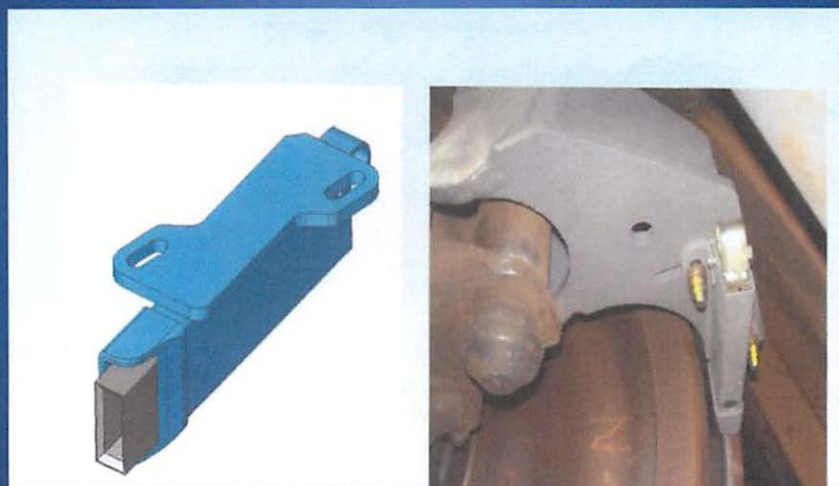


Figure 5

Standard Spring Load Applicator

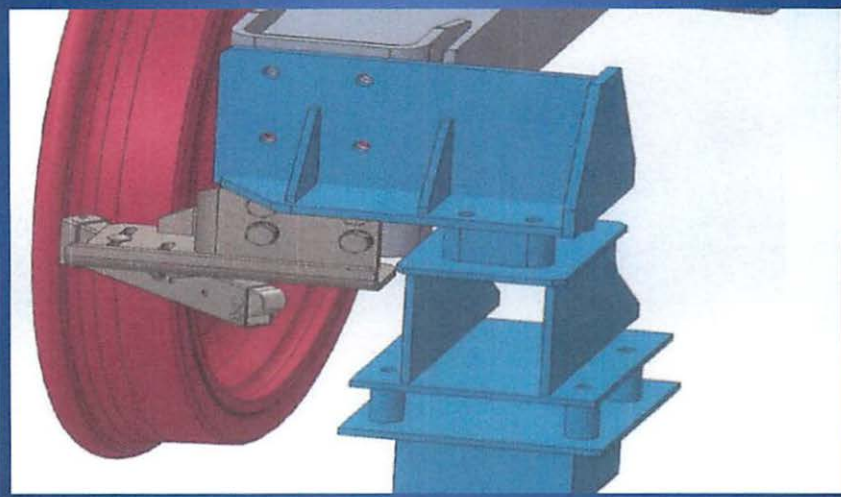
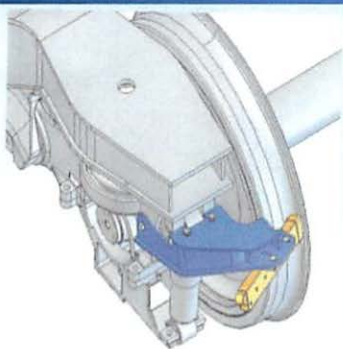


Figure 6

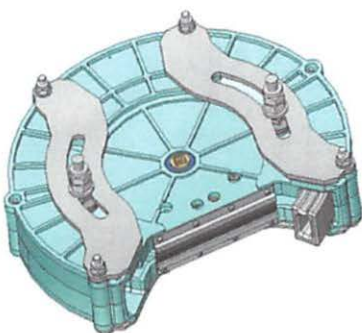
Metro Insulation



Metro System

Figure 7

Freight Locomotive



Circular Applicator on Freight Locomotives



Figure 8

Multiple Types of Applicators

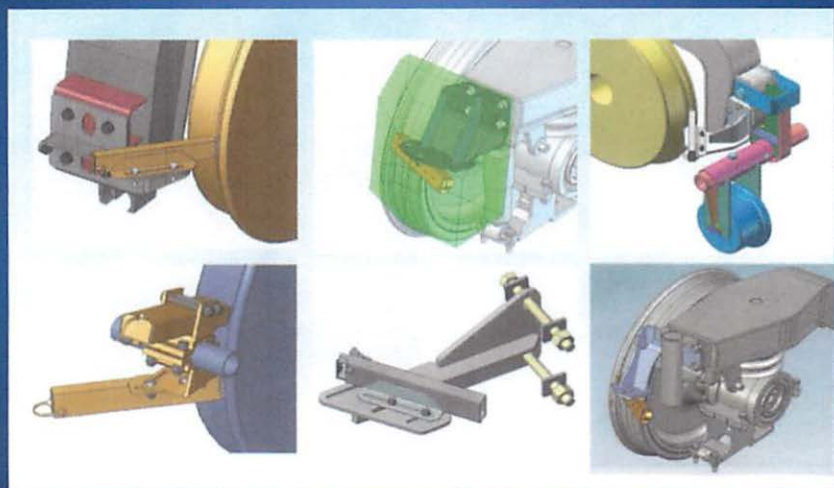


Figure 9

Noise is Reduced through reduced corrugation,
extending grinding opening back to 5-9 months.

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15.6% HPF Coverage - (31.2 % Effective)

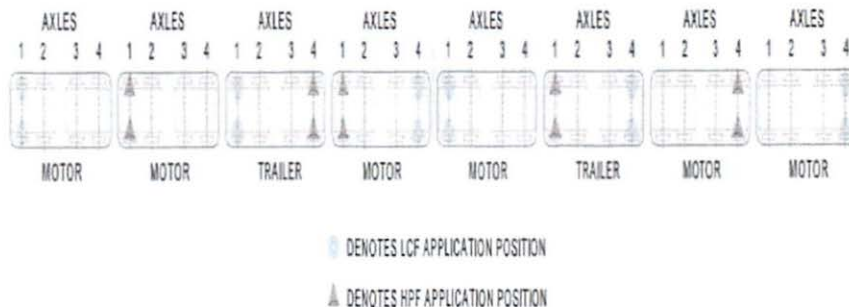
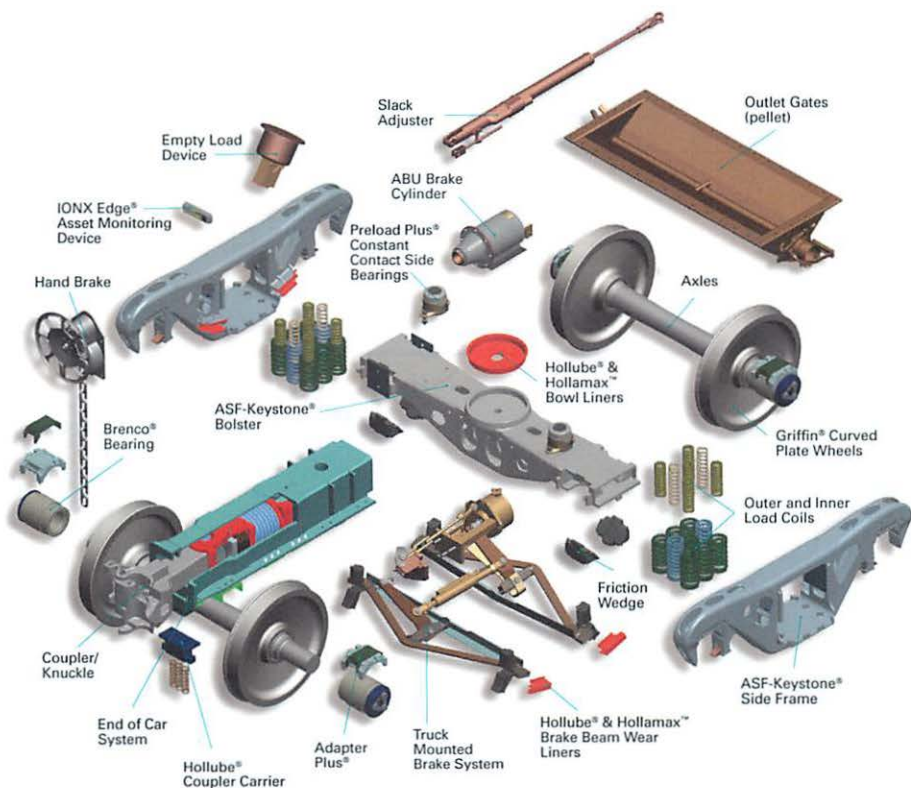


Figure 10

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Track Curve Wear

% Wheel Coverage Based on Flange Wear Index (FWI)

System	No. of Curves				FWI
	0 – 300 m	301 – 500 m	501 – 1000 m	≥ 1001 m	
A	1	1	24	25	0.22
B	1	17	29	8	0.35
C	5	12	4	7	2.04
D	25	24	38	28	3.16

A Comparison of Flange Wear Indexes

Figure 11

Chemical Deposits of Lube Stick



Figure 12

Flange Wear Goals

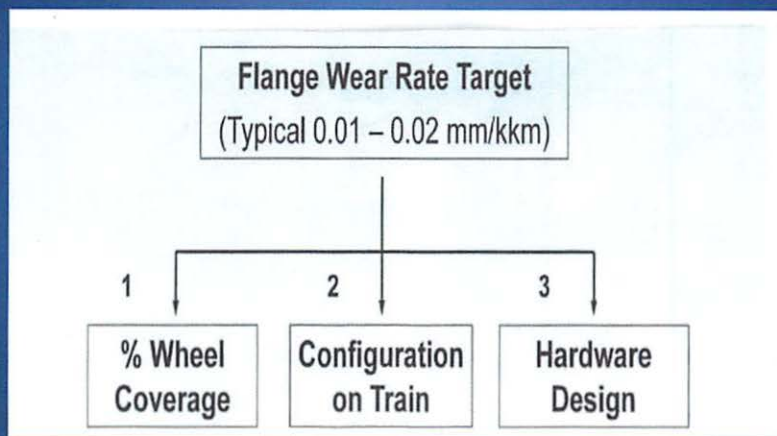


Figure 13

Wheel Applicator



Figure 14

Freight Applicator



Figure 15

NS CNG Locomotive Test Program

Prepared by:

Mark Duve, Norfolk Southern Corporation



Intro

As natural gas has become abundant and competitively priced in the last several years, railroads have shown much interest to use natural gas as a locomotive fuel. There have been many LMOA papers written about natural gas as a locomotive fuel and there are several locomotive tests currently in process. Those natural gas tests involve road locomotives over 4300 traction horsepower and the use of a tender. Up to this time, not much attention has been given to the yard and local locomotives around 2000 horsepower or less. This paper documents Norfolk

Southern's experience with converting a GP38-2 locomotive to burn natural gas. At the time of the writing this paper, the project is still in process and is not complete.

Why Convert a GP38-2?

Although one would think there are greater economic benefits to converting road locomotives to natural gas as road locomotives burn greater amounts of fuel which lead to greater fuel savings costs, there are other reasons to look beyond the fuel costs, the main reason being emissions. In a majority of metropolitan areas,

there are regions designated by the Environmental Protection Agency as not meeting the National Ambient Air Quality Standards for particulate matter, oxides of nitrogen (NO_x) and hydrocarbons. These areas are designated as Non-Attainment zones. Within the Non-Attainment zones many states or Metropolitan Planning Agencies have set up grants to fund emissions reduction by repowering locomotives or by employing emissions reduction technologies. The idea behind the grants is to fund emissions reductions that are lower than what is required by law. For instance, if a rebuilt locomotive would legally have to meet Tier 0+ after overhaul, a grant could assist in repowering the locomotive to either Tier 3 or Tier 4. These grants are typically funded through federal programs such as the Congestion Mitigation and Air Quality (CMAQ) and Diesel Emissions Reduction Act (DERA). The locomotives eligible for the grants must operate a majority of their time within the specified grant non-attainment zone. This essentially makes most grants applicable for yard and local locomotives, and prohibits road locomotives. Norfolk Southern has received many CMAQ grants for funding yard and local locomotive repowers in Atlanta, Chicago and Pittsburgh. These grants have targeted the reduction of PM_{2.5} which is a common exhaust emission of burning diesel fuel and a major concern of the EPA.

Contrary to diesel fuel, burning natural gas produces very little particulate matter. Most if not all of the particulate matter produced by a natural gas

engine is produced by the burning of the lube oil. On the other hand, natural gas has a tendency to have greater hydrocarbons than a diesel engine, which can be caused by unburned methane that is known as methane slip. But careful engine tuning and in some cases using an oxidation catalyst can reduce hydrocarbons. The NO_x emissions are dependent upon how the combustion is tuned; but, since natural gas engines operate at a lower compression ratio, it can be expected the natural gas engines can attain NO_x emissions standards much easier than a diesel engine. All engines have their own unique exhaust emissions based upon the design and tuning of the engine.

At this point in time, there is no low horsepower (below 2300 brake horsepower) natural gas engine that is locomotive emissions certified. This creates a problem for applying for government funded emissions reduction grants, as any technology used in the grant must be certified by the EPA. Norfolk Southern chose to pursue the GP38-2 to see what emissions savings could be in addition to the fuel savings by using natural gas.

CNG vs. LNG

All of the current natural gas experiments are using Liquefied Natural Gas (LNG) and road locomotives. Due to the fact that the energy density of LNG is about 1.7 times that of diesel fuel, these experiments are using a fuel tender. LNG storage in the tender has some issues in that LNG is cryogenic liquid with a temperature of -260 degrees F. As the LNG heats up,



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it boils into a gas and causes the pressure inside the tender to increase. For safety reasons, the natural gas is vented to the atmosphere when it approaches the maximum tender working pressure. This natural gas venting is a waste of fuel and it has some environmental concerns as methane gas can have a global warming potential of 21 to 72 times greater than CO₂.

Road locomotives use greater amounts of natural gas in less time. In addition, by using one tender between two locomotives, the locomotives will burn the LNG before it has enough time to warm up to boil and vent off. On the other hand, due to the sporadic use and low duty cycle of a typical switcher locomotive, it is more likely that an LNG fueled switcher would vent off a considerable amount of natural gas. With the use of Compressed Natural Gas (CNG), the probability of natural gas being released to the atmosphere is greatly reduced as CNG

pressure vessel vessels can hold the gas indefinitely. The basic problem with CNG is that it has a lower energy density than LNG; therefore, a tender should be used. However, in Norfolk Southern's CNG experiment the CNG is stored inside of slug.

CNG Storage Inside of Slug

Norfolk Southern has much experience with a large fleet of slug locomotives that are used in yard and local service. Since the slug requires a weight that is equivalent to the mother locomotive, the yard slugs are ballasted with concrete in the fuel tank and a concrete block in place of the engine. Instead of the concrete weight on the slug, NS has equipped an RP-E4C slug 799 with eight Type 1 CNG Cylinders made of steel. These cylinders are 2 feet wide and are 22 feet long with a working pressure of 4000 psi, which provides 1000 diesel gallon equivalent of fuel. The tanks along with the support



Figure 1. NS 799 RP-E4C slug under construction showing the natural gas cylinders.

rack weigh 69,000 pounds empty. The slug is also equipped with a crash worthy cab, and is modified such that the dynamic brake is mounted on the rear of the slug instead of directly above gas cylinders. (See Figure 1)

Technically the slug is not a tender but a locomotive, as the definition of a tender is an appearance of a locomotive. In this case the slug is a locomotive with its own traction motor, but it gets its power from a mother locomotive, and provides fuel to the mother locomotive

Engine Selection:

There are many 2000 HP natural gas off road engines available on the market. However, none of them have

yet to be tried on a locomotive. There are also a considerable amount of dual fuel engines that use diesel to ignite the natural gas, but since a switcher can see more than 50% of its time at idle, it was decided a dual fuel engine may not be the practical solution for switching service. Engine Conversions Incorporated has developed a natural gas conversion kit for a 645E engine and has used this kit in repowering an Alco FPA-4 on the Napa Valley Wine Train. This kit provides 100% replacement of diesel with gas at all throttle positions. This conversion was completed in 2002 and has been running since. (See Figures 2 and 3.)



Figure 2. Napa Valley Wine Train FP4 Locomotive with natural gas 645E engine.

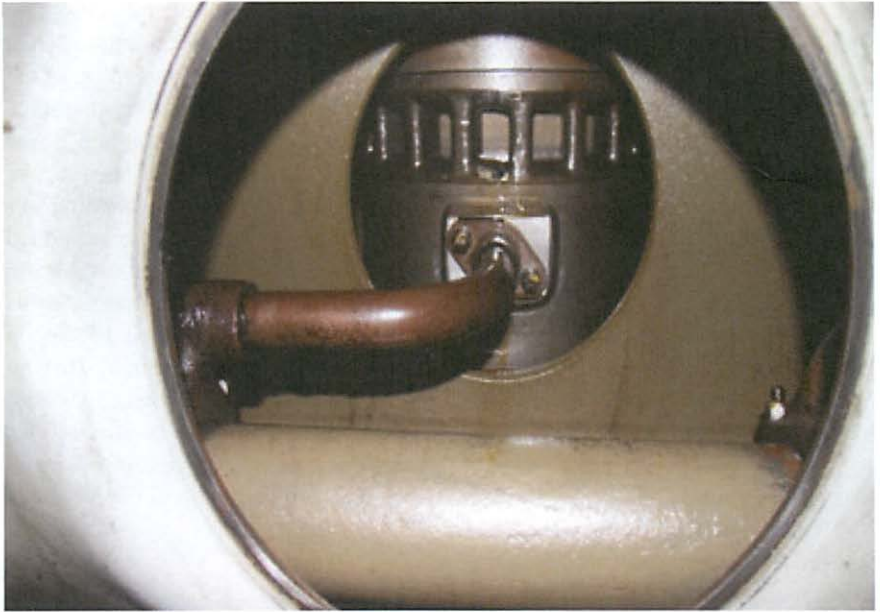


Figure 3. Airbox of Napa Valley Wine train after 11 years of service.

After review of the Napa Valley Wine train conversion and careful consideration, Norfolk Southern selected a 645E conversion kit from Engine Conversions, Inc. (ECI), and applied it to NS GP38-2 5053. There are many advantages to using this kit. These advantages include:

- Re-use of most 645E engine components
- Re-use existing cooling system
- No modification of under frame engine mounting pads
- Re-use of Dash 2 control system

APPLYING THE ECI 645E NATURAL GAS CONVERSION KIT

645E Engine Conversion

Norfolk Southern's Juniata Locomotive shop rebuilt a 645E engine with ECI's natural gas conversion kit. The basic changes to the engine include the addition of a gas manifold and the governor is replaced with ECI's electronic engine controller. The engine is also rebuilt without the fuel injector rocker arms. The power assemblies contain ECI's new cylinder head with a gas injector port and a new 12.8:1 compression ratio piston. The fuel injector is replaced with a pre-injection chamber that has a spark plug and an ignition coil. The gas injectors are hydraulic actuated. (See Figure 4.)

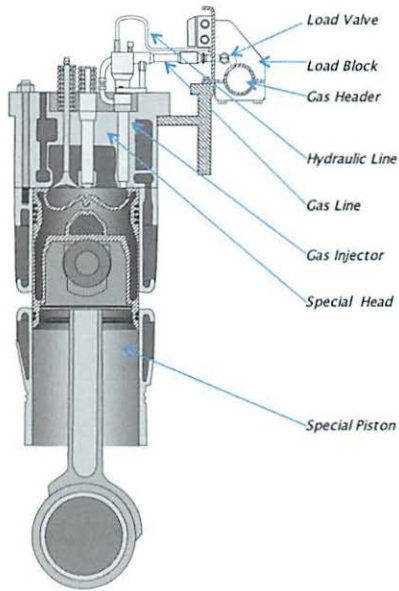


Figure 4. Cut away view of Natural Gas Power Assembly



Figure 5. Natural Gas Cylinder Head



Figure 6. Natural Gas Manifold on side of 645E engine.



Figure 7. Diesel Injector (left), Pre-Ignition Chamber (middle), Gas Injector (right).



Figure 8. NS GP38-2 5053



Figure 9. NS RP-E4C Natural Gas Slug

Locomotive Changes

The natural gas crosses over from the slug as high pressure. The locomotive is equipped with a heat exchanger that uses the engine coolant to heat the gas prior to passing through a pair of pressure regulators in parallel that are in series with final stage regulator that will drop the gas pressure to approximately 100 psi before entering the engine gas manifold. There is several methane detectors located in various areas on both the mother and the slug that are connected to several gas shut off valves in gas delivery system. (See Figures 8 and 9.)

Conclusion

At the time of writing this paper the engine has just been started and it is in the tuning process. This is the first 16 cylinder application for ECI. By the fall of 2015 the NS 5053 will be emissions tested at Southwest Research Institute. Revenue testing will commence upon completion of the safety study and FRA testing approval. A follow-up paper will be written on lessons learned from the emissions and revenue testing.

Utilizing Modern Electronics to Assist with Mechanical Maintenance Planning

Prepared by:

Casey Shepherd, Arkansas & Missouri RR and James Sherbrook, Sherpower

This paper will introduce an overview on how to plan mechanical-related maintenance by utilizing modern electronics to monitor past and real-time events to predict maintenance concerns, potential haul failures, and minimize "NO PROBLEM FOUND" issues when locomotives are backshopped. This can be accomplished using electronics on modern locomotives and aftermarket upgrade kits to retrofit older locomotives. Those of us who work in back shops commonly refer to such technology as "magic boxes." Not all uses or products will be covered, but some of what we have found useful will, by way of monitoring real-time data and other means.

The United States in service fleet of locomotives is approximately 36,300 diesel electric locomotives (Kerr/USITC). Locomotives are a high value asset... wouldn't it be nice to know where they are located and how they are performing at all times? Many manufacturers have answered this question. For us mechanical types, this is the "magic box." The "magic box" is connected through a series of sensors to monitor different parameters within a locomotive. If we incorporate the utilization of the "magic box" into our maintenance programs, we

can conserve manpower and resources when troubleshooting and repairing locomotives.

I. Past: Monitoring

Data monitored includes such things as the following: engine health, hard couple events, engineer-induced emergencies ("EIE"), event recorder activity, digital video recorder fault, fuel drop, battery voltage, emissions, GPS location, kilowatt hour usage, traction motor current, and alternator overload.

Engine health includes reviewing the following: temperature overload, a hot engine alarm, automatic engine start-stop ("AESS"), faults, low horse power, low water, no water, cold or hot water, engine shut down with or without AESS, low engine oil, low air compressor oil, and engine freeze. On older units equipped with plug-in block heaters, some systems can be configured to monitor analog signal input and output to determine if someone might have forgotten to plug the block heater into an outboard electrical source. Engine health also refers to reviewing motion-related issues like throttle position monitoring, locomotive speed, and over-speed incidents.

Hard couple events are monitored through accelerometers and gyroscopes built into the “magic boxes.” This data can be configured to send immediate alerts to specific individuals (“data managers”) within a specific organization who control said data and the required responses. With the use of the accelerometers and gyroscopes, one can also determine such events as a train-roll-over, train-handling exceptions, excessive impacts, and derailments. With the advent of such technology, often one can be alerted before the operator can report the incident himself.

Engineer-induced emergencies (“EIE”), when connected to the “magic box,” can alert data managers as emergency brake applications or inactivity penalty applications occur.

Event recorder activity is verified during 49 CFR 229 scheduled maintenance. When performed, event recorder functionality is tested every 92 or 184 days. Typically, no functionality checks are performed between periodic maintenance dates unless there is an accident. Then, event recorders must be downloaded manually, and a chain of custody established. With the advent of “magic boxes” and sensors, event recorder functionality can be tested daily and downloaded remotely. In the event of an event recorder failure, the user can be notified immediately. In the event of an EIE or accident, a user can be notified and the event recorder downloaded and populated wirelessly.

As we all know, the advent of digital video recorder (“DVR”) technology and its application to locomotives has saved railroads countless time and

money, particularly in hours and dollars not having to be spent defending frivolous lawsuits. The “magic box” can now conserve man-hours by monitoring this technology and allowing remote downloads. Also, sensor configuration will allow a short video clip to be sent to the data manager in the event of an EIE, hard couple event, or derailment.

Fuel drop incidents, from a mechanical perspective, might include items like a damaged fuel tank or plugged fuel filters. With a “magic box,” we can also know when idle is prolonged (wasting fuel) and even fuel theft.

Battery voltage sensor parameters can be set to monitor low and high strictures. As we know, this is imperative with AESS, as if the run-time is not lengthened to properly charge the batteries, it kills battery life.

Locomotive emissions are monitored through different manufacturers and the parameters they set. Such sensors and software now allow for extensive report history on emission output, excessive idling, fuel conservation, and engine-run activities. Conservation efforts even include increasing engine efficiency with skip-fire technology, allowing an engine to run on fewer cylinders.

Most “magic boxes” are now equipped with satellite GPS locating technology. GPS is used to locate locomotive position and also can be used to set up geo-fence parameters for one’s railroad. So, if the asset is on or leaves your track, you will know where it is located. You can also use it to alarm

the data manager if the asset leaves your property. Weigh points can be set up on one's track for things like speed restriction.

Kilowatt-hour usage now can be conveniently organized and specific reports generated by locomotive and hours-run. Such reports can be used by us to track what maintenance needs are required to be performed at what interval.

Traction motor current and alternator overload also can be conveniently tracked by the "magic box" and reports generated. Such information can be used to track occurrences such as operator abuse or used in conjunction with GPS to locate poor track conditions. It should also be noted that, some leasing companies, if you lease power, track such overload occurrences as a way to determine if their AC generation locomotives were abused while on lease. If an alternator, through its history, is shown to have been abused, the leasing company may issue you a back-bill when it pulls the locomotive from the property.

The "magic box" monitors and records the above-referenced data. Parameters can be established to report this data to the data manager in real time, as well.

II. Present: Real-time Events

In the event of EIE, event recorder and DVR data are downloaded. This information can be sent to the data manager immediately and wirelessly by text message, phone call, and/or email alert. Physical data for chain of custody purposes can be obtained and downloaded

on-site at the incident with modern technology. Some may be downloaded with USB drives rather than "ancient" laptops with pin connectors.

III. Other

There are a variety of other concerns for our industry not necessarily mechanical, that need to be addressed and monitored by others within one's organization. With on-board technology and certain web portals, one can manage his entire rail system to include events such as severe weather monitoring and asset details. Reports can be generated through software and algorithms for each rail's use to include things like daily utilization reports, control summary reports, and fleet reports. Such reports can help managers obtain information to conserve fuel, minimize locomotive fleets for unused assets, identify problematic locomotives, and reduce shop time and troubleshooting labor.

In conclusion, we attempted to provide an overview on how "magic boxes" might be used to help correct maintenance-related issues. Mechanically, we like to see the cause of a failure. Theoretically, if we are provided the data rather than visual evidence, we can save time and money, and stop the problem before it starts.

Resources

Brookville Locomotive,
CoGeneration, www.brookville-corp.com.

Electro-Motive, EM2000, Control
System Retrofit, FIRE,
Functionality Integrated Railroad
Electronics, Intellitrain, www.emdie-sels.com.

GE Transportation, RailConnect 360
Remote Monitoring & Diagnostics
Suite, Smart Display,
www.getransportation.com.

Kerr, James, Locomotive Rosters &
News, The Official 2013 Edition.

Lat-Lon, Locomotive Monitoring
Unit, www.lat-lon.com.

National Railway Equipment,
NFORCE, www.nre-electronics.com.

New York Air Brake, LEADER
AutoControl, www.nyab.com/en/.

Peaker Services, Inc., T)+ EUI Kit
HMI, www.peak.com.

R.J. Corman, Railpower, www.rjcor-man.com.

Railsolve, LEAF, www.railsolveleaf.biz.

Wabtec, MotivePower,
MotivePower™ Central
Diagnostics System, www.wabtec.com.

Wi-Tronix, Wireless Processing Unit
(Wi-PU), www.witronix.com.

United States International Trade
Commission, Rolling Stock:
Locomotives and Rail Cars,
www.usitc.gov/publications/332/ITS-08.pdf.

ZTR Control Systems, NEXSYS III-I,
www.ztr.com.

Shore Connection Heating Systems for Locomotives Electric Heating Systems with New Implementation Techniques

Prepared by:

Mark Duve, Norfolk Southern Corporation

Introduction

Through the rail industry's continual pursuit to reduce emissions, rather than committing financial investments in the development of new innovations, perhaps the best alternative is making use of existing technology that has been at our disposal for decades. One proven method for emissions reduction is through idle reduction. To enable idle reduction while maintaining safe locomotive temperatures, Automatic Engine Start/Stop (AESS) and Auxiliary Power Units (APUs) have been tried and proven. However, in certain instances there are limitations to those systems that make them less effective. One technology that provides reliable idle reduction is the Shore Connection System for Locomotives. This paper will detail Norfolk Southern's approach to implementing commercially available Shore Connection Systems and instances where the systems are most effective.

The Shore Connection System for Locomotives

A Shore Connection System for locomotives is quite simply a locomotive coolant heater that receives power

through the commercial grid. The system consists of a controller, coolant piping/tubing, a pump and a coolant heating element or heat exchanger. There are electric shore connection systems available on the market as well as a diesel fueled furnace heat exchanger system. There are also systems that have an additional pump and heating chamber for the engine oil. Oil heating is beneficial in areas where subzero Fahrenheit temperatures are common.

Under the Verified Idling Reduction Technologies section of the EPA's SmartWay Technology website, there are two commercially available full electric Shore Connection Systems; the HOTSTART System (Figure 1) and the TMS FreezeBeater (Figure 2). The HOTSTART System has the option of the additional oil heater. Both systems are eligible for CMAQ and DERA grants.

External power is provided to the heating system by a wayside plug-in station that provides 480 volt, 3 phase power. The wayside station also has built-in ground fault detection, phase imbalance protection and loop complete detection before the 480 volts are energized. There are a couple



Figure 1. HOTSTART System



Figure 2. TMS FreezeBeater System

variations of the wayside power station that will be described in a later section. Why Use Shore Connection Systems?

Each idle reduction system has its strengths and weaknesses and each system may not be suitable for all locations or conditions. Table 1 shows the strengths and weaknesses for the idle reduction practices and technologies.

AESS is quite common and required by law on all locomotives that are emissions certified under 40CFR Part 1033. However, there is a limit to the number of engine starts per day that a locomotive battery can handle. Once

the daily maximum number of engine starts are met, the AESS system will not shut down the engine. Thus, on a cold winter day, the locomotive will accrue many hours of idling.

APUs have their advantages but due to their complexity, the devices require additional maintenance of the APU engine, alternator and battery which consumes shop time. In addition, the APU still burns some fuel and produces some emissions.

Both AESS and APUs have the advantage in that they are both self-contained on the locomotive and do not need shore connection.

Practice or Technology	Strengths	Weaknesses
Manual Shut Down	No Fuel Burn No Emissions Assured Shut Down	Potential Freeze Damage Battery Life Issues
AESS	Electronic – No Moving Parts Automatic Complete Onboard Locomotive System	Battery Life Issues Limited Daily Starts/ Stops Low Temperature Effectiveness
APUs	Automatic Complete Onboard Locomotive system	Extra Maintenance Some Emissions
Furnace Coolant Heater	Automatic	Uses Battery or shore power Igniter and burner maintenance Battery life issue Some emissions
Shore Connection System	One Moving Part – minimal maintenance No Local Emissions	Requires Shore Power Hook Up

Table 1: Strengths and Weaknesses of Idle Reduction Practices and Technologies

NS has tried a manual shut down policy and has experienced battery failures because the battery was not at a sufficient charge when the locomotive was shut down. Also, a manual shut down policy is not very effective in winter months and is dependent upon weather forecasts that can change.

The advantage of the shore connection system is that the only moving part is the pump (two pumps for oil heating systems), which reduces the maintenance. An additional advantage of the electric driven shore connection system is that there are no local area emissions. On the other hand, the major disadvantage of the shore connection system is the offboard locomotive infrastructure required. This infrastructure consists of power lines, poles, transformer(s) and the wayside station itself.

Best Applications for Shore Connection Systems

To apply the required infrastructure for shore connection systems to road locomotives on Class 1 railroads would be a major undertaking. Due to the amount of road locomotives, it would take years to apply these systems to the whole fleet which makes the shore connection system less desirable for road locomotives. However, Norfolk Southern has found that applying these systems to the yard and local locomotive fleets that are assigned to specific terminals or regions and maintained out of the same system shop, is beneficial and can be accomplished in shorter time. Often, yard and local locomotives are used for one to two shifts per day and usually idle overnight and/

or during most weekends. In some of these areas, yard locomotives are kept on standby to switch auto plants when needed. In these instances, there can be significant reductions in idle emissions as well as fuel savings from using the shore connection systems. Currently, Norfolk Southern is applying shore connection systems infrastructure in rail yards located in Kanas City, Chicago, Atlanta and Northeast Ohio as well as its local locomotive fleet.

Lessons Learned – Ideas to make Shore Connection Systems Successful

Through implementation of Shore Connection Systems, Norfolk Southern has learned to modify the system by addressing the following issues

- Emergency Fuel Cutoff (EFCO) interlock
- Battery Charging
- Electrical Connectors
- Cab Heat
- Wayside Power Stations

Emergency Fuel Cutoff (EFCO) Interlock

Adding a relay to the EFCO circuit prevents the engine from starting as long as the shore connection system is connected to the locomotive. This assures the engine cooling system and the shore connection system will not conflict with each other resulting in issues with the coolant water circulating pump. This concept also forces the crew to disconnect the shore power before the locomotive can be started and moved.

sit idle without idling

By equipping a locomotive with a HOTSTART block heater, the prime mover can be shut down and easily restarted, even after days sitting in freezing weather. This eliminates the problems with idling including wasted fuel and oil, wet-stacking, emissions, noise and engine wear.

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Battery Charging

When the locomotive is shut down the status state of battery charge is not known. The battery charger has successfully prevented batteries from dying while shut down. There are many locomotive battery chargers on the market. Norfolk Southern's experience has shown that it is best to use a three phase charger as the single phase charger has a tendency to trigger the phase imbalance detection on the wayside station.

Electrical Connectors

Initially, Norfolk Southern used the tried and proven railroad Head End Power (HEP) connector (Figure 3), which is designed for 3 phase 480 volt with three extra low voltage circuits required for the connection complete circuit. However, NS crews found the 75 pounds of force required to insert the connector too strenuous. To resolve this issue, NS substituted the HEP connector with the Meltric three phase 480

volt twistlock connector (Figure 4). The Meltric connector is relatively easy to insert into the mating receptacles and a simple twist of the electrical plug engages the contacts. Additionally, the Meltric connector features side clamps to aid in insertion.

Cab Heat

In the extreme winter cold, the yard crews typically start up the locomotives and warm them up for an hour before beginning their shift. By adding dual element strip heaters in the cab and installing a 50 degree F thermostat in the cab sub base, the cabs stay warm, eliminating another daily hour of idling.

Wayside Power Stations

The prototype plug-in station was mounted on a utility pole with the cable coiled up as seen in Figures 5 and 6. This station presented risk in that the cable is lying on the ground, allowing vehicles to drive over the cable



Figure 3: HEP Connector



Figure 4: Meltric Connector



Figure 5: Conventional Plug In Station



Figure 6: Shore Connection Cable



Figure 7: Snyder Equipment Co. electric Plug-in Station at North Kansas City Yard

and causing damage to the insulation. Additionally, if the crews do not coil up the power cable in the winter it would be lost in the snow. The solution was an improved ergonomic wayside plug-in station (Figure 7) manufactured by Snyder Equipment Inc. using hardware from Snyder's fuel crane. This station utilizes an arm to hold the cable and swivels 270 degrees. It contains the electrical control cabinet with the built-in safety features listed above while keeping the cable off the ground. The apparatus requires a maximum of 18 pounds of force to connect the cable to the receptacle when the arm is fully extended. In addition, there is an LED work light that tracks with the station as it swivels.

Conclusion

Applying Shore Connection Heating Systems to yard and local locomotives can reduce idle emissions by heating the engine coolant with an electric heating system. This type of heating device allows the engine to be shut down for extended periods of time in freezing temperatures and easily restarted. The key to making the Shore Connection Heating System a success is by providing an EFCO interlock, a locomotive battery charger, ergonomic connectors and a safe, ergonomic plug-in station that provides ground fault detection, phase imbalance, loop complete detection and ease of use.

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Locomotive Exhaust Emission Regulations: Is Tier 5 Next?

Prepared by:

John C. Hedrick and Steven G. Fritz, Southwest Research Institute

Introduction

This paper reviews the US-EPA's stated intent while developing the Tier 4 locomotive exhaust emissions standards, how locomotive emissions standards have progressed from Tier 0 to Tier 4, and how the Tier 4 emissions standards compare to current on-highway truck emissions standards. The goal of this paper is to compare locomotive and US-EPA heavy-duty on-highway diesel emission standards, and then use this comparison to help assess "is Tier 4 the end, or is it just the beginning"? Note that the contents of this paper are drawn strictly from publically-available information, and there has been no input from locomotive Original Equipment Manufacturers (OEM's), United States Environmental Protection Agency (US-EPA), California Air Resources Board (CARB), or any other agency.

Background

The US-EPA stated in the preamble of their 2008 regulations introducing the Tier 4 emissions standards that "*Tier 4 standards, ... reflect the application of high-efficiency aftertreatment technology*".¹ Additionally, the US-EPA estimated that by "*2030, this program will reduce annual emissions*

of NO_x by about 800,000 tons and PM emissions by 27,000 tons and those emission reductions continue to grow beyond 2030 as fleet turnover is completed."¹ These large reductions are driven by the Tier 4 emissions standards that went into effect in 2015, and the transition as the older pre-Tier, Tier 0, Tier 1, and Tier 2 locomotives are replaced with the new Tier 4 locomotives.

Today GE is building line-haul locomotives that meet Tier 4 emissions without using aftertreatment, even though the US-EPA expected Tier 4 emissions standard to be aftertreatment forcing. GE stated that their Tier 4 "locomotive is powered by GE's 12-cylinder EVO engine and requires absolutely no after-treatment system."² EMD has stated that they will not release a Tier 4 line-haul locomotive until 2017, and it could be speculated that their Tier 4 locomotive will also be designed to operate without aftertreatment, if for no other reason than to be competitive with GE.

Interestingly, on the passenger locomotive side, there are two new passenger locomotive offerings that are reported to meet Tier 4 emissions using Selective Catalytic Reduction (SCR) aftertreatment systems. EMD's F125

passenger locomotives to be powered by a Tier 4, 3,500 kW (4,700 BHP) Caterpillar C175-20 engine, fitted with both a Diesel Oxidation Catalyst (DOC) and SCR.³ Siemens Rail System is building a Sprinter passenger locomotive using a Tier 4, 3,281 kW (4,400 BHP) Cummins QSK95 diesel engine that also has an SCR system.⁴

GE's (and potentially EMD's) ability to meet the US-EPA's Tier 4 emissions levels on line-haul locomotives without aftertreatment, and the use of SCR aftertreatment on new high-power passenger locomotives, raises the prospect that in the future US-EPA could mandate even lower locomotive emissions standards by combining these two technologies (Tier 5?). If so, then the major area of speculation is how low might the Tier 5 emission levels be?

Discussion

The current US-EPA exhaust emissions standards for line-haul locomotive NO_x and PM are shown in Figure 1. These include Tier 0, Tier 1, Tier 2, Tier 3, and Tier 4 for new locomotives, dependent of the time of manufacture. At time of overhaul, locomotives originally manufactured between 1973 and 2011, the engine emissions need to be further reduced to meet the applicable Tier 0 Plus, Tier 1 Plus, or Tier 2 Plus emissions standards. Figure 1 graphically shows the dramatic reductions in NO_x and PM emissions from locomotives since the introduction of the regulations in 2000; Tier 4 is an 86 percent NO_x reduction and the PM is a 95 percent reduction compared to Tier 0 emissions limits. The actual limit values are given in Table 1.

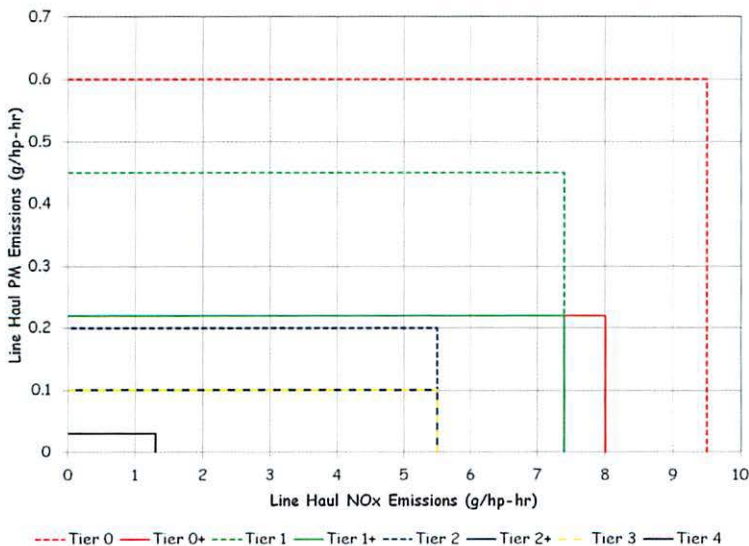


FIGURE 1. Tier 0 Through Tier 4 Line-Haul NO_x and PM Emission Limits

	NO _x (g/Hp-Hr)	PM (g/Hp-Hr)
Tier 0	9.5	0.60
Tier 4	1.3	0.03
Percent Difference	-86%	-95%

TABLE 1. US-EPA Line-Haul Cycle Emissions Reduction Between Tier 0 and Tier 4

Though locomotive emissions have been reduced dramatically to today's Tier 4 levels, it is instructive to consider how locomotive emissions compare to other competing transportation modes, namely on-highway heavy-duty diesel trucks. Figure 2 looks at the difference between the US-EPA Tier 4 line-haul locomotive emission limits and the US-EPA 2010 heavy duty, on-highway emissions limits.⁵ While the test cycles for these two type of engines are very different, the normalized brake-specific (g/hp-hr) emissions are one way to compare the emissions profile from these different types of engines. As shown in Figure 1, the Tier 4 locomotive NO_x and PM emission limits are a small box in the lower left corner of the graph. In Figure 2, because of the scaling of the X and Y-axis on the graph, the Tier 4 locomotive NO_x and PM emissions box consuming nearly the entire graph. The red colored box in this graph represents the US-EPA's emissions limit for heavy duty, on-highway trucks that have been in place since 2010. Plainly stated, allowable Tier 4 locomotive NO_x emissions are 6.5 higher

and PM emissions are 3 times higher than the 2010 on-highway truck standards. Furthermore, these 2010 trucks are fitted with a diesel particulate filter (DPF), and as a result, the actual PM emissions are typically 1/10 of the limit (0.001 g/hp-hr) which is represented by the green box in Figure 2. Therefore, the allowable Tier 4 locomotive PM levels are on the order of 30 times higher than 2010 and newer trucks.

Note, however, that the HD on-highway diesel truck regulations continue to push technology development as even further reductions from truck engines are expected. In late 2014, the California Air Resources Board adopted optional low NO_x emissions standards of 0.02 g/hp-hr for HD on-highway diesel engines. Assuming DPF level PM at 0.001 g/hp-hr, you end up at the small blue box in the lower left of Figure 2. At this NO_x level, the Tier 4 locomotive NO_x standards are 65 times higher. This NO_x the stage for speculating whether there will be future locomotive regulations beyond Tier 4.

Table 2 shows the percent difference between Tier 0 and Tier 4 locomotive standards, Tier 4 locomotive



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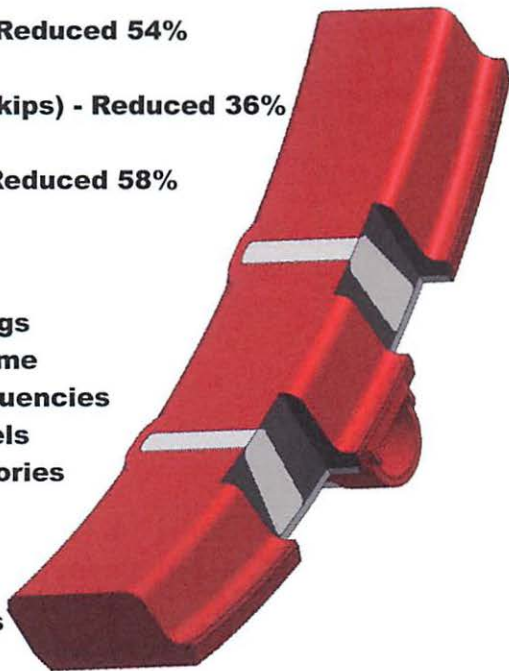
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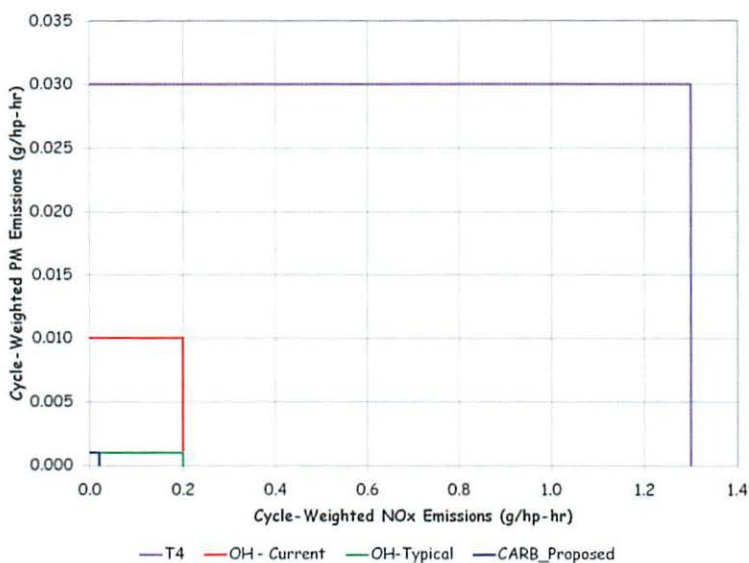


FIGURE 2. Comparing Tier 4 Locomotive to HD On-highway Diesel Emission Limits

	NO _x	PM
Locomotive Tier 4 to Tier 0	-86%	-95%
US-EPA 2010 HD On-highway to Tier 4	-84.6%	-66.7%
CARB Optional HD On-Highway to Tier 4	-98.5%	-96.7%

TABLE 2. Percent Difference Between Tier 0, Tier 4, and CARB's Proposed On-highway Emission Levels

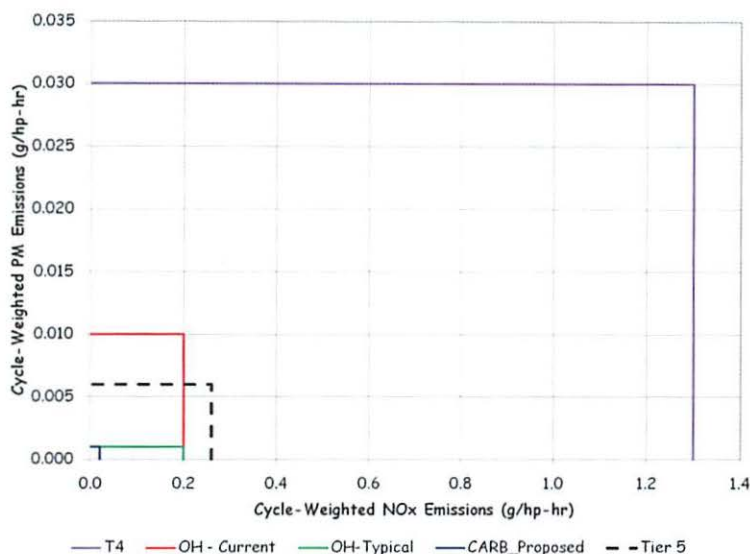


FIGURE 3. Comparing Tier 4 Locomotive to HD On-highway Diesel Emission Limits

and the US-EPA 2010 HD on-highway emission standards, and the percent difference between the Tier 4 and the optional CARB HD on-highway emissions standards. Each step has a significant emissions reduction, with an 86 percent reduction in NO_x and a 95 percent reduction in PM between Tier 4 and Tier 0. However, the percent difference between Tier 4 and the US-EPA HD on-highway are -85 percent for NO_x and -67 percent for PM emissions. Looking at the percent difference between Tier 4 and CARB optional emissions limits, the CARB optional NO_x limit is -98.5 and PM is -96.7 percent of Tier 4.

Locomotive Tier 5?

CARB is already working to get US-EPA to consider a locomotive Tier 5 emission standard that will be “based on aftertreatment, liquefied natural gas, and/or zero emission track miles”.⁶ CARB’s stated goal is to have US-EPA complete the Tier 5 rulemaking by 2018 and mandate the Tier 5 emissions standards for new locomotives in 2025, a mere 10 years away.

Despite progress in air quality improvement, approximately 75 million people nationwide lived in counties with pollution levels above the primary National Ambient Air Quality Standards (NAAQS) in 2013.⁷ With the large difference between the HD on-highway emissions standards and the current Tier 4 locomotive standards,

one can envision that the US-EPA may mandate a Tier 5 locomotive emissions standard. The question is; what emissions reduction could one expect between Tier 4 and a Tier 5? For the purpose of this paper, we will assume that the PM and NO_x emission reduction will be 80 percent below current Tier 4 levels, which appears to be reasonable based on the percent differences shown in Table 2. To meet this Tier 5 emissions standard, aftertreatment would be required, in addition to many of the current in-cylinder emissions strategies that are being used to meet the Tier 4 locomotive emissions standards.

At an 80 percent reduction from Tier 4, the Tier 5 NO_x emissions limit would be 0.26 g/hp-hr and the PM limit would be 0.006 g/hp-hr, as shown in Figure 3. At these Tier 5 locomotive emissions level, the existing 2010 HD on-highway emissions would still be 23 percent lower NO_x. However, recall that the typical HD on-highway engine only produces 0.001 g/hp-hr PM, which is 83.0 percent lower PM emission level compared to a 0.006 g/hp-hr Tier 5 target PM emissions level. In other words, a Tier 5 locomotive standards 80 percent lower than today's Tier 4 levels, is still effectively higher than the 2010 HD on-highway truck standard. This suggests that an even more aggressive Tier 5 may be pursued.

Conclusions

Tier 4 locomotives may not be the final locomotive emission standard. The current Tier 4 locomotive emissions standards are a significant emissions reduction over previous standards and at the time that the US-EPA released the Tier 4 standards, they believed that Tier 4 standards would be aftertreatment forcing. However, the ability to meet Tier 4, without the use of aftertreatment, has been demonstrated and is in commercial production. This advancement and the large difference between the locomotive Tier 4 and the HD on-highway emissions standards suggests that there could be a Tier 5 emissions standard released sometime in the future. CARB is currently working to get the US-EPA to develop and propose Tier 5 emissions standards by 2018, and have new locomotives meet Tier 5 by 2025.

If Tier 5 represented a 80 percent reduction from the Tier 4 PM and NO_x emissions limits, the new NO_x limit would be 0.26 g/hp-hr and the PM limit would be 0.006 g/hp-hr. These emissions levels are still above the US-EPA's 2010 HD on-highway NO_x limit and the typical PM level of a HD on-highway engines.

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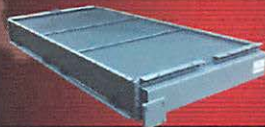
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- 6 *Sustainable Freight: Pathways to Zero and Near-Zero Emissions*: AIR RESOURCES BOARD (ARB) Discussion Dated April 2015, Page 31
- 7 EPA - Air Quality Trends, 10/8/2014; <http://www.epa.gov/airtrends/aqtrends.html>

Report on the Committee on Fuel, Lubricants and Environmental

Tuesday, October 6, 2015 at 9:15 A.M.



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Note: Dan Meyerkord announced his retirement from EMD

PERSONAL HISTORY

Tom Gallagher

Thomas E. Gallagher was born and raised in New York City. He is a graduate of the United States Merchant Marine Academy located in Kings Point, NY. Tom worked in the Nuclear Engineering Department of the Charleston Naval Shipyard in Charleston, SC for 3 plus years prior to accepting a technical service engineer position with Chevron International Oil Company addressing fuel and lubricant related issues for equipment onboard merchant vessels from offices located in Stamford, CT and Media, PA. In 1996, he accepted a position with Chevron Oronite as technical sales representative and was based in Rolling Meadows, IL and Lexington, KY locations during the following 6 years.

Tom assumed the responsibilities of Global Railroad Technical Liaison for Oronite in 2000 and has had the pleasure of actively participating in the Fuels, Lubricants & Environmental Committee for the past 14 years. His current position affords Tom the opportunity to work with N. American & International Railroads, OEMs and oil companies to effectively address the research and development requirements of additive technology solutions for emerging emission and fuel regulations in order to advance locomotive engine oil performance attributes and standards.

Tom is a retired Lieutenant of the United States Naval Reserve. He and his family reside in Commerce, MI.

The Fuel, Lubricants and Environmental Committee would like to express their sincere appreciation to American Refining Company for hosting the committee's winter meeting and lunch on board the SS Natchez Riverboat in New Orleans, LA.

The LMOA committees might not be able to conduct their internal meetings without the support of companies such as American Refining.

Railroad's Fuel Options, Research and Literature Review

Prepared by:

Dennis McAndrew, Consultant and Leighton Haley, Norfolk Southern

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Abstract

Introduction

Six papers reviewed

Authors review of each paper

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ABSTRACT:

Due to increased pressures to reduce exhaust emissions and dependence on petroleum fuels, interest in alternative fuels has swelled. This interest has resulted in a growing use of bio, renewable and synthetic fuels along with investigations into other potential alternative fuels. With the increased interest and content of alternative fuels in the railroad's supply chain, several noteworthy research papers and review articles have been written on alternative fuels, their performance in locomotives and potential changes to the railroad's fuel supply infrastructure. This paper reviews several of those research and literature review papers.

INTRODUCTION:

For over four decades, diesel fuel supplies to the railroads were fuels that met the ASTM International (ASTM) D975 Grade No. 2-D. However,

government regulations to reduce exhaust emission and environmental impact, along with a desire to reduce dependency on foreign oil, have resulted in some significant changes to the fuel supplies available to railroads. These changes included lower sulfur content of conventional No. 2-D and inclusion of alternative fuels and alternative fuels blended with conventional No. 2-D. Alternative fuels encompass bio fuels; both biodiesel and renewable fuel made from plant and animal materials, synthetic fuels, compressed or liquefied gases as well as hydrogen fuels. As the availability of these fuels has increased, coupled with changes in the ASTM D975 specification, use of alternate fuels by the railroads has also increased. Some are in widespread use today (biodiesel), some are being actively investigated (natural gas), and some remain long-term options not currently under active study (hydrogen) for railroad applications.

The research or test reports reviewed were part of government contracts or independent investigations. The papers reviewed by the Fuel, Lubricants and Environmental Committee (FL&E) were found to be informative and dispelled hearsay with test data, and creditable references.

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REVIEWED PAPERS:

Of the many quality papers available to study, the papers the authors have chosen to review are as follows:

- Association of American Railroads (AAR) sponsored paper AAR R-999 on *Alternative Fuels Availability, Make-up, and Potential Impact on Locomotive Engines*¹
- FRA research grant FR-RRD-0047-12-01-00 to Southwest Research Institute (SwRI) part five was a literate research paper on biodiesel fuels. *Biodiesel as Locomotive Fuel Literature Review*²
- Battelle Memorial Institute was contracted to investigate the storage tank corrosion issue with Ultra Low Sulfur Diesel fuels (ULSD), *Corrosion in Systems Storing and Dispensing Ultra Low Sulfur Diesel (ULSD), Hypotheses Investigation*³
- United States Air Force (USAF) investigated the factors into storage tank corrosion when 20 percent biodiesel fuels were used. *Biodegradation, Biofouling, and Biocorrosion Activity in USAF Biodiesel (B20) Storage Tanks*⁴
- Natural Resources Canada March 30 2012, *Study of Hydrogenation Derived Renewable Diesel as a Renewable Fuel Option in North America*⁵
- American Society of Agricultural and Biological Engineers, *Energy Life—Cycle Assessment of Soybean Biodiesel Revisited*⁶

NOTE: Because of the amount of detail in the above papers, the authors summarized two of the papers, and only a high level executive summary of the other papers are included in this LMOA paper.

PAPER 1, AAR R-999: *Alternative Fuels Availability, Make-up, and Potential Impact on Locomotive Engines*¹

Locomotive engines have mainly used grade No. 2-D fuels since the end of the steam era. Although this fuel has worked well for many years, increasing fuel costs and a greater emphasis on exhaust and greenhouse gas emissions has resulted in several efforts to use alternative fuels. In addition, since the move to ultra-low sulfur diesel an increase in storage tank corrosion has been observed.

This paper investigated alternative fuels under consideration worldwide, for potential use in current and future design of locomotive engines. Items included were future alternative fuel options, fuel supply infrastructure, high level review of new engine combustion technology, alternative power generation technology, and potential barriers e.g., cost, production capabilities, warranty issues, materials problems, complications in delivery and storage.

The goal of the paper was to “identify alternative fuel sources used around the world that might be applicable and beneficial to North American railroad operations”. Ten fuels were investigated.

Fuel investigated:

- a. Biodiesel
- b. Coal Slurry
- c. Synthetic Diesel
- d. Renewable Diesel
- e. Natural Gas
- f. Propane
- g. Dimethyl Ether
- h. Ethanol-Diesel Blends
- i. Electrification
- j. Hydrogen Technology

a. **BIODIESEL** has been the term used for various fuels derived from biomass sources. Since a wide variety of fuels would fall under this category creating confusion, ASTM established the definition as "fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100". Other definitions are also used by various entities such as the U.S. Energy Policy Act of 1992 (EPA) biodiesel is "a diesel fuel substitute produced from non-petroleum renewable resources that meets registration requirements for fuels and fuel additives established by the Environmental Protection Agency under section 211 of the Clean Air Act" (10 CFR 409.702). The current ASTM specification for No. 2-D fuel (D975) allows up to 5% biodiesel to be blended with diesel fuel but the biodiesel used must, in its neat form, meet ASTM D6751 prior to blending. Also a separate specification has been developed, ASTM D7467, for blends containing 6% - 20% biodiesel.

The ASTM definition permits various fatty acids with their resultant property differences to be reacted with

typically methyl or ethyl alcohols to produce the finished product. Since various molecules are produced, the properties of each biodiesel produced can vary also. Biodiesel made from a solid animal fat can have a higher freeze or solidification point than one made from vegetable oil so cold weather operability may be an issue. Energy content, combustion properties, tendency to form deposits, etc. can also vary based on the composition of the biodiesel. The energy content of biodiesel is lower and the specific gravity is higher than No. 2-D. As a result, increased fuel consumption, and in some cases loss of power can be expected, depending on the design of the locomotive and engine evaluated. However, all biodiesel must meet ASTM D6751 and blends containing up to 5% biodiesel must meet the ASTM D975 specification.

Biodiesel fuel quality has been a concern since its introduction and several surveys have been conducted on quality. One estimate from 2007 was that 10% may be out of specification (Alleman 2008). As a result, a voluntary quality program has been initiated, BQ-9000, in the US that allows producers or marketers to certify their B100 fuel meets the ASTM standard (D6751). The majority of the B100 biodiesel fuels are currently supplied is from BQ-9000 sources.

One of the advantages from using biodiesel blends is the lowering of most exhaust gas emissions. The majority of this work has been in high-speed engines with few medium-speed engine results. In general there is a reduction

of all emission parameters with the exception of NO_x.

Tests using an EMD GP38-2 locomotive with both EPA line haul and EPA switch duty-cycles showed statistically significant increases in NO_x of about 5 to 6 percent and decreases in CO with B20. No impact on PM or THC was detected (Fritz 2003). Another study using a 4-stroke single cylinder medium-speed research engine having a similar power assembly to a GE 7FDL locomotive engine, B5 and B20 blends were tested using an Association of American Railroads (AAR) 3-mode test cycle. With the B20 blend, a 13 to 19 percent decrease in CO, 7 to 8 percent increase in NO_x, and 13 to 19 percent decrease in PM emissions were noted (Su 2005).

Some additional European studies using passenger rail locomotives powered with multiple small diesel engines i.e., Cummins NT855 and with blends higher than 20% biodiesel indicate the PM and HC reductions may not be as given as significant increases were seen at B50 and B100 levels (Skinner 2007). The increases in NO_x with higher biodiesel blends may be a concern to railroads as estimated NO_x emissions are near the capped limit in Canada and increases cannot be tolerated (Dunn 2003).

Biodiesel raw materials are renewable resources and have the potential to positively affect the life cycle energy balance over petroleum use. Several technical papers were referenced that noted changing beliefs on life cycle advantages. National Renewable Energy Laboratory (NREL) conducted

one of the first life cycle analyses for biodiesel (Sheehan 1998 & 1998b), "biodiesel yields about 3.2 units of fuel product energy for every unit of fossil energy consumed in its life cycle (Sheehan 1998). In other words, 0.31 megajoule of fossil energy is needed to produce 1 megajoule of biodiesel, thus representing a 69-percent energy gain over the fossil energy input".¹

However, later evaluations factoring in additional parameters found "the complex issue of life cycle energy efficiency of biodiesel remains largely uncertain"¹. There are several fossil fuel energy inputs, such as those in the process of growing biodiesel crops that might have been underestimated or overlooked. At the time of this report, some authors estimated that growing and processing soybeans requires 32-percent more fossil energy than the energy content in the produced biodiesel. However, advances in crop yields and processing technology are changing the life cycle balance so additional studies may show improvements in energy gain.

Compatibility between biodiesel and locomotive engine components has been and remains a concern. Although some of these issues have been addressed with lower concentrations of biodiesel (B5), extended use of higher blends (B20) remains a question. Lubricating oil dilution, injector deposits, seal and gasket compatibility are some of the areas of concern.

Since the publication of the AAR R-999 report, the SAE International committee TC-7 investigated some of these issues. Activity has since

moved to the LMOA FL&E committee. Concerns were broken down into four categories: Material Compatibility, Engine Oil Dilution, Fuel System Compatibility, and After Treatment Effects. "Experience with high-speed diesel engines indicates that low level blends, up to B5, can be used in most existing engines with no engine modifications. Almost all heavy-duty highway and non-road engine manufacturers allow up to B5 with no changes."

With increasing pressure to use biodiesel fuel, the major manufacturers of diesel fuel injection equipment issued a statement that up to 5% biodiesel blended in mineral diesel should not cause any serious engine problems. The locomotive engine manufacturers also issued position statements: At the time of this report, GE did not approve the use of biodiesel but has since changed their position and approves the use of diesel fuels meeting the ASTM D975 diesel fuel specification as an acceptable fuel. That specification allows up to 5% biodiesel. EMD "does not approve or prohibit the use of biodiesel fuels or biodiesel blends in excess of 5% with distillate diesel fuel". MotivePower follows Caterpillar recommendations since Caterpillar supplies the head end power engine and allows the use of biodiesel blends up to B20.

b. COAL SLURRY FUELS

"Coal slurry fuels are obtained typically by mixing finely dispersed coal particles with conventional diesel fuel or water with additives. The mixture is then combusted in the diesel engine."

"There are no comprehensive literature reports on the effect of coal slurries on the performance and emissions in modern diesel engines and the technology must be considered experimental. A number of potential issues exist, including the effect on slurry properties (stability, heat value, rheological behavior with potentially high viscosity), on combustion and emissions, and on fuel injection components and engine wear." *However, it should be noted there were extensive Department of Energy funded research projects on this subject in the mid-1980s, but no coal slurry fuels advanced to locomotive field testing.*

c. SYNTHETIC DIESEL fuels are produced from various carbon bearing feedstocks such as natural gas, coal, or biomass. The first and best known synthetic fuel technology is the Fischer-Tropsch (FT) process developed in Germany in the 1920s. The FT process is a gas to liquid (GTL) process in which typically carbon monoxide and hydrocarbon gases are combined into liquid fuels and lubricants. Synthetic fuels are generally compatible with conventional diesel fuel and require no modification to current diesel engine design. Very good ignition properties, low aromatic and polyaromatic content and very low or no sulfur similar to diesel fuel are the desirable characteristics. On the negative side, they typically have poor lubricity, cold flow properties, and energy density approximately 7% lower. These negatives can sometimes be addressed through the addition of additives. *These fuels*

may also have very high cetane numbers (>74) that may create combustion problems in older technology engines with timing set several degrees before top dead center.

Various studies in truck size engines have shown emission advantages with FT diesel fuels, both neat and blended with petroleum diesel, but this difference appears to be engine specific with older technology engines showing greater benefit than newer technologies with optimized combustion systems.

With the current concerns with greenhouse gas emissions the source of the carbon for the FT process has a great effect. Biomass derived FT fuels exhibit a clear CO₂ advantage over FT fuels derived from either natural gas or coal.

Although synthetic fuel has made a small inroad in locomotive use, the long term effects on engine durability have not been reported.

d. **RENEWABLE DIESEL** usually refers to hydrotreated vegetable oils (HVO) or animal fats, also known as hydrogen derived renewable diesel (HDRD). The feedstocks, identical to those used for ester-based biodiesel production, are treated with hydrogen in a refinery process which removes oxygen, resulting in a paraffin fuel similar to FT/GTL diesel. At the time of this paper, there were no reported engine compatibility concerns, stability or cold temperature issues similar to those that have been seen with biodiesel. Like synthetic diesel, they do have very high cetane numbers (up to 90) and the same potential energy density and combustion issues.

e. **NATURAL GAS** is a mixture of gases typically containing more than 90% methane plus small amounts of ethane, propane, nitrogen, carbon dioxide and other gases at trace amounts. It is commercially available as either liquefied natural gas (LNG) or compressed natural gas (CNG) with each having its advantage. Neither form is completely compatible with conventional diesel engines as the low cetane number requires either diesel pilot ignition or spark ignition.

Although natural gas has a wide distribution network it is not optimized for use as a transportation fuel.

Switch locomotive operation may be more suited to CNG as refueling can take place during long idle periods and these locomotives often stay close to servicing areas and gas supplies. The current trend for road locomotives is to use LNG due to the higher energy content of the liquid.

f. **PROPANE** or liquefied petroleum gas (LPG) in North America is a byproduct of natural gas and petroleum processing containing at least 90% propane, about 2.5% butane and larger hydrocarbons with the balance being ethane and propylene. It has been experimentally demonstrated as a locomotive fuel but special storage and handling requirements exist. LPG can be stored at lower pressures than natural gas and at ambient temperatures. Engine technology requirements and emissions issues are very similar to natural gas. The cost of LPG has been an issue unless incentives are used.

g. DIMETHYL ETHER (DME) is a small ether molecule that is receiving interest due to being produced from natural gas or from coal gasification. In addition it can be produced from biomass which may be a more carbon friendly greener option. Although it has a low heating value, about 1/3 less than diesel fuel, it does have a higher cetane number and a low auto ignition temperature making it suitable for use in diesel engines with modification. DME is a gas under ambient conditions but can be stored as a liquid under moderate pressure eliminating the need for high pressure containers or cryogenic storage as required for natural gas products. However, handling and storage issues remain similar to those of the LPG fuels..

h. ETHANOL-DIESEL BLENDS or e-diesel is used in unmodified diesel engines. Up to 15 % ethanol is blended into diesel fuel along with additives to stabilize the blend and provide lubricity and other properties. However, low flash point and volatility issues remain. The lower flash point makes storage and handling of the now Class I liquid the same as gasoline. Use of e-diesel can reduce exhaust particulate matter (PM) but the results of other emissions have been reported to be variable (Corkwell 2003). *However, the authors know of no tests in locomotives.*

i. ELECTRIFICATION can be supplied by a third electrified rail or an overhead wire catenary system. As is generally the case there is a trade-off

between the hazards associated with higher voltages to minimize line losses and the cost of on-board equipment to handle these voltages. Many new systems compromise between cost and efficiency by using a voltage of 25 kV.

Excluding how the electricity is produced, the locomotive produces zero emissions. Other benefits include (Butterworth 2005): lower noise, high power to weight ratio that can accelerate rapidly and maintain high speeds, high availability of rolling stock, rolling stock with low mass that results in relatively low wear and tear on infrastructure and higher efficiency, fuel source flexibility (fossil, nuclear, renewable), regenerative braking option whereby the kinetic energy of trains can be converted back into electrical power.

Challenges facing an electrification expansion include (Butterworth 2005): a major investment is required to install and maintain the power distribution system, a perceived loss of services on an electrified route due to a single infrastructure failure, planning is needed to understand the electromagnetic compatibility between rolling stock and infrastructure. New locomotives may draw more power than their predecessors, and there can be a loss of flexibility in the introduction of new trains.

j. HYDROGEN TECHNOLOGY FOR LOCOMOTIVE APPLICATIONS include fuel cells and hydrogen fueled internal combustion engines. Fuel cells are electrochemical devices that convert energy derived from a chemical reaction directly into electricity.

The only by-products/emissions are heat and water. Several types of fuel cells are being developed and each has its own advantages and disadvantages. Currently, Polymer Electrolyte or Proton Exchange Membrane Fuel Cells (PEMFC), also known as Solid Polymer Fuel Cells (SPFC) appears to be the leading candidate for transportation applications. They operate at lower temperatures 80 – 120 °C (176 – 248 °F), utilize high purity hydrogen, have quick start capability due to the low temperature requirement, and a favorable power-to-weight ratio.

Fuel cell systems remain complex and costly because of the expensive materials used for catalysts, electrodes, and membranes, and because additional peripheral equipment (e.g. cooling systems, complex fuel storage requirements, power conditioners, and fuel processor/reformer) are required.

Hydrogen internal combustion engines may allow rapid deployment of hydrogen-fuelled vehicles and enable a hydrogen refueling infrastructure to become more economically viable. Hydrogen internal combustion engines are much closer to commercial deployment for transport applications than fuel cells. Hydrogen internal combustion engines can currently be manufactured more cheaply than fuel cell powertrains. They are only about 15 percent more expensive than conventional petrol engines (EERE, 2005) used in road vehicles. They also have the additional advantage that they can run on pure hydrogen or a blend of hydrogen and CNG. *The paper did not discuss the source for the hydrogen.*

This AAR R-999 review focused on the different fuel types. However, the paper discussed in detail storage issues, new engine technology, advanced combustion concepts, and energy recovery technologies.

**PAPER 2: FRA research grant
FR-RRD-0047-12-01-00 Biodiesel as
Locomotive Fuel Literature Review²**

The principal author of this paper was also the principal author of the AAR R-999 paper discussed above. However, this 73 page paper's literature review only covered biodiesel fuels in detail. It starts off with an overview of the driving forces followed with: EPA Renewable Fuel Standard, Canadian Renewable Fuel Requirements, State Mandates, Price and Commercial Factors, and Future Regulation Trends.

This was followed with very detailed reporting on what are biodiesel fuels, their chemical and physical properties, handling and storage, blending, and quality issues. The third section of the paper dealt with Environmental Impact such as: Life Cycle, GHG Emissions, Pollution Emission, and Locomotive studies. The last two section covered Compatibility with Existing Engines, and Railway Experiences.

Items were previously reported on by the FL&E committee in earlier papers, however not in the level of detail of the above paper.

PAPER 3: Corrosion in Systems Storing and Dispensing Ultra Low Sulfur Diesel (ULSD), Hypotheses Investigation³

Soon after the introduction of Ultra Low Sulfur Diesel (ULSD) in 2007, a dramatic increase in corrosion of the components of fuel underground storage tanks (UST) and dispensing equipment was observed. Also, the Renewable Fuel Standard required a significant increase in biofuel production which includes biodiesel and ethanol. These changes were expected to cause some differences in the fuel properties but accelerated corrosion was not one of them. This paper describes the investigation to understand the factors contributing to the increased corrosion.

The following three hypotheses were proposed for the investigation:

- 1) Aerobic and anaerobic microbes are producing by-products that are establishing a corrosive environment in ULSD systems
- 2) Aggressive chemical specie(s) (e.g., acetic acid) present in ULSD systems is(are) facilitating aggressive corrosion
- 3) Additives in the fuel are contributing to the corrosive environment in ULSD systems

Six sites (underground storage tanks) were selected for the investigation with one being the control. However, once site inspections were performed it was found the control site also showed corrosion but to a lesser

degree than the others. Site locations were in North Carolina (1), New York (2) and California (3). The tank sizes ranged from 6,000 to 17,265 gallons with ages between 4 and 22 years. The monthly fuel throughput ranged from 1 to 4 times the tank volume.

Test specimens for evaluation were:

- 1) Vapor from the tank headspace
- 2) Corrosion scrapings from equipment with excessive corrosion
- 3) Fuel
- 4) Water/sediment from the tank bottom

Specimens were tested for microbial presence and type as well as chemical composition. Chemical analysis showed the unexpected presence of acetic acid in most of the fuel and vapor samples and all the bottom water samples. Ethanol was also found in most of the fuel and water samples and was believed to be from contamination with ethanol containing fuels (gasoline). Microbial analysis found *Acetobacter*, a common bacterium, which utilizes water, oxygen and a fuel source (ethanol in this case) produce acetic acid as a byproduct of metabolism/respiration.

The first hypothesis was accepted with the change to only include aerobic microbes of the family *Acetobacteraceae* as they metabolize ethanol in the presence of oxygen and water to form acetic acid.

The second hypothesis was also accepted as acetic acid was found in substantial concentrations in the fuel,

water, vapor and scraping samples and the reaction rate of acetic acid is sufficient to account for the observed corrosion.

The authors rejected the third hypothesis since the nature of fuel additive degradation do not fit with the observations and corrosion rates found.

The conclusions based on this limited study was that the common bacteria *Acetobacter* feeds on ethanol, probably from contamination by other fuels, converting it into acetic acid which disperses throughout the storage system causing rapid and severe corrosion. They also state additional work needs to be performed to verify their results.

“The project final hypothesis for this investigation is that corrosion in systems storing and dispensing ULSD is likely due to the dispersal of acetic acid throughout USTs. It is likely produced by *Acetobacter* bacteria feeding on low levels of ethanol contamination.”

The researchers are continuing their evaluations. As new information and tests results are generated modifications to their conclusion could be required. For example, the CRC/EPA are collecting, testing, and studying data from 42 additional tanks.

PAPER 4: Biodegradation, Biofouling, and Biocorrosion Activity in USAF Biodiesel (B20) Storage Tanks⁴

The United States Air Force Petroleum Agency received tank bottom specimens from three ULSD B20 storage tanks that were contaminated and experiencing corrosion problems. Although there were differences in the three storage tanks, the gross observations applied to all three tanks. Their gross observations were as follows:

- Turbidity in the fuel phase
- Emulsified brown/red material
- Presence of rag phase
- Precipitated material
- Differences in clarity and color of fuel from near vs. far from water bottom
- Filters changed frequently
- Issues with dispensers

Chemical testing:

- Bottom-water pH < 4.5
- Fe in water: 200 mg/L

The researchers ask some fundamental questions: what are the contaminating organisms, and are they capable of fuel degradation resulting in corrosion? Their approach was a microbiological and chemical analysis of tank system, In situ corrosion study, and isolation of microorganisms for additional in-laboratory fuel degradation and corrosion studies.

Using deoxyribonucleic acid (DNA) isolation of the 16s ribosomal ribonucleic acid (rRNA) they found

the tank bottoms were highly heterogeneous, while bulk fluids were predominantly composed of fungi. They isolated 7 different species of bacteria from the fuel water interface. The following three species *Roseomonas*, *Pseudomonas*, and *Gluconoacetobacter* comprised up to 80% of the population.

Analytical testing of the diesel fuel found little evidence of hydrocarbon degradation, i.e., they did not detect metabolites of anaerobic or aerobic diesel fuel degradation. However, the researchers found evidence for degradation of fatty acid methyl esters (FAME), and with acid production enhances the likelihood of corrosion. A metabolite, i.e., byproduct of metabolism, of one species of the identified bacteria, *Gluconacetobacter liquefaciens*, is acetic acid, which likely contributes to low pH of bottom water in one of the tanks. Another bacterium, *Roseomonas ludipueritiae*, subsistence is on ethanol or fatty acid methyl esters while producing acetate as a byproduct of its metabolic process. This production of acetate, could potentially contribute to viscous biofilm and acidic pH. *Pseudomonas* a known hydrocarbon degrader was also detected; however there was no evidence of fuel (hydrocarbon) degradation.

Laboratory work was followed with a field corrosion study of three and six month's evaluation of test coupons. The finding suggested there was an association between biomass and pitting, corrosion rates (weight loss). The weight loss was moderate at 2.1 mils penetration per year. Low pH could be

the results of acidification of fluids by microbial metabolism, and likely contributed to vapor phase corrosion.

Their summary was as follows:

- Gross observations and chemical analyses: high probability of microbial activity and corrosive environment
- Fuel phases: fungal contamination
- Water phase (tank 2): Acid-producing bacteria, cellulose-producing bacteria
- Biofilm samples were highly heterogeneous
- No indication of hydrocarbon degradation, but evidence of degradation of FAMES

It was reported to the authors of this paper that further studies are ongoing.

PAPER 5: *Study of Hydrogenation Derived Renewable Diesel as a Renewable Fuel Option in North America*⁵

Before the technical discussion of Hydrogenation Derived Renewable Diesel (HDRD), the authors commented on governmental requirements on the use of renewable fuels. By 2011 there were 27 national governments and 29 state/province governments that had implemented policies that mandate the use of a minimum amount of renewable alternatives to diesel. Those governments or regions include Europe, six South American and six Asian countries, Canada, the United States, Costa Rica and the Dominican Republic.

The government of Canada amended the *Renewable Fuels Regulations* in 2011 to include 2% requirement of renewable content in diesel and heating oil effective on July 1st, 2011. *The Canada government current requirement is 5%, and will be increasing the renewable concentration in the future.*

Under the Canadian *Renewable Fuels Regulations*, both ester-based biodiesel and HDRD would be admissible as renewable content, and could be used to meet the requirements of the regulations. Currently biodiesel is the most widely available diesel fuel alternative. However, there has been increasing interest by the regulating parties in using HDRD to meet the requirements. The purpose of this study was to evaluate the potential for HDRD production and use in Canada

Biodiesel and HDRD can be made from the same feedstocks, but their chemical composition and physical properties are different. The differences are due to the processing pathways that are used for their production. Biodiesel fuels are produced via transesterification with glycerol as a by-product, and HDRD fuels are produced via hydroprocessing with propane, carbon monoxide (CO) and carbon dioxide (CO₂) as by-products. The paper discussed the different production options for the HDRD fuel, such as using an existing hydrotreating facility vs. building a new standalone processing plant.

It was noted that HDRD fuels can be produced from a wider range of feedstocks than biodiesel. The two principal reasons for this are as follows: 1) the degree of unsaturation of the feedstock molecules is not a consideration with HDRD (hydroprocessing results in paraffinic hydrocarbons that are fully saturated), 2) during hydroprocessing to produce HDRD, free fatty acids (FFA's) are converted to paraffins, whereas in biodiesel production they can react with alkali catalysts to produce soaps. Therefore FFA content of the feedstock is not a concern for HDRD production.

"Currently, there are no fuel standards that have been developed uniquely for HDRD, neat or blended. HDRD is comprised of the same types of hydrocarbons as conventional diesel and therefore is subject to the same fuel standards as No. 2 diesel or ULSD: CGSB 3.517 in Canada, ASTM D975 in the United States and EN 590 in Europe (Hoekman, 2009). Since

HDRD is a fuel that is fully fungible with ULSD, infrastructure requirements for blending HDRD with ULSD are minimal and are mostly related to inventory management (ÉcoResources Consultants, 2010), (Lambert 2012). No significant vehicle equipment compatibility issues have been found either (Rilett, 2008), (Climate Change Central, 2009) (Neste Oil, 2009)."

Recent information, supplied from one of the Canadian railroad's personnel, is the 5% required renewable fuel concentration is a yearly average. However, because of the fuel's properties at extreme cold temperatures the fuel suppliers are not supplying renewable fuel blends in the coldest winter months. Therefore, to meet the yearly 5% average, the suppliers start to increase the concentrations as the weather warms in the late winter and early spring to a concentration higher than 5% in the warmest months. Conversely they decrease the concentrations in the autumn as the daily temperatures drops. In addition, the Canadian government has a time schedule to increase the concentration of renewable fuels above 5% in the future.

The paper covered in detail the following items: 1) for the history buffs, the historical use and development of renewable fuels in Canada, 2) HDRD production and production options, 3) fuel properties, 4) fuel standards, 5) infrastructure and equipment compatibility, 6) market (regulations, policies and intensives, potential markets, 7) existing and potential HDRD production capacity, prices, and availability,

and 8) next generation of renewable alternatives to diesel.

Their conclusions were that, "in this study it was shown that HDRD is a renewable alternative to diesel with favorable physical properties that allow it to be blended with ULSD with less of the additional storage and blending infrastructure required for biodiesel and less kerosene requirements for cold-weather blending. It has a high cetane number and higher energy content than biodiesel. Due to the chemistry of the hydrotreatment process, HDRD can be made from a wider variety of feedstocks than biodiesel without compromising the final product quality."

Future perspective conclusion was "In the Canadian context, one 215 ML/yr plant would be able to account for 30% of Canada's current total requirement for renewable alternatives to diesel and heating oil. Adding another plant of the same size would account for 48% of the projected requirements in 2035. Alternatively, a 906 ML/yr plant would provide 33% more than the total Canadian federal requirements in the short term, allowing for potential exports to the US, and in 2035 would account for 100% of the projected requirements." *This paper does not discuss potential problems with HDRD fuels or were pricing differential of HDRD to biodiesel compared.*

PAPER 6: *Energy Life—Cycle Assessment of Soybean Biodiesel Revisited*

This paper's energy life cycle analysis (LCA) or cradle-to-grave analysis, of soybean biodiesel fuel was built upon past research. Their main references were to the National Renewable Energy Laboratory (NREL) Sheehan et al. (1998) and Pradhan et al. (2008) reports. NREL's reports were referenced in the earlier discussion of AAR R-999 paper.

The analysis of the life-cycle of biodiesel was divided into four subsystems which are as follows:

- feedstock production
- feedstock transportation
- soybean processing with biodiesel conversion
- product distribution

With each subsystem the researchers included all the various energy inputs for each subsystem in the determination of the energy balance. Two items excluded in their calculation were the removal of the energy required to produce the two co-products, i.e., production soybean meal and crude glycerin. Since this energy life-cycle focuses exclusively on biodiesel, the energy associated with the production of the other two co-products was estimated and excluded from the calculation.

One of the major points in this paper was because life cycle analysis is dynamic; there is a need to use the most current data as input to the models.

Improving crop production and plant processing improvements are two areas of major improvements. Farmers, for the most part have adopted the use of genetically modified soybeans thereby improving crop yield, and technological improvements in the processing plants have reduced energy input need in the production thereby improving the energy balance.

The quote is from their conclusions/summary "The fossil energy ratio (FER) of biodiesel was 5.54 based on 2006 soybean production data. This is a significant improvement over the study by Sheehan et al. (1998), which reported an FER of 3.2, and even notably better than the FER of 4.56 that was found by Pradhan et al. (2009), which was based on 2002 data."

RECOMMENDATIONS:

Because of the increasing amount of alternative fuels available to the railroads, and their increasing use by the railroads, the following are helpful suggestions that are thought to be more important than when the fuels were more homogenous, i.e., diesel fuel:

- Read technical papers on alternative fuels
- Develop questions for your suppliers
- Understand/know what fuels each storage locations are receiving
- Obtain certificate of analysis from suppliers
- Validate suppliers' analysis with your own fuel testing program
- Do in-house laboratory evaluations/investigations

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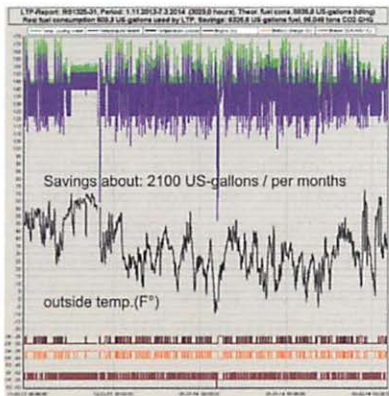
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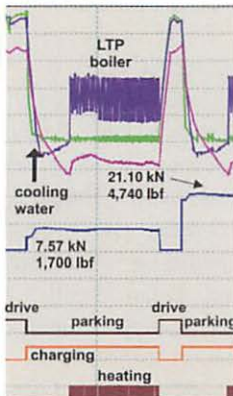
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Contact: kevin.lopresti@ast.de
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- If/when issues arise, investigate to find root cause
- Follow through with implementation of corrective action
- Frequent storage tank maintenance
- Verify alternative fuel's performance with field testing
- Publish your findings

SUMMARY: At this point in time, the research efforts on the alternative fuels reported on above are believed to be credible. However, it needs to be pointed out there is still a significant amount of research and investigation ongoing. What our current understanding of fuels and alternative fuels might be today, with new test results, and/or technological advancements could alter our current understandings. The fuels and alternative fuels stories are still in an evolving period.

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ACKNOWLEDGEMENTS:

The authors wish to thank the LMOA FL&E committee members for their helpful comments on the paper and associated presentation.

Transmix-Derived Fuel for Locomotives

Prepared by:

*Steven G. Fritz, Southwest Research Institute, John Hasterlo,
Union Pacific Railroad, and Bruce Thomson, CSX Transportation*

Abstract

Tier 4 locomotives are here, and with them come important requirements for operations and maintenance so that they remain compliant with EPA exhaust emission regulations. Many of the engine technologies used to meet Tier 4 are sensitive to fuel sulfur levels, and as such, it is essential that only Ultra-Low Sulfur Diesel (ULSD) (< 15 ppm S) fuel be dispensed into these locomotives. Many railroads purchase a fuel product known as “500 ppm sulfur LM fuel” (LM means Locomotive and Marine) produced from transmix. Transmix is the non-compatible refined product interfaces between jet fuel/kerosene, gasoline, and ULSD fuel generated by the transportation of refined products by pipelines. Jet fuel can have up to 3,000 ppm sulfur, and the LM fuel can have up to 500 ppm sulfur. This paper is presented in a “Ten Questions” format, covering the EPA fuel regulations related to locomotive diesel fuel, how transmix-derived LM fuel is produced and handled, and why it is important to keep this fuel from being dispensed into Tier 4 locomotives.

1. What is Transmix?

Transmix is the interfacial mix in refined product pipelines between two dissimilar products that is cut out and isolated. Figure 1 shows a representation of transmix as the interface between jet fuel and diesel fuel, and gasoline and jet fuel. Jet fuel can contain up to 3,000 ppm sulfur whereas the diesel fuel in the pipeline is ultra-low sulfur diesel (ULSD), with a maximum sulfur level of 15 ppm. A more typical sulfur level in the pipeline is about 7 ppm, with an upper limit of 11 ppm. In pipeline terminals, where products coming out of the pipeline are segregated, this interfacial mix product is stored in separate tanks from the certified refined products. EPA limits the sulfur of the resulting LM (Locomotive and Marine) fuel to a maximum of 500 ppm.

In December, 2012, EPA issued a Final Rule to amend the transmix provisions under the Diesel Sulfur Program, permitting the sale of 500 ppm sulfur LM fuel (hereafter referred to as LM fuel in this paper) to railroads and marine operators, with no volume limits, and with no termination date.

Bottom Line: Locomotive fuel with sulfur levels > 15 ppm is available with appropriate handling / storage.

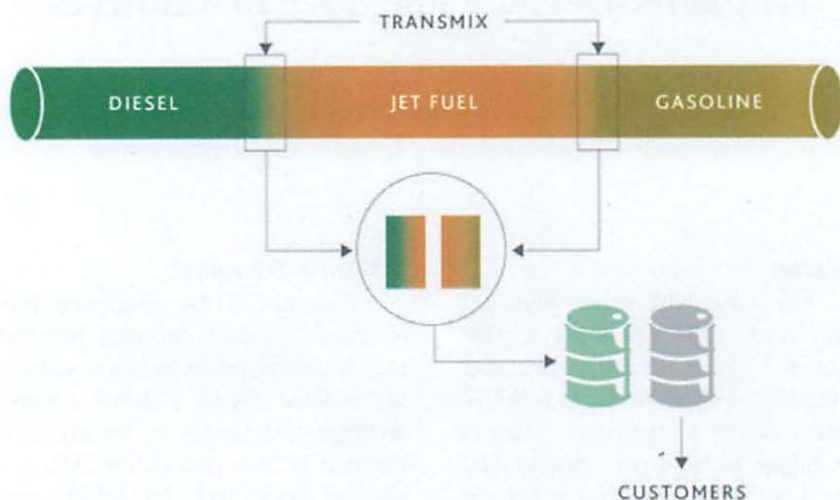


Figure 1. Transmix

2. How much of this stuff is out there?

Figure 2 shows that railroads in the U.S. use approximately seven percent of all diesel fuel. In 2013, the Class 1 railroads consumed 3.71 billion gallons of diesel fuel. EPA estimates that there is approximately 450 million gallons of transmix-derived LM fuel generated each year, with roughly 25 percent of that total going into home heating oil. Making broad assumptions, if all the remainder ends up as LM fuel to railroads, it represents about 10 percent of railroad diesel fuel. If only half the remainder of the fuel goes to the railroads, it could be as much as 5 percent. Therefore it is reasonable to assume that roughly 5 to 10 percent of diesel fuel used in locomotives has a sulfur level greater than 15 ppm. A recent locomotive fuel survey by a locomotive OEM showed that approximately

10 percent of samples had Sulfur levels greater than 15 ppm.

3. Can I use this LM fuel in my locomotives?

EPA Diesel fuel regulations for nonroad engines, including locomotive and marine, went into effect on June 1, 2007, and limited fuel sulfur to 500 ppm maximum, and also required Cetane greater than 40, and aromatics less than 35 volume percent. Effective June 1, 2010, the maximum allowable sulfur content was reduced to 15 ppm, except for locomotive and marine use, which were delayed two years until June 1, 2012, when locomotive and marine diesel also had to meet the 15 ppm max sulfur limit.

In December, 2012, EPA issued a Final Rule to amend the transmix provisions under the Diesel Sulfur Program, permitting the sale of 500

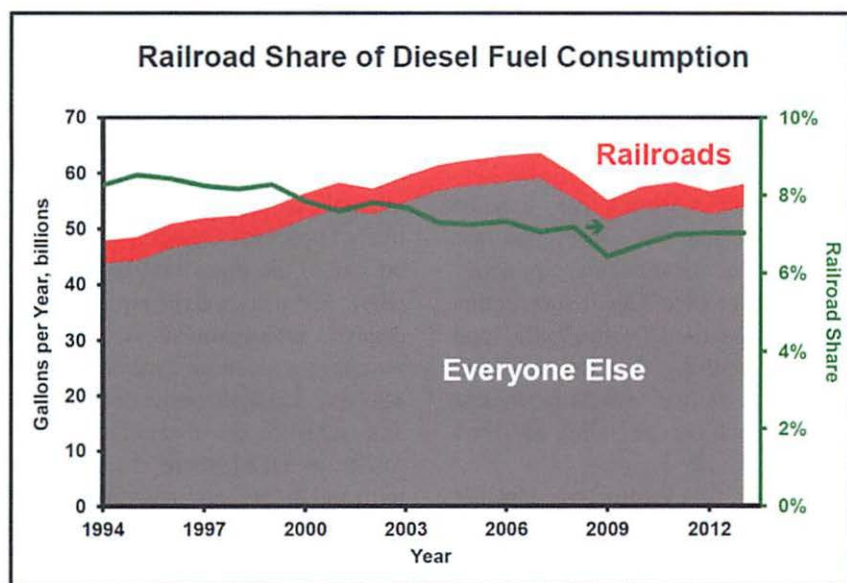


Figure 2. Railroad Fuel Consumption



Figure 3. Example of Tier 4 Locomotive Fuel Labeling

ppm sulfur LM fuel to railroads and marine operators.

4. Are there special labeling requirements for Tier 4 locomotives?

The EPA locomotive exhaust emission regulations state “We are requiring the manufacturer to notify the purchaser of a Tier 4 locomotive that it must be fueled with ULSD,” and “We are requiring the use of ULSD in locomotives and vessels labeled as requiring such use, including all Tier 4 locomotives....”

Details for locomotive labeling are given in 40 CFR Part 1033, and require a label near the fuel tank filler neck to identify allowable fuels -- §1033.135(b)(3): Label diesel-fueled locomotives near the fuel inlet to identify the allowable fuels, consistent with §1033.101. For example, Tier 4 locomotives should be labeled “ULTRA LOW SULFUR DIESEL FUEL ONLY”. Figure 3 shows this labeling on a pre-production Tier 4 locomotive. You do not need to label Tier 3 and earlier locomotives certified for use with both LSD and ULSD.

5. What happens to a Tier 4 locomotive that gets a load of LM fuel?

In general, a single load of LM fuel will not immediately impact the operational performance of a Tier 4 locomotive. However, there will be an immediate and direct negative exhaust emissions impact in the form of increased SO₂ and PM emissions, proportional to the fuel sulfur concentration.

In addition, sulfur sensitive emission reduction technologies will be impacted. For exhaust gas recirculation (EGR)-equipped engines, there will be an increased presence of sulfuric acid that can lead to corrosion of internal engine parts, and could negatively impact life expectancy of engine oil due to the impact on base number (BN). For locomotives equipped with catalytic aftertreatment systems, such as diesel oxidation catalysts (DOC), selective catalytic reduction (SCR), and catalyzed diesel particulate filters (cDPF or DPF), there are both short term and longer term negative effects.

If a Tier 4 locomotive is inadvertently fueled with anything other than ULSD, this Committee recommends that the locomotive be removed from service, and the fuel tank drained and refilled with ULSD fuel

6. What happens when my locomotives go off line, or into Mexico or Canada?

Figure 4 shows the diesel fuel sulfur limits in Canada

In Mexico, the sulfur limit was supposed to be reduced to a maximum of 15 ppm by September 2009, but Pemex is reported to be behind schedule. KCSM reports that Pemex supplies only ULSD (15 ppm) in Nuevo Laredo (and basically all along the Mexican Border). In main cities like Monterrey, Guadalajara and Mexico City, Pemex supplies ULSD only when it is available, and gives priority to on-highway supplies, so most of the time the railroads receive LSD (500 ppm). In the rest of Mexico, Pemex



Figure 4. Diesel Fuel Sulfur Limits in Canada

supplies LSD (500 ppm S) for on-highway use. S5000 (5000 ppm S) is still available for nonroad engines.

Even when a Tier 4 locomotive goes off-line but remains in the U.S., there is the possibility that the host railroad could misfuel the locomotive with LM fuel. Unfortunately, there is no way to tell where or when a locomotive was fueled with LM fuel. Where it will become an issue is likely with the onset of reliability issues in the EGR system due to accelerated corrosion over time, and subsequent deterioration of the exhaust emissions performance of that locomotive.

7. Where can I get a copy of my railroad's transmix compliance plan?

All LM fuel must come from transmix suppliers (i.e. not from the refinery). Suppliers of transmix were required to submit a Compliance Plan for EPA

approval under 40 CFR Part 80.513(g) (h) by June 1, 2014. Each compliance plan needs to provide details on how the LM fuel will be segregated through to the ultimate consumer and its use limited to the legacy LM fleet (i.e., how this fuel will not end up in Tier 4 locomotives). The plan must identify the entities that would handle the fuel and the means of segregation. The plans also cover notification procedures to EPA in the event of misfueling which could result in revoking of a plan.

The Compliance Plan must:

- detail how the facility will segregate any LM fuel from the supplier through to the ultimate consumer,
- demonstrate that the end users of LM fuel will also have access to ULSD fuel for use in those engines that require the use of 15 ppm diesel fuel,

- detail how misfueling will be prevented.

All parties that take custody of LM fuel must segregate the product from other fuels and adhere to the provisions of the Compliance Plan. Presumably, each railroad that purchases LM fuel is the last “entity” in the chain of custody of the fuel, and as such, is party to that supplier’s Compliance Plan. Note that EPA defines an entity as any company that takes custody of LM fuel.

There is also an EPA requirement specifying that entities who handle LM fuel must calculate the balance of LM fuel received versus the volume delivered and used on an annual basis.

As of 2014, the person at EPA Office of Transportation and Air Quality (OTAQ) who is receiving, reviewing, and approving these plans is Deborah Adler-Reed, (734) 214-4223, adlerreed.deborah@epa.gov. In October 2014, Ms. Reed reported that Compliance Plans are in place with the transmix suppliers, and that she talked with all the major railroads using LM fuel, including staff from Environmental, Legal, and Facilities Engineering.

Another requirement of the regulation is that suppliers of LM fuel must initiate a Product Transfer Document (PTD), and are required to indicate that the LM fuel must be distributed in compliance with the approved compliance plan. Entities in the distribution chain for LM fuel are required to keep records on the volumes of the LM fuel that they receive from and deliver to each entity. Entities are also required to

keep records on how the fuel was transported and segregated.

8. What are the RRs doing now to plan for LM fuel with the introduction of Tier 4 locomotives?

Several major railroads have indicated that they intend on stopping LM fuel purchases in the Summer of 2015. This is a logical approach, but will only provide sufficient protection to Tier 4 locomotives if all the major railroads follow this practice, due to the interoperability of locomotives between railroads.

9. What about using LM fuel in nonroad MOW equipment?

Maintenance of Way (MOW) equipment is generally powered by relatively small nonroad diesel engines that are also regulated by EPA. Diesel fuel used in nonroad diesel engines is regulated by EPA, and since June 2010, its sulfur was limited to a maximum of 15 ppm (ULSD), the same as for on-highway diesel fuel. Tier 4 regulations for nonroad diesel engines were phased in during the period 2008 to 2015, largely as a function of engine power rating. Various in-cylinder and aftertreatment emission reduction technologies were employed by the various nonroad diesel engine suppliers, but it is safe to say that essentially all Tier 4 nonroad diesel engines use sulfur-sensitive technologies, and as such, diesel fuel with sulfur content greater than 15 ppm should not be used in these nonroad diesel engines. At issue is if MOW equipment is fueled by the railroads from a transportable fuel tank that itself

was fueled at a locomotive fueling rack that contained LM fuel with a sulfur level greater than 15 ppm. There do not appear to be any provisions in the LM fuel regulations permitting its use in MOW equipment.



10. If the RRs stop buying LM Fuel, where will it go?

In the short term, the options for what to do with this product are limited to continued use as home heating fuel, to smaller railroads that will not see Tier 4 locomotives, and to transport the fuel back to the refinery to be re-refined. In the long term, jet fuel is likely to move toward 15 ppm S.

List of Abbreviations:

DOC - Diesel oxidation catalyst
 DPF - Diesel particulate filter
 EGR - exhaust gas recirculation
 EPA - U.S. Environmental Protection Agency
 LM - Locomotive and Marine diesel fuel
 LSD - Low Sulfur Diesel (< 500 ppm S)
 MOW - maintenance of way
 PM - particulate matter
 S - Sulfur

SCR - selective catalytic reduction

SO₂ - Sulfur Dioxide

ULSD - Ultra Low Sulfur Diesel (< 15 ppm S)

References:

1. Federal Register, Vol. 77, No. 247, PP 75868-75880, *Regulation of Fuels and Fuel Additives: Modifications to the Transmix Provisions Under the Diesel Sulfur Program*, December 26, 2012.
2. Railroad Facts – 2014, published by the Association of American Railroads, L.C. Card No. A66-7305, November 2014.
3. Federal Register, Vol. 77, No. 247, PP 75868-75880, *Regulation of Fuels and Fuel Additives: Modifications to the Transmix Provisions Under the Diesel Sulfur Program*, December 26, 2012.
4. “Technical and Economic Analysis of the Transition to Ultra-Low Sulfur Fuels in Brazil, China, India and Mexico”, report prepared for The International Council on Clean Transportation (icct), October 2102 (http://www.theicct.org/sites/default/files/publications/ICCT_ULSF_refining_Oct2012.pdf)

Energy Outlook to 2040

Prepared by:

Virginia Wiszniewski, Exxon Mobil

The Outlook
for Energy:
A View to 2040

Locomotive Maintenance
Officers Association (LMOA)
Annual Meeting
October 2015
Presented by
Virginia C. Wiszniewski

This presentation includes information regarding ExxonMobil's long-term view of global energy demand and supply. The information is based on assumptions and is not intended to be used as a basis for investment decisions. The information is not intended to be used as a basis for investment decisions. The information is not intended to be used as a basis for investment decisions. The information is not intended to be used as a basis for investment decisions.

ExxonMobil
Energy lives here™

The *Outlook for Energy* provides ExxonMobil's long-term view of global energy demand and supply. Its findings help guide the company's investments, which support its business strategy.

ExxonMobil's Outlook for Energy Sees Global Increase in Future Demand

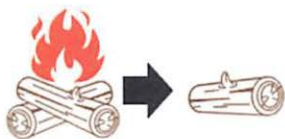
- Global energy demand seen rising 35 percent from 2010 to 2040
- Energy demand shifts strongly to developing nations as middle class expands
- North America to become a net exporter of oil and natural gas

Energy Outlook Development



The ExxonMobil Outlook For Energy to 2040 is developed by examining energy supply and demand trends in 100 countries, 15 demand sectors covering all manner of personal and business needs and 20 different energy types.

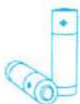
Energy Measures and Units



1 log = 24,500 BTU



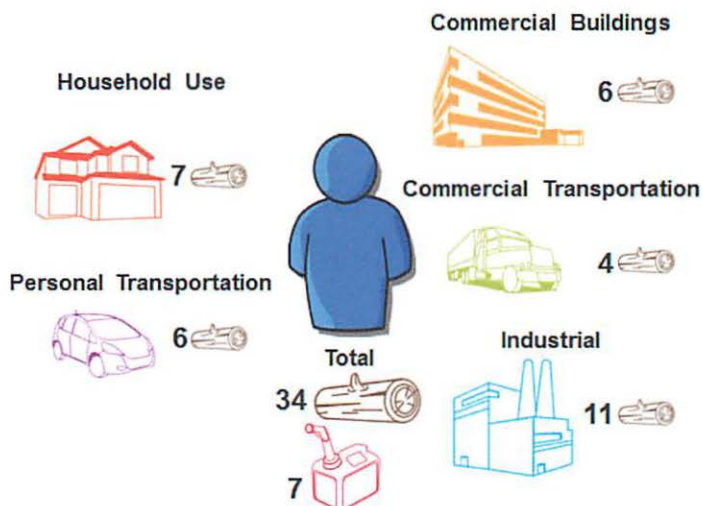
1 gallon gasoline = 5 logs



1 gallon gasoline = 36 kWh
13,000 AA batteries
4,000 smart phone batteries

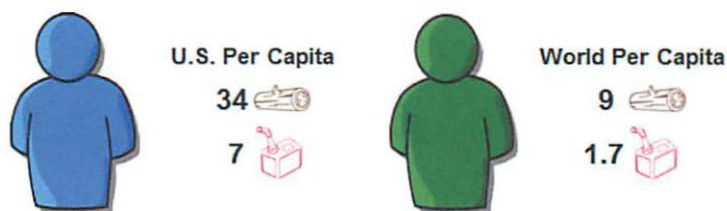
Gains in living standards over the past two centuries have been enabled in large part by a transition to modern energy sources. One element driving this transition is the “energy density” of various energy types. Fuels high in energy content use less space and are often the easiest to transport for various uses. This helps explain why gasoline is prevalent as a transportation fuel and why people in high-rise buildings do not rely on wood for heating and cooking. To help compare energy content, we’ve converted some sources of energy used today to one of mankind’s earliest forms of energy: wood logs used as fuel for fire.

2010 U.S. Daily Per Capita Energy Demand



Daily U.S. energy demand per person in 2010 is estimated as 34 logs. This includes usage based on household use, personal transportation, commercial buildings, commercial transportation, as well as industrial applications.

2010 World Daily Energy Demand

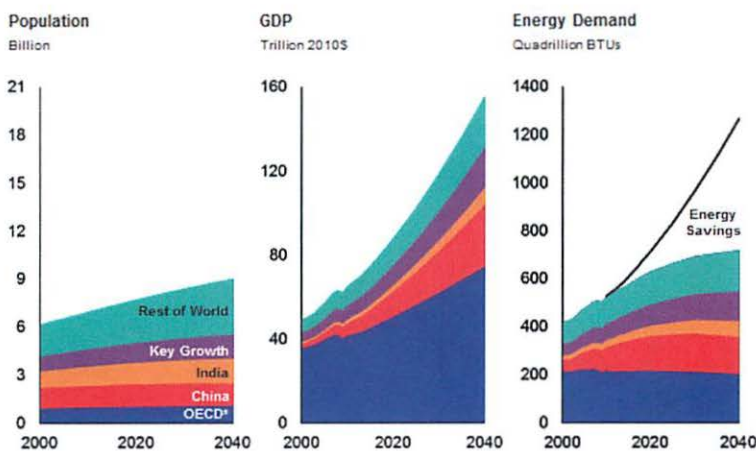


Times 7 billion people =
~12 billion gallons per day

260 MBDOE
525 QUADS

The world daily energy demand is calculated based on population, with adjustments for usage outside the United States.

Global Progress Drives Demand

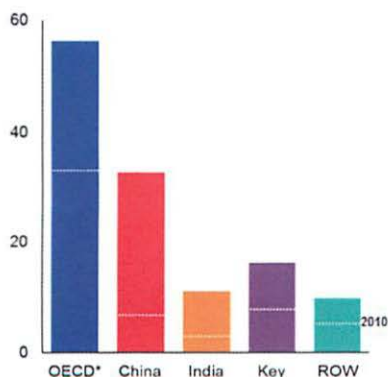


*Mexico and Turkey included in Key Growth countries

Two main factors, population growth and economic progress (based on GDP) drive global energy demand. Developed countries are represented by Organisation for Economic Co-operation and Development (OECD) member countries.

Standards of Living Increase in the Non OECD

2040 GDP per Capita
PPP 2005\$K



*Mexico and Turkey included in Key Growth countries

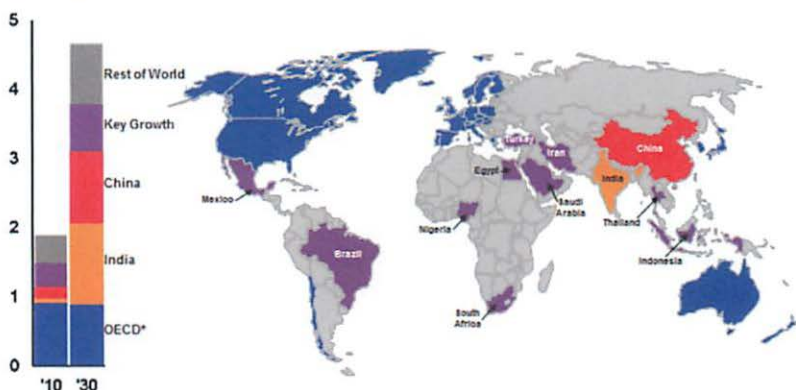


GDP increases over the Outlook period of 2010 through 2040 show increases in non-OECD regions, and quality of life improvements.

The Middle Class Continues to Grow

Middle Class per The Brookings Institution

Billion People



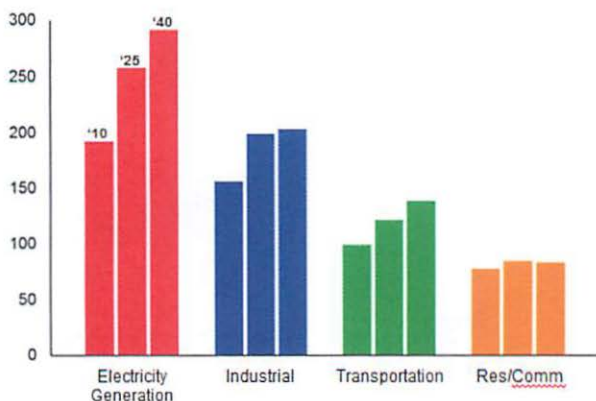
*Mexico and Turkey Included in Key Growth countries

The global middle class is expected to climb from about 2 billion in 2010 to almost 5 billion people by 2030, representing more than half of the world's population, according to the Brookings Institution. As projected, that middle class expansion – largely in India and China – will be the largest in history and will have a profound impact on energy demand.

Electricity Generation Leads Growth

Primary Energy Demand by Sector

Quadrillion BTUs

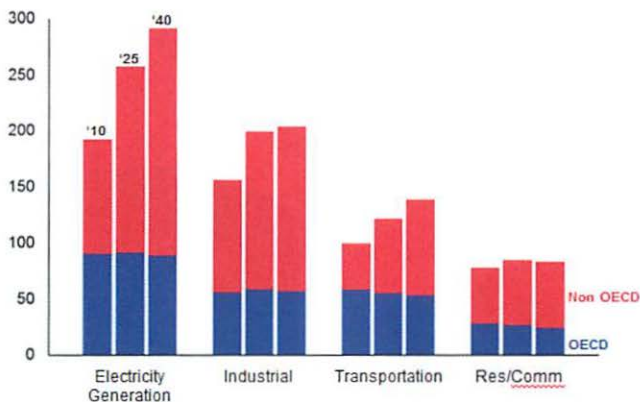


Electricity generation leads the energy demand growth relative to other segments. Energy required to meet rising electricity demand will account for about half of total demand growth.

Electricity Generation Leads Growth

Primary Energy Demand by Sector

Quadrillion BTUs

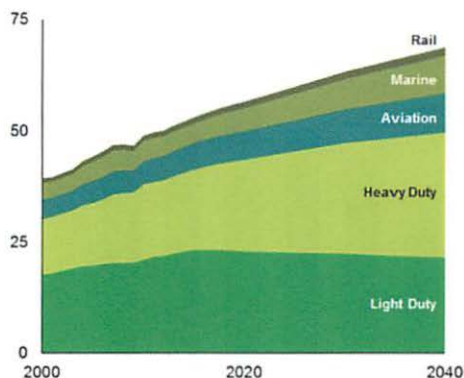


The highest growth is expected in developing countries

Transportation Demand

Sector Demand

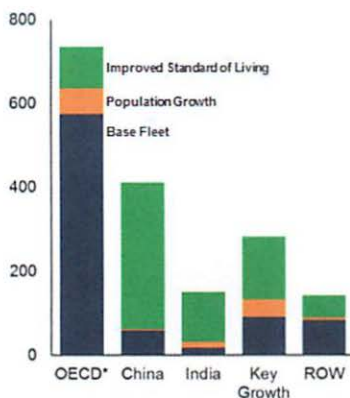
MBDOE



Transportation demand grows 40% through 2040, and encompasses light duty vehicles, commercial heavy duty vehicles, as well as aviation, marine and rail applications.

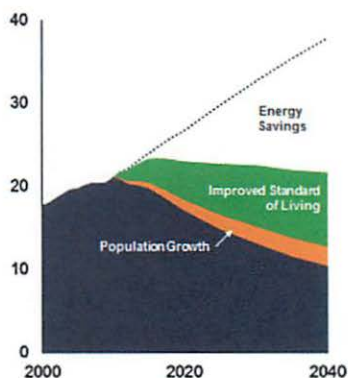
Light Duty Vehicle Fleet and Demand

2040 LDV Fleet
Million



*Mexico and Turkey included in Key Growth countries

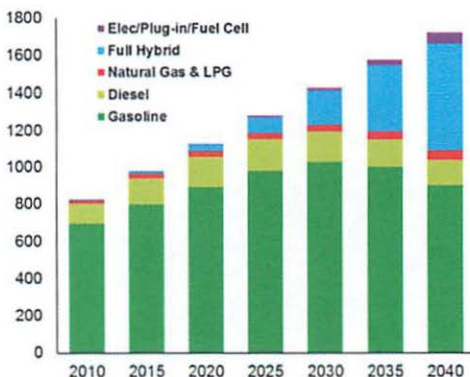
World LDV Demand
MBDOE



Light duty passenger car fleets are expected to increase significantly, predominantly due to standard of living improvements.

Light Duty Vehicles

Fleet by Type
Million

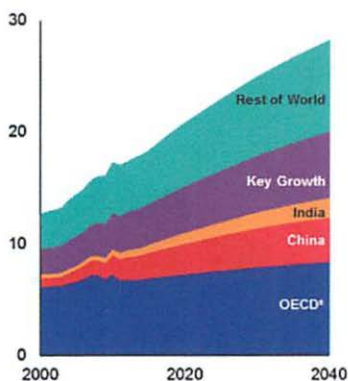


Light duty (passenger car) vehicles types continue to develop technology alternatives with hybrids exhibiting the most significant growth/

Heavy Duty Transportation

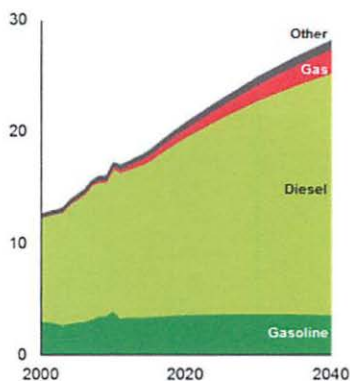
Heavy Duty Demand by Region

MBDDE



Heavy Duty Demand by Fuel

MBDDE



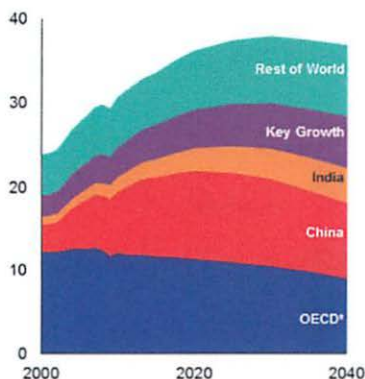
*Mexico and Turkey included in Key Growth countries

Heavy duty transportation segments exhibits significant energy demand increases, and the development of natural gas to significant levels.

World Emissions

CO₂ Emissions by Region

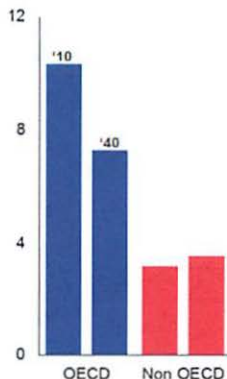
Billion metric tonnes



*Mexico and Turkey included in Key Growth countries

Emissions per Capita

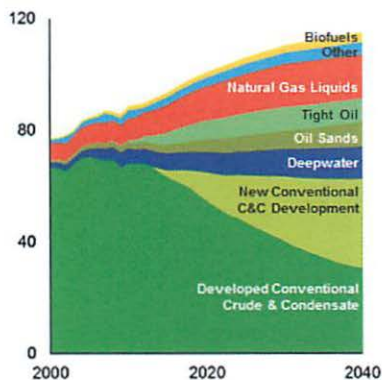
Tonnes/ Person



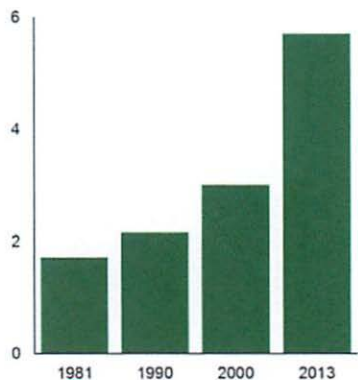
Progress on curbing carbon dioxide emissions through 2040 will be led by OECD nations as energy demand declines and a shift to lower-carbon fuels occurs. Energy-related carbon dioxide emissions in those countries are projected to be about 10 percent below 1980 levels, even though they will have about 40 percent more people and significantly larger economies.

Liquids Supply

World Supply by Type
MBDOE



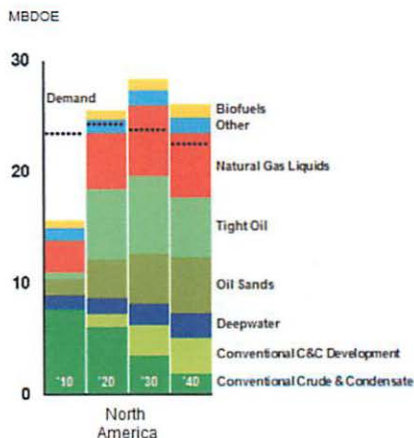
Crude & Condensate Resource Estimates
Trillion Barrels



Source: USGS and IEA historical estimates

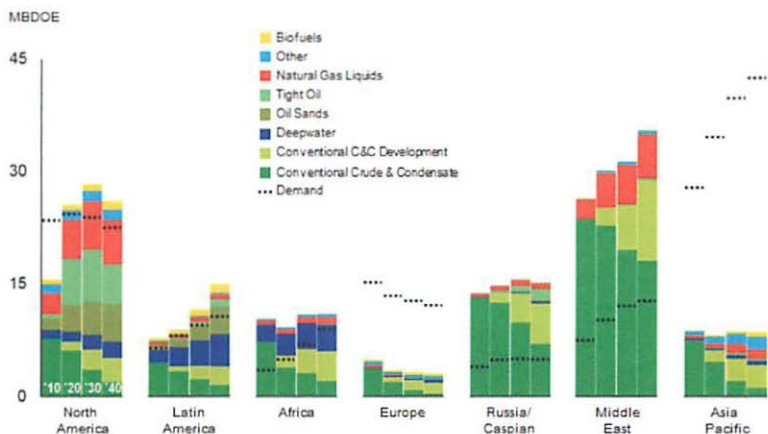
By 2040, abundant sources other than conventional crude and condensate will account for about 45 percent of global liquids production, compared with less than 25 percent in 2010. Remarkably, estimates of remaining recoverable crude and condensate relative to current demand have risen from about 60 years in 1981 to about 150 years as of 2013.

Liquids Trade Balance by Region



In North America through 2040 the liquid supply is expected exceed demand, based on a diversified liquid supplies.

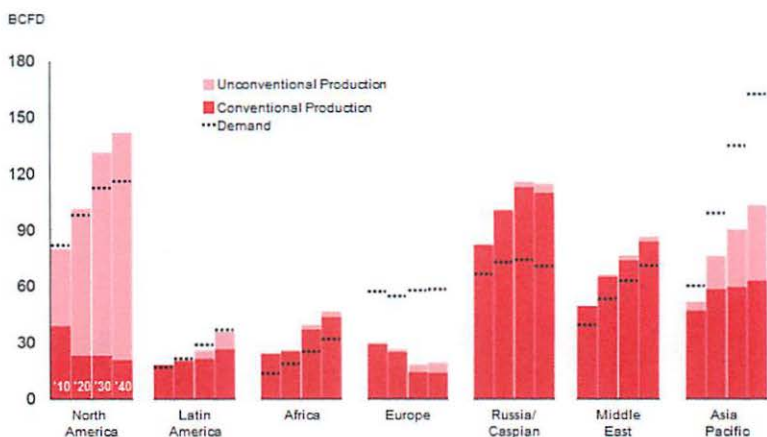
Liquids Trade Balance by Region



The *Outlook for Energy* identifies a significant evolution in the trade of oil and other liquids. A major shift is seen as North America will likely become a net exporter of liquids by 2020 as supplies of so-called tight oil, natural gas liquids and bitumen from oil sands increase. This is expected to open new trading opportunities as Asia Pacific's net imports are projected to rise by nearly 80 percent by 2040. Africa's liquids exports are expected to decline as local demand more than doubles. In Latin America, growth in supplies is anticipated to outpace demand as supplies of deepwater and unconventional liquids expand.

North America unconventional gas production will nearly triple by 2040 and the region is expected to surpass the combined output of Russia and the Caspian region as the largest gas-producing area. In Asia Pacific, gas production is seen doubling by 2040, driven partly by unconventional production technologies. Demand in the region is expected to climb by about 170 percent, according to the outlook, and as a result, Asia Pacific will likely overtake Europe as the world's largest gas importer

Gas Trade Balance by Region



North America unconventional gas production will nearly triple by 2040 and the region is expected to surpass the combined output of Russia and the Caspian region as the largest gas-producing area. In Asia Pacific, gas production is seen doubling by 2040, driven partly by unconventional production technologies. Demand in the region is expected to climb by about 170 percent, according to the outlook, and as a result, Asia Pacific will likely overtake Europe as the world's largest gas importer.

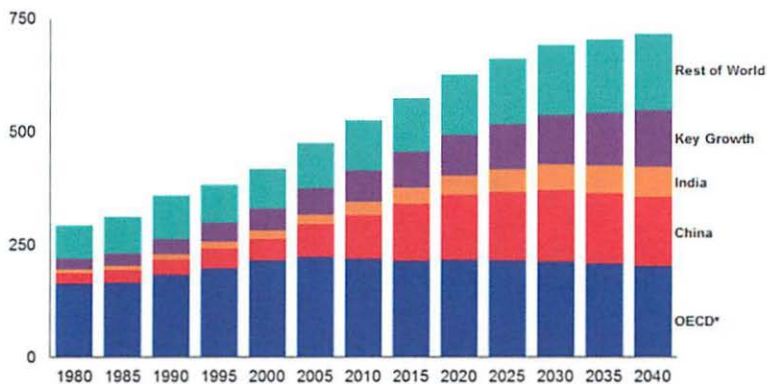
Natural gas is expected to be the fastest-growing major fuel source during the outlook period as demand increases by about 65 percent. Half of that increase will come from the Asia Pacific region, led by China. Utilities and industrial operations are expected to account for about 80 percent of the demand increase worldwide, as operators increasingly choose natural gas because of its lower emissions and versatility as a fuel and feedstock. By 2040, natural gas is expected to account for more than a quarter of global energy use, surpassing coal in the overall mix.

Rising natural gas demand will be met with abundant new supplies and significant expansion in trade as unconventional gas production nearly quadruples and LNG trade triples by 2040.

Developing Economies Dominate Growth

Demand by Region

Quadrillion BTUs



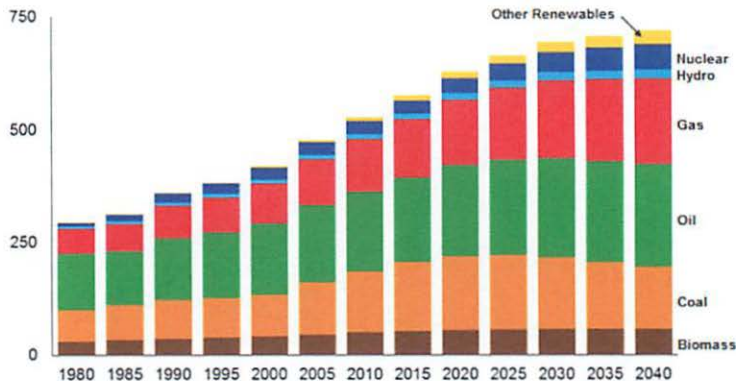
*Mexico and Turkey included in Key Growth countries

Population and progress continue to develop economies and drive demand.

Energy Use Evolves Over Time

Demand by Fuel

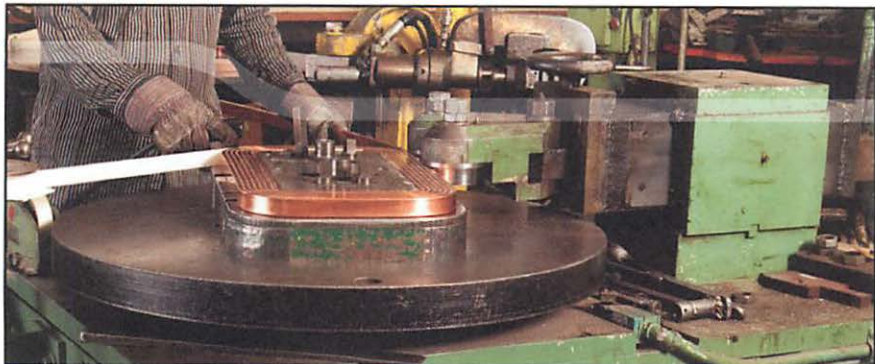
Quadrillion BTUs



ExxonMobil's Outlook for Energy projects that carbon-based fuels will continue to meet about three quarters of global energy needs through 2040.

The outlook shows a shift toward lower-carbon fuels in the coming decades that, in combination with efficiency gains, will lead to a gradual decline in energy-related carbon dioxide emissions.

The energy mix continues to evolve over time. Wind, solar and biofuels are expected to be the fastest-growing energy sources, increasing about 6 percent a year on average through 2040, when they will be approaching 4 percent of global energy demand. Renewables in total will account for about 15 percent of energy demand in 2040. Nuclear energy, one of the fastest-growing energy sources, is expected to nearly double from 2010 to 2040, with growth in the Asia Pacific region, led by China, accounting for about 75 percent of the increase.



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Ron Sulewski,
National Sales Manager
Phone 314.872.9175

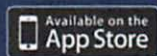
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Report on the Committee on Diesel Material Control

Tuesday, October 6, 2015 at 11:15 AM



Chairman

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Vice President-Sales & Marketing
Rail Products International, Inc
St. Louis, MO

Vice Chairman

Fred Miller

Fred Miller
VP-Sales
Chromium Corp
Cleveland, OH

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T. Lumpkin	Supply Chain Manager	CSX Transportation	Jacksonville, FL
B. Marty	Marketing Director	Metro East Industries	E. St. Louis,
M. Zerafa	Corporate Dir of Purchasing	National Railway Equipment	Dixmoor, IL

Note: Bruno Soto of BNSF is joining the committee
Regional Exec Ron Sulewski assumed the role of interim Chairman replacing Michael Hartung of Norfolk Southern

PERSONAL HISTORY

Ron Sulewski

Ron Sulewski was born in Erie, Pennsylvania and earned his BSME from Rensselaer Polytechnic Institute in 1970. He joined General Electric upon graduation and worked in Erie Locomotive and the GE St. Louis Apparatus Service Shop for over eighteen years with various positions in Sales and Production 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 Vice President, Sales and Marketing, for Rail Products International Incorporated since 2005. Ron and his wife, Marjorie, have five grown children, six grandchildren, and reside in St. Louis, Missouri. He has been active in LMOA activities for over forty years.

The Diesel Material Control Committee would like to sincerely thank the Union Pacific RR for hosting/supporting the committee's meeting at Proviso Diesel Shop, Northlake, IL in December 2014.

The Committee would also like to express their gratitude to Metro East and Brian Marty for hosting the committee's meeting on April 13-14, 2015 in East St. Louis, IL.

These meetings may not have been held without the support of companies such as Union Pacific and Metro East.

“CORES” Long term assets... What is their value?

Prepared by:

Eric Armstrong, Armstrong & Assoc.

In evaluating the lifecycle of a part that is in some way re-used within the repair process, parts are applied, removed, transported, overhauled, evaluated, repaired, qualified, returned and reused. A part that travels through this process is commonly referred to as a, “core.” The purpose of this paper is to discuss the various attributes that determine the actual value of core material used in locomotive maintenance and overhaul to various stakeholders in the value stream. In the course of this paper we will discuss the following topics.

1. Value cycle of a core
2. What is a core
3. Valuation of a core
4. Costs of cores
5. Reducing costs

For the purpose of this paper a core is, a part or material that is repaired, remanufactured, rebuilt, refurbished, reworked, reused, recycled or repurposed in the process of returning the part or material to usable service.

Most cores begin their life cycle in the value stream as either new on locomotives or new part in the repair process used as a replacement. During the normal course of the usage cycle

the product is removed in either a running or failed condition. If the part shows minimal wear or signs of failure at inspection, it may be returned to service. If the duty cycle of the part is deemed to be less than required before the next maintenance cycle it should be segregated for reuse as a core.

The next level of selection is how will the core be treated before it is applied to the locomotive again. Will it be used as a running take out? Re-qualified and used? Replaced with a unit exchange (UTEX) part? Remanufactured by inside or outside suppliers? If the part is to be RTO'ed or re-qualified then it will probably not travel far from the point of removal but in some cases end users may do this work at a different location.

When returning the part for repair or remanufacture there are several transactions that may take place. Below are the most common process transactions common to locomotive parts.

- 1) Repair and return
- 2) Unit exchange, UTEX
- 3) Outright purchase of remanned parts
- 4) Replace with new

Different end users and suppliers can define each of these processes slightly differently, but all except, "replace with new," require a core to be returned to the place the part is rebuilt.

After the part is remanufactured it is returned to the end user for the next use cycle, which may include another turn of being a core.

How cores can save us money and time

Core material enables us to reduce costs by reusing parts rather than scrapping and buying new parts. The pricing of rebuilt versus new can vary by part and by supplier. The added costs in transportation and transactional costs must be added to realize the true value of the rebuild process. Because of the high labor content in rebuilding, often times it is more lucrative for suppliers to sell only new instead of handling transactions with a lot of core material. Reworked cores often supplement pools of material when new parts are scarce, have long lead times or unavailable.

Many locomotive parts are designed to be reused creating the natural need for core pools. If the intent is to remanufacture those parts then we must consider buying additional core pool at the time of purchasing the locomotives. This does not mean that the core pool needs to be purchased with the locomotives, but some planning must be in the works from the outset or else the prices for buying the core pools later can be significant.

The question of, "who should own the core pool," is complex. Certainly

the end user needs to support cores for repair and return transactions, but in the case of outright purchase or unit exchange there are many views. If the end user is comfortable with the supplier(s) in the industry doing their rebuild business then the argument can be made the supplier should support the cores pools. If however only a single supplier controls all the cores or the state of the supply base with core available is in flux the end user needs to evaluate the risks of having to sole source or deal with an inflexible supply base. Otherwise consider the cost for a supplier to build core pool down the line when the locomotives are in need of rebuildable parts. If the suppliers cannot support a large enough core pool then end users will suffer with long lead times and missed deliveries.

How do I value a core? Some questions to help... As our committee studied rail and non-rail industry best practices the value put on cores became elusive. In fact the committee found it difficult to find any two stakeholders in the core value stream that valued cores with the same financial process. Between end user and supply company there was a big divide of opinions in core valuation. Below are some questions to begin the thought process regarding core valuation your organization might use.

- When and how should the core pool be purchased?
- What is the cost of not owning a core pool?
- How large of a pool needs to exist to support my needs?

- What did the core cost me? Did I buy it new? Outright purchase? Scrap?
- Are there tax implications or inventory concerns on your core valuation?
- What department has the responsibility of the inventory value of the core pool?
- If I lose or destroy a core, what will it cost me to replace it?
 - Often times it must be replaced with a new part.
 - What budget will be responsible for replacing the missing core?

A stack of dirty and greasy cores is often mistreated, damaging the cores or losing or forgetting to ship the cores altogether. Wouldn't it be better to consider those cores more on par with a new part? That is probably what will be paid to replace the core.

Basic Core Costs and the Remanufacture Process

During the life-cycle of a part the original acquisition of the part is the single largest cost associated with the part. However the total cost of owning the part through several rebuild cycles is generally greater than the original cost. Transactional costs, transportation and of course the cost to rebuild the core combined determine the life-cycle cost. Other than direct acquisition of the part through a new locomotive purchase or a new part purchase there are some alternatives to develop the core pool. Finding cores through scrap and salvage operation is a typical means of acquiring core pools especially as

the locomotive fleets begin to age. Outright purchase of a remanufactured part is also common among older fleets of locomotives where the supply community is able to save usable cores from going in to the scrap pile.

As there is always some fall-out in core pools from cores that are beyond repair, maintaining and replenishing the core pool is an ongoing task. The number of return cycles on a core part is not infinite and it's dependent on a number of factors including:

1. Requalification design specifications
2. Part duty cycle
3. In use maintenance
4. Repair cost threshold of customer

Solid business practices, that process, track, transport and deliver cores to the internal or external suppliers are key. The critical path includes a multiple of stakeholders throughout the supply chain. An important improvement that the committee identified is that key stakeholders need better communication to save costs. Each end-user and supplier seem to have internal processes to track and transport cores that do not necessarily align with others in the value stream. Lost cores, cores delivered to the wrong party, returning the incorrect part number and incomplete parts all drive higher costs throughout the industry.

Other costs that need to be tracked to completely understand core valuation includes transactional, return packaging (Don't forget the cost to clean grease and oil from the part before shipping!), handling, transportation,

disposal and storage. Now add in the cost of remanufacture for the part before determining if purchase of new parts is more or less economical.

Reducing core/rebuild costs

Finally we would offer some recommendations to help develop a process to make core recovery more economical.

- Make someone/some department accountable for cores
- Have a value and keep the inventory on the books, part of your MRP system
- Track all of the costs; storage, handling, transportation, lost or damaged cores, transactional, etc.
- Eliminate accidentally damaging cores and vandalism
- Avoid storing cores outside. Electrical materials in particular, but all cores in general. It is better to send them back to the supplier.
- A dirty greasy core can have the same value as new if it is lost. Treat it that way.
- Return cores promptly. If not you may need to replace it with a new part. 90 days maximum!
- Find other (old) replacement cores in the market instead of adding new parts to fill out your core pool.
- Establish guidelines with supplier for product recovery expectations
 - Technical specifications
 - Cores damaged in packaging/transportation
 - Fallout percentage based on age, duty cycle and condition
 - Flat rate pricing
- Make sure you recover the scrap rate for the parts not returned because of fallout
- Package carefully for transportation – reduce damage/lower fallout
- Sell the cores you don't need to others







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Innovations in Material Storage/Management

Prepared by:

Brian Marty, Metro East Industries

Innovation takes many shapes

There are vending machines that can dispense safety equipment, tooling, kits, etc. There are vertical storage units for parts and kits which maximize space that results in safe storage habits.

DRIVING CHANGE-WE ALL HAVE THE RESPONSIBILITY

Figure A is a vending machine on the Alton Southern which dispenses safety equipment.

Figure B is a vending machine on the Norfolk Southern in Altoona, Pennsylvania. This machine was installed in 2000 and its primary function was to dispense safety equipment. Employees must input a personal code in order to retrieve the PPE. This system allows to track consumption by individual employee and helps reduce inventory. The vendors are responsible to restock the machine and invoice for consumed items which results in more control and less effort for all concerned.

Figure C is a vending machine at Magnatech in Huntington, West Virginia. It was installed in October 2012 and is primarily used for small

(overhead) items. This is considered consignment inventory and customer is not charged by vendor until items are consumed. Vendor is responsible for maintaining stock levels. Employee inputs code and material dispensed is assigned to a job number in order to allocate expenditure to a specified project. The vendor receives real-time updates.

Figure D is an example of a kit made up by supplier. Many benefits are derived

1. One purchase order to vendor each month instead of 15-20 orders
2. Consignment inventory-pay for it when consumed
3. Cost correctly/properly assigned to a job-previously considered overhead
4. No shipping or material handling
5. Material always on hand/available-not necessary to expedite
6. Reduces wasted material estimated to be around 30%

Vertical Warehouse Concept-
Maximizing Storage and Leaning the
Material Handling Process

Figure E illustrates a typical parts stock bin (before) and Figure F depicts a vertical storage tower (after). Many

improvements are realized from utilization of the parts tower such as reducing the material storage footprint and eliminating risks when retrieving parts from stock (climbing, bending and lifting). Other advantages are locator panels, 30 second retrieval (access) and adjustable storage shelves. Vertical storage

solutions improve safety, productivity and inventory accuracy.

We must all strive to make a concerted and continued effort to drive innovation in material storage management. What's your view?



Figure A

Vending Machines- NS Altoona, PA



Figure B

Vending Machines- Magnatech



Figure C

Vending Machines – Magnatech Huntington, WV

- Kits made up by supplier



Figure D

Maximizing Storage & Leaning the Material Handling Process



Reducing the material storage footprint, eliminating risks with climbing, bending, and lifting.

Before



After



Figure E

Maximizing Storage & Material Handling Process



Vertical Storage Solutions:
Improve safety, productivity & inventory
accuracy



- Multiple Manufacturers
- Locator panels
- Adjustable storage
- 30 second retrieval



Figure F

Bar Coding: A 2015 Update and Beyond

Prepared by:

Ron Delevan, Morgan Advanced Materials

Carl Sagan, a world renowned Astrophysicist was rumored to make a comment about “Billions upon Billions of stars...” To track, Inventory, name and follow such a number would most likely be more than just a daunting task. It may very well be impossible from our vantage point here on Mother Earth. Keeping track of inventories, deliveries, shipping, locations, applications, originations, vendors, reporting requirements, car movement, etc. is a lesser daunting task.

Bar Coding in its many forms can and does provide us with solutions to many of our requirements.

Common examples in our personal lives are Bar Coding labels on Grocery and Food Items, Clothing, Shoe Boxes, Drivers Licenses, Airline Tickets and Boarding Passes, Hardware Store Goods, Library Cards, Frequent Flyer Membership Cards, Medical Cards, Movie Theater Tickets, Concert Tickets and so on.

In our business world we see many of the same examples plus: Shipping Labels and Bills of Ladings, Inventory, Paint Cans, Fasteners, Railway Cars, Axels and Wheel Sets, Etc. Areas where bar coding may be a powerful ally include:

1. Emissions Compliance under Title 40 of EPA Regulations
2. Warranty issues
3. Locomotive and Railcar core components
4. Locomotive Inspection tracking
5. Inventory Part Vendor and Purchase info

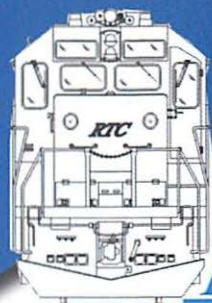
Methods of Bar Coding:

- Self-adhesive labels
- RFID (Radio Frequency)
- Laser

All of these methods have advantages and disadvantages. For example: Paper labels generally are applied to items not subject to water or other fluids. A Laser applied label is fairly indestructible under most circumstances except for extremely high temperature.

UPS Shipping Label:

Shipping date and time, tracking of movements, intermediate stops and delivery are provided by scanning the shipment. No manual inputs are required, thus providing accurate information that is readily available to all concerned parties to the transaction. The history is archived for future access. Limiting human data input provides more accurate data.



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UPS labels are found generally on the outside of a package or item being handled for shipment by UPS. The Labels are fairly resilient and this is especially true when one attempts to remove the label to re-use the container or carton. UPS labels can withstand water for a small period of time.



Figure 1: UPS Shipping Label an example of paper tag

AAR Wheel and Axles:

Not long ago, July 2012, the AAR released, "AAR Component (CID) Bar Code Standard". The practice became one of being able to identify the vendor, facility and pertinent data on the assembly and its components. Such data, when "scanned and recorded" can be used to trace components that may be subject to various reason such as a recall due to defects. Such information could be valuable in incident investigation or recalls due to other issues.



Figure 2: AAR S-290 Sample Axle (with CID) Bar Code

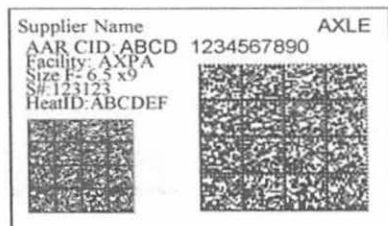


Figure 3: AAR S-290 Sample Axle (with CID) Bar Code

The second AAR sample provides an additional Bar Code Schemes. AAR wheel and axle tags and UPS tags are examples of paper tagging that has a limited life. Those tags can be fairly easily removed or destroyed. Those Bar Code samples above can double as inventory control tags, as in the previous examples. Serial numbers can be used by maintenance forces to track age, where applied, when applied data for tracking for many reasons.



Figure 4: Computer controlled Laser Bar Coding

Durable Bar Coding Methods:

Laser Bar Coding are nearly non destructible (by ordinary conditions). As mentioned, high heat issues such as acetylene burning and welding can of course remove the bar code.

Laser Bar coding, in most cases,

requires "Shop Facilities" to maximize the clarity of the finished Bar Code. However, reading the Bar Code is accomplished with hand held field portable units.

Sample Laser produced Bar Codes are shown below:



Figure 5: Example of Laser Bar Code on tool



Figure 6: Laser produced Bar Code

Radio Frequency Identification:

Radio Frequency Identification does not necessarily require line of sight to operate. Some RFID devices operate on battery and have an operating range beyond fifty feet. Other RFID devices operate on nearby magnetic fields and still others on a radio frequencies directed at them. In any case, RFID devices may be inserted into some items or packaging. These particular devices are often inserted into a pet as they do not require being surface mounted.

Some RFID devices are being implanted in human beings for identity and security access. RFID devices have been implanted in waste materials during entombment for purposes of location detection and verification. You are probably most familiar with their use in clothing and credit cards.

Samples of RFID Devices are provided (Figures 7 and 8):



Figure 7: RFID device for implanting into animals

RFID devices have proven effective in many applications and are being considered for many other applications involving security, adolescent identification, medical alerts, theft deterrent applications and property theft prevention.



Figure 8: RFID device as applied to Credit Cards

Recap:

The previously mentioned devices were acceptable methods of Bar Coding over the last few years. Other than Laser applied Bar Codes, the others are relatively prone to tampering or defeating. As we proceed into the newest innovations, we have to agree that there has been progress made in material and parts identification through the previous methods. The future still looks interesting with work being done in more robust direction. None-the-less, these systems are still viable and enjoy wide use.

NEW AND IMPROVED CODING

High Temperature Chemical Resistant Tags:

Ceramic on ceramic Bar Code labels are appearing that provide temperature ranges up to 1700 F and provide resistance to most chemicals.



Figure 9: High Temperature Ceramic on Ceramic Tags

Ceramic on Stainless Steel tags are reported to be viable up to 1800 F and are resistant to most chemicals. These tags are intended for use where high temperature washing process are common place and are ideal for applications to diesel engines and their components and other locomotive components where traceability is paramount.



Figure 10: Ceramic on stainless steel tag

These Bar Code tags, Ceramic on Ceramic and Ceramic on steel, are solutions to higher temperature applications. With operating temperatures exceeding 1500F, these tags exceed common locomotive operating and maintenance temperatures.

Ceramic on etched metal would be possible on new manufactured parts for traceability through out the components life.

Such component applications to engine components subject to Emissions Certified engines and components subject to “40 CFR 92.8 – Emission Standards” and manufactured on or after January 1, 2005. Electronic traceability through Bar Coding using the High temperature ceramic Bar Code tags could provide positive proof safe guards in the compliance as set out in the CFR.

Unique Identification (UID) Coding:

UID was developed to provide coding that is globally unique and ambiguous. It is based on a Unix-like operating system. The system produces a unique identifier alphanumeric or numeric code that is unique to and is associated with one single entity. As noted the string is to be globally unique. This allows for ownership / entity identification.

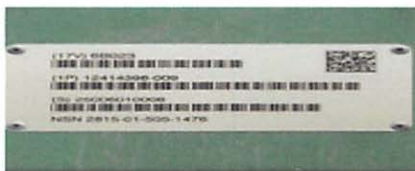


Figure 11: UID Code tag

A system developed by the military and is an off shoot of UID is called "IUID". Item Unique Identification (IUID) takes UID to another level. UID includes or encompasses: people, tangible property and real property, wherein IUID relates to only the tangible property.

Property included in IUID have two files associated. A Unique Item Identifier (UII) and a 2-D data matrix. These files allow a computer to find the UII and associate it with all of the data.

IUID is purposed to provide, in part, the following:

- Data for engineering analysis
- Accurate data for valuation and accountability
- Intelligence for operational planning
- Lower item management costs
- Improved inventory accuracy
- Reduced work force burden through efficiency
- Access to historical data

Where do UID and IUID take us?

More data, more accurate data and even more data could, if gathered and handled correctly, result in real time cost savings.

Stand by, as we continue to track the benefits of Bar Coding and its progress towards the future and our involvement.

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 bear the expense of such bond.

Section 4-The Regional Executive officers shall:

A. Participate in the General Executive Committee meetings.

B. Monitor material to be presented by the technical committees to ensure reports are accurate and pertinent to the goals of the Association.

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

D. Promote Association activities

and monitor membership levels within their assigned areas of responsibility.

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

Section 5-Duties of General Executive Committee:

A. Assist and advise the President in long-range Association planning.

B. Contract for the services and compensation of a Secretary-Treasurer.

C. Serve as the Auditing and Finance Committee.

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

E. Exercise general supervision over all Association activities.

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

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

H. Approve the schedule for the Annual program.

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

Section 6-The General Executive Committee is entrusted to handle all public relations decisions within LMOA and coordinated associations with confidentiality.

Article VII-Technical Committees

The technical committees will consist of:

Section 1-A chairperson, appointed by the President and approved by the General Executive Committee.

Section 2- A vice Chairperson, selected by the chairperson and

approved by the President.

Section 3-Committee members 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.



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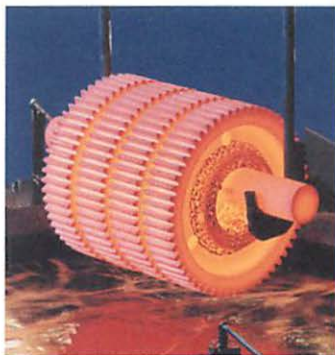


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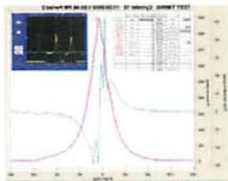


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