LMOA

Locomotive Maintenance Officers Association

Proceedings of the 61st Annual Meeting

September 20-22, 1999

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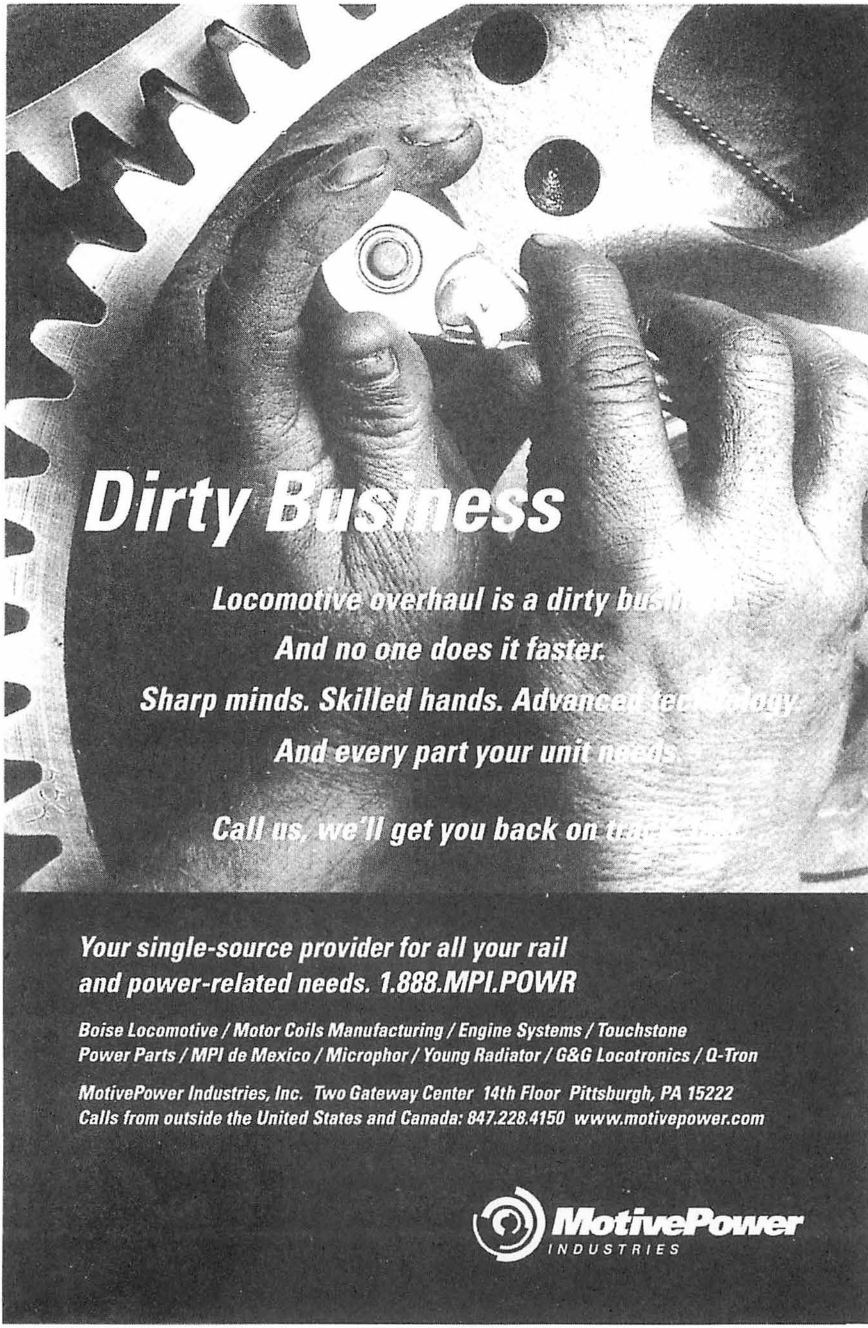
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1998 LMOA MVP RECIPIENTS

The executive board of LMOA wishes to congratulate the following individuals who were selected as the Most Valuable People of their respective committees in 1998.

Name	Company	Committee
Bob Runyon	Norfolk Southern	New Developments
Brian Hathaway	Florida East Coast	Diesel Electrical
Lee Oviatt	DM&IR (retired)	Diesel Mechanical
Chuck Kunkel	Union Pacific	Fuel, Lube & Environ.
Pat Gagne	St. Lawrence & Hudson (CP Rail)	Shop Equipment & Processes
Bob Faulconbridge	CP Rail	Diesel Material Control

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

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1954 & 1955 - F. D. SINEATH, Retired Chief of Motive Power, Seaboard Coast Line R.R., 1061 Nelson Ave., Jacksonville, FL 32205
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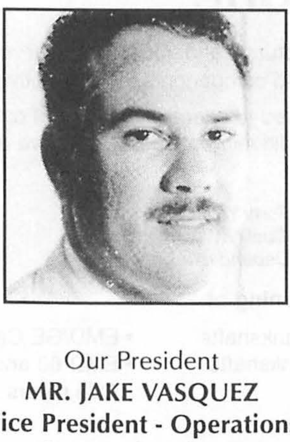

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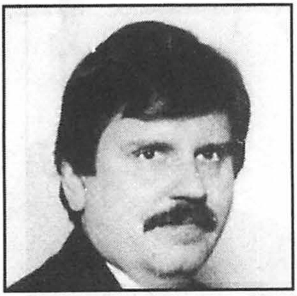

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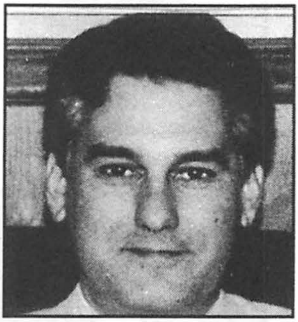

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Norfolk Southern Corp.
Roanoke, VA 24042

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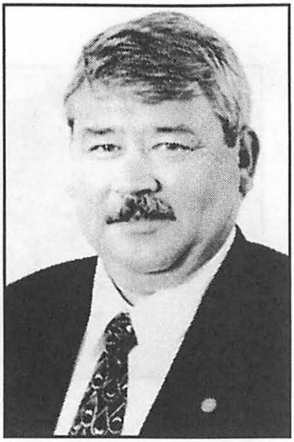

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MR. CHARLES MILLER
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Omaha, NE 68179

MR. DARRELL M. WALKER
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Atlanta, GA 30315

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Kansas City, MO 64120

MR. ALLEN KELLER
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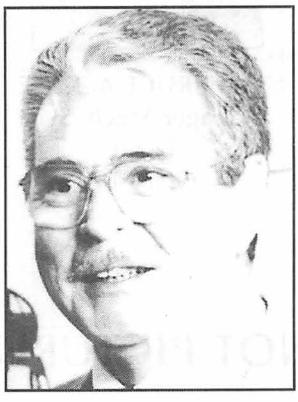
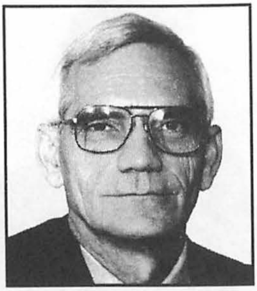
Reading Railroad Services Co.
Cleona, PA 17042



MR. WILLIAM BROWN
Director - International Mech. - Sales and Service
Montana Rail Link
Silvis, IL 61282

OUR REGIONAL EXECUTIVES



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Florida East Coast Rwy.,
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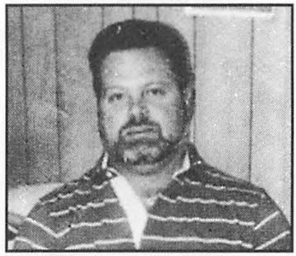

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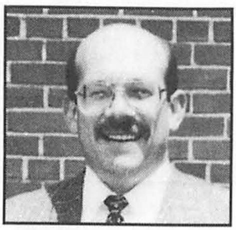
Norfolk Southern
Altoona, PA 16603



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Manager Mech. Svcs.
EJ & E
Gary, IN 46402

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

NOT PICTURED

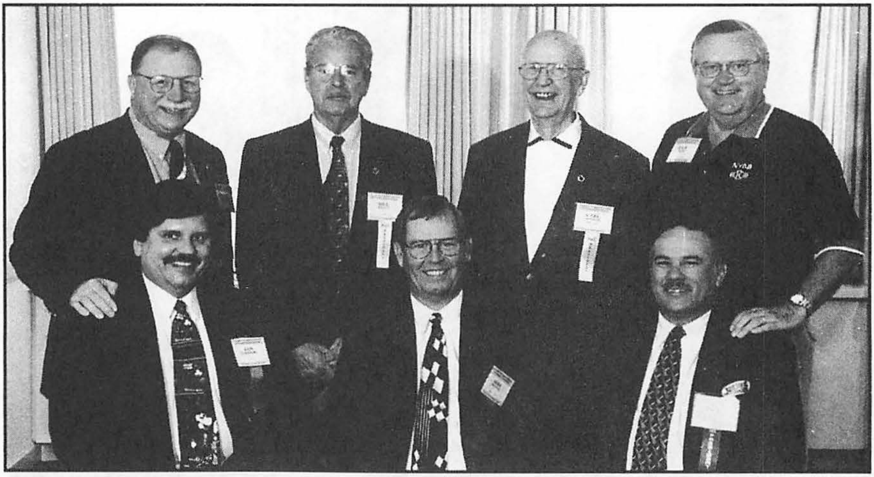
MR. CHUCK KUNKEL
Sr. Mgr. Research & Dev.
Union Pacific
Omaha, NE 68179

NOT PICTURED

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

Past President Dale Propp, New York Air Brake, presents Past President's Pin to outgoing President Mike Pennell, Ellcon National, which was witnessed by Chairman of the Board David Wetmore, Amtrak.

Past President Bill Brown, Montana Rail Link, presents General Desk Set to outgoing President Mike Pennell, Ellcon National, as Past President Carl Stendahl, BN-retired, looks on.



LMOA Executive Committee Members: Seated (left to right) - 2nd Vice President Ron Lodowski, Conrail/CSX; President Mike Pennell, Ellcon National; 1st Vice President Jake Vasquez, CMC Railroad.
Standing (left to right) - Chairman of the Board David Wetmore, Amtrak, Past President Bill Brown, Montana Rail Link; Past President Carl Stendahl, BN (retired); Past President Dale Propp, New York Air Brake.

Outgoing President Mike Pennell, Ellcon National, passes gavel to newly installed President Jake Vasquez, CMC Railroad, as newly elected 1st Vice President Ron Lodowski, Conrail/CSX looks on.

Address by
President H.H. (Mike) Pennell,
Ellcon National
September 21,1998

Good afternoon, Ladies and Gentlemen.

Welcome to the Monday afternoon session of the Locomotive Maintenance Officers Association.

This is the 60th year for LMOA. This past year we have seen many changes, with more to come in the near future. Mergers and downsizing have become commonplace. New and innovative technology has changed how our business is being conducted today.

I have been a member of LMOA for 20 years and have seen a lot of changes over the years. However when you are personally affected by some of these drastic changes it starts to really hit home. When I left the BN 3 years ago it was great to hear from so many LMOA friends that I have known over the past 17 years. This organization has benefited me in my career, as I am sure it has done and will do for many others.

This past year we were able to have all of our committees together for the first time in many years. Our meeting this year was in Little Rock, Arkansas.

These meetings are very beneficial, as they give everyone the opportunity to get to know each other better, to exchange ideas and to discuss common problems and concerns.

In these changing times an organization such as LMOA is the best way to keep abreast to the changes that are taking place in the rail industry.

This past year the executive committee agreed that our direction in the future should be to continue to provide beneficial information such as the Best Practice series. These papers will continue to address concerns of regionals and shortlines, as well as the Class I railroads.

Participation from all members is encouraged. Please get involved in any one of the committees. It is a very rewarding experience and we welcome your participation.

Help us help you by suggesting topics you would be interested in for future papers. Our organization will only be as good as our continued member involvement. If you are interested in participating on any committee, please see me or any executive committee member.

I think this has been a great year with only better things to come.

I want to thank the executive committees, the Chairmen of each committee and their respective members, and most especially our Secretary-Treasurer, Ron Pondel for all the help that I have received this past year. It has been my pleasure to work with all of you. Thank you for the opportunity.

REPORT OF THE COMMITTEE ON NEW DEVELOPMENTS

MONDAY, SEPTEMBER 20, 1999
10:15 A.M.

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

COMMITTEE MEMBERS

R. Brewer	General Foreman	Illinois Central	Homewood, IL
B. Brown	Dir-Intl Mech. S&S	Montana Rail Link	Silvis, IL
T. Brunner	Gen. Supt.-Locos.	Amtrak	Philadelphia, PA
K. Nguyen	R & D Engineer	Farr Co.	El Segundo, CA
A. Oser		General Electric Transp.	Erie, PA
R. Parent	Sr. Mech. Rel. Spec.	CN Rail	Montreal, PQ
C. Prudian	Proposal Manager	Electro Motive Div.	LaGrange, IL
D. Robey	Mgr-Loco. Engineer	CSX Transp.	Jacksonville, FL
R. Runyon	Engineer-Loco. Design	Norfolk Southern	Roanoke, VA
B. Smith	Mgr-Tech. Services	New Jersey Transit	Kearny, NJ
R. Smith		Farr Co.	Memphis, TN

Note: Tim Black, Union Pacific, has recently been appointed Vice Chairman of the New Developments Committee.

PERSONAL HISTORY

Bruce M. Butts

Bruce M. Butts received his B.S. degree from the University of Wisconsin in 1970. His background experience includes DC motors, drives and drive systems and industrial pump design.

Bruce joined National Electric Carbon Products, Inc. in 1988. His current position is Manager, Corporate Accounts. He and Corinne, who have been married for 26 years, live in a far Western suburb of Chicago.

I. LOCOMOTIVE FILTRATION WHERE ARE WE GOING?

by RéJean Parent - CN

Where are we going with locomotive filtration? I will review today the different filter design criteria being used in air filtration as well as fluid filtration and share with you CN's experience with filtration over the past few years.

Let's start by looking at the numerous design criteria. Manufacturers take into consideration their past experience; they look at the specific application; they also have to consider the acceptable pressure drop, the required efficiency, the holding ability, and the cost. But there is much more to take into consideration, such as the temperature range for the operation, the structural integrity requirement, the flame retarding ability, the ease of handling and change-out of the filter as well as the environmental issues related to the disposition of the filter.

On the air filtration side, there are two general types of filters: viscous impingement and barrier. The viscous impingement types are built with a very open media coated with oil (gel) that acts as an adhesive to retain dirt. They are generally built with large media fiber, visible with naked eye. Examples are oil bath and railroad baggie filters.

The barrier type is built with a very dense wet-laid fibrous media. The media fiber is much smaller and requires some form of enlargement to be observed. The well known Dynacells are an example of this type of filter.

The viscous impingement filters have the advantage of offering a very low pressure drop and a low cost. Their efficiency on the other hand is low; they require frequent re-oiling or replacement, they can experience oil carry-over and also unload dust on the clean side.

The barrier type has a higher efficiency, with no oil or dust unloading but exhibits a higher pressure drop and has a higher initial cost.

When looking at liquid filtration (lube oil), there are again two types of filtration: centrifugal; which by mechanical mechanism separates heavier particles, and the barrier filter, which is made of a dense wet-laid fibrous media. The 6"X29" cylindrical railroad filter is a well known example of this type.

The centrifugal filter advantages are an unlimited service life and no disposal cost. Its disadvantages are an inability to filter below a 10 micron size, a need for frequent clean-outs, a high pressure drop and a expensive purchase cost. On the other hand, the barrier type filter advantages are a low pressure drop and a high efficiency at a low cost. However, it must be changed-out on a regular interval, which generates a disposal cost.

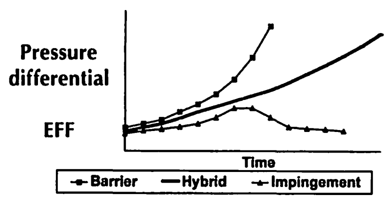
Over the years, Canadian National Railway has done extensive testing, and at this point we would like to share some of our experience in filtration. In the mid 80's, we were facing a shutdown problem on our Alco engine fleet which is similar to the GE design.

Contrary to GM, the Alco engine is equipped with a relief valve on the oil system that returns the oil to the the crankcase when the filter is exposed to excessive pressure. The end result of this is that the engine will shut down due to low lube oil pressure.

With the 10 TBN oil used in those years, and the basic 6"X29" paper filter, we were not able to make the 92 day filter change out intervals. After discussion with Filtration Systems Inc. (FSI) personnel, we began a test with their depth filter. This was a new concept of filtration by layer, including wood fiber. In the beginning, there were numerous skeptics, but soon after that, our Alco fleet was running with the depth filter. In the early 90's, the depth filter became the system standard for CN, not only on the Alco fleet but also on the GM fleet. During our test period, the CN oil analysis system was used to monitor the health of the fleet. No negative impact of the filter type change was noted and in fact, many tests ran the filter over a 6 month period to ascertain durability.

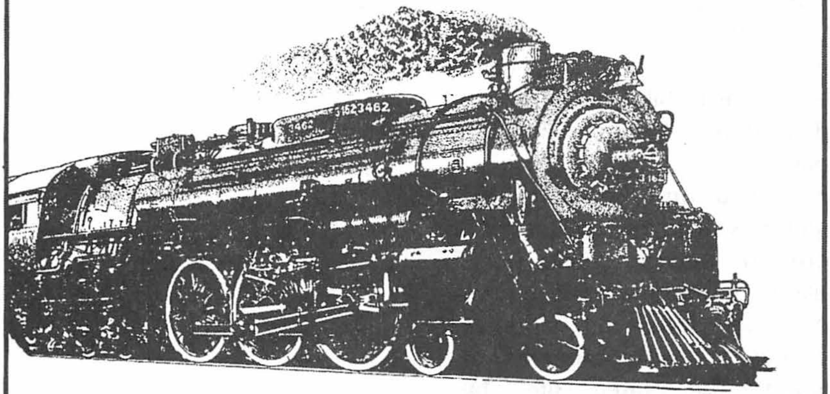
On the engine air side, a turbocharger failure study in early 90's led us to believe that some oil migration from the baggie air filter was the source of the imbalance condition leading to some failures. Discussions with Farr personnel lead to the development of hybrid baggies that were designed to prevent gel (oil) unloading. Through initial lab testing, they realized that the life expectancy was much higher than expected. In the first field test on 3 locomotives, one locomotive was left in service for 9 months, with monthly pressure drop readings taken. Satisfied with the results, we expanded the test and equipped an additional 100 locomotives with the new filter.

The intent was to keep them on the road for 6 months. However, more than 50 locomotives had their filters changed after only 3 months. We soon realized the cause was that the shops were trained to renew filters at a 3 month interval, which was standard procedure. Through the entire test period, the oil analysis system was used to monitor conditions, with no negative results.



As you can see on this graph, the hybrid bag is performing in between the standard baggies and the paper filter, but is able to maintain an acceptable level of efficiency for a longer period, without any sign of distress.

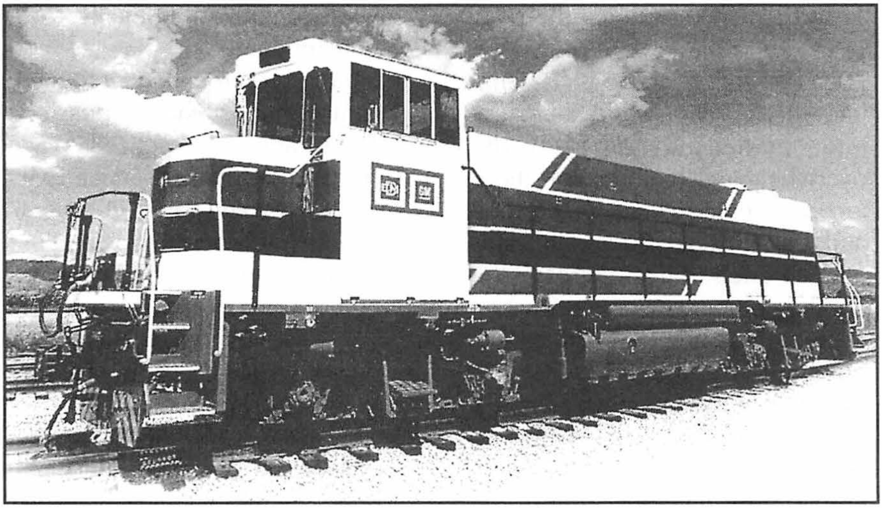
Following that test and under increasing operating pressure, CN Mechanical decided in 1994 to move most of the non-regulated maintenance to a 6 month interval, (under-deck safety related items



were kept as is). The hybrid engine air filters and the depth lube oil filters were changed on the CN-maintained fleet to the new 6 month interval.

Again, the oil analysis system constantly monitored the health fleet. The availability has improved and we haven't seen any negative impact.

In conclusion, the 6 months filtration is working for the CN. There are new long life filters available on the market. The new-generation lube oil additive packages are also expected to prolong the filter life by maintaining the dirt in suspension in the oil. Furthermore, the builder's new designs are all based on a longer filter change-out interval. So where are we going in locomotive filtration? Draw your own conclusions.



II. EMD MARKETS A NEW LINE OF SWITCHERS

Prepared by:
Craig Prudian,
Electro Motive Divn. - GMC

Since Electro-Motive offered its first 600 Horsepower "SC" switcher locomotive in 1936, EMD has produced more than 5000 new switchers for the North America market. During the peak years from the 50's through the 70's, the bulk of these units came into service and found their way into immediate duty. The overwhelming majority of these locomotives continue to live long and colorful lives today, in yards and branch lines across the continent.

Since the early 1980's there has not been a new switcher to gain the favor of the American railroads, as most of them were content to give the old rosters "one more rebuild". To date, the strategy has worked, but with each rebuild, the need for a new affordable switcher locomotive notches up.

Today, there is a new series of switcher locomotives on the market to answer the call for this product. It comes as a cooperative effort between General Motors Electro-Motive Division, Boise Locomotive and Caterpillar. Built in Boise Idaho, the units take maximum advantage of the strengths of each of the principals, to yield maximum utility at a minimum life cycle cost.

These locomotives, the GP15D and the GP20D, offer many features that railroads have come to be most comfortable with over the years, along with some new innovations that provide economical operation, while meeting the newest safety and environmental standards, as well as anticipating some of the newest regulations on the immediate horizon.

This paper will briefly cover these new locomotives, primarily from the standpoints of features and maintenance procedures required. Maintenance, where possible, follows traditional practice in place in today's shops that service EMD locomotives, and varies in general, only due to changes brought about by new technology advancements.

Overview

The GP15D and GP20D locomotives are a culmination of many years of effort toward development of a new model, and a true amalgamation, utilizing the talents of each of the partners in this endeavor. For those who have been in tune with recent developments in switcher locomotives, it is well known that Boise Locomotive had developed the forerunners of each of these models earlier this decade, using Caterpillar power and a wealth of experience delivering rebuilt locomotives. EMD's direct contribution has been more recent, providing expertise in the areas of system and subsystem integration, locomotive control and mechanical design. Bringing all of these disciplines together has resulted in a product that offers top-of-class performance, at an extremely affordable price. What will follow in this paper, is roughly a "by system" tour of these locomotives, with notes for shop personnel as to what procedures may be expected.

With reference to Figure 1, we see the platform utilized for each of the locomotives in this series. At the center of this locomotive is, of course, the prime mover. The engines for this locomotive series carry the EMD designations "GM12V170B15" and "GM16V170B20". The cab is a full-vision design, meeting clean cab safety guidelines. Dynamic brakes are available on the GP20D, using EMD standard 700 Amp box grids. The standard air compressor is a three cylinder WLN-style unit, separately motor-driven. The underframe is the main structural member of the locomotive, strengthened specifically for the installed equipment on these models. Underneath the locomotive, a 2300 (useable) gallon fuel tank meets all AAR RP-506 requirements for strength and safety.

New "170" Engine

At the heart of the locomotive (Figure 2) is a new "170" series engine (which, to the trained eye, could be mistaken for Caterpillar 3500 series engine), used for both models. The engine used has either a 12 or 16 cylinder configuration, and is rated at 1800 rpm, to meet the horsepower requirements for either the GP15D or the GP20D model. The designation breaks down as follows: engine model GM16V170B20 refers to the engine used for the GP20D. The 16 refers to the number of cylinders, the "V" designates the cylinder arrangement, in this case, a 60°Vee, the 170 is the cylinder bore in millimeters and the "B" is the Caterpillar engine version designation, in this case denoting electronic control. For those interested in displacement criteria, this engine is sized at 263 cubic inches per cylinder. It develops sufficient brake horsepower to supply 2000 traction horsepower. The engine employs a 4 stroke cycle, and thus has no need for pressurized air flow into the airbox. As such, the turbochargers (there are two) are freewheeling, and require no geartrain or overrunning clutch. Caterpillar had full responsiblilty for the engine design and development, with control and interface issues being handled as a cooperative effort by all parties.

Engine control is provided by an on-board microprocessor, which oversees the fuel injection system and local diagnostic functions. Upstream, the microprocessor is overseen by the EM2000 main control computer for locomotive-related commands. The computer also provides fault and diagnostic data to the EM2000, which processes this information and acts as the port into the locomotive human-machine interface for the engine.

With this engine, comes some other special features as well. The mounting of the engine to the underframe is unlike traditional EMD practice. In these locomotives, the engine, rotating generators and most support systems are mounted on a single skid, and then set into the locomotive. This helps preserve critical alignment between the engine and other rotating machines and also provides vibration isolation. This isolation serves to provide a better environment for crews and equipment, by reducing cab and wayside noise, as well as conducted vibration into the cab and locomotive carbody.

Another advancement provided is an anti-freeze based coolant in the engine. No more worries about coolant dumping due to auto-drain problems or coolant freezing in the radiators.

Engine Support Systems

Looking at some of the engine support systems, engine cooling is noteworthy for its differences (Figure 3). As mentioned before, the engine is provided with a water/anti-freeze mixture (along with the requisite rust inhibitor). Some of the benefits available with this change go beyond not having to worry about engine freeze. Some current equipment is now eliminated, yielding a simpler system. For instance, there is now no need for radiator shutters or automatic drain valves. Fans also become simpler. The familiar 48" fan is retained for this model; a four blade fan is utilized with six-row mechanically-bonded radiators. At this time, emission requirements allow for the use of a single circuit cooling system. To further reduce locomotive emissions, a second charge-air cooling circuit can easily be added, using eight-row radiators.

Auxiliary pumps (water, fuel and lube oil) are all mechanically driven off the accessory drive gear train of the engine. This provides an optimal match of fluid flow to engine speed. An added benefit of this approach is longer pump life and a reduction of parasitic loads on the engine. The engine intake is first treated with a traditional inertial air filter with dust bin blower, and then with replaceable "baggie" type air filters. These filters are located in a clean air compartment, similar to main-line models. The GP15D and the GP20D each employ a different number of these filters, based upon the engine air requirements.

Engine starting uses a traditional EMD concept, employing two 32 Volt starting motors, connected in series. The engine start switch is located in the cab, for crew convenience. No "fuel prime" sequence is required.

As for the traditional equipment rack area, the use of the Caterpillar power plant obviates the need for a separate rack. Most of the engine support equipment is directly mounted to the engine, with a minority of pieces (for example, the water expansion tank) directly attached to the long hood structure.

The fuel system is a simple application, with the fuel pump collocated with the lube oil and water pumps at the engine accessory drive. As mentioned above, a fuel prime sequence is not required. Yet, following long periods of shut down time or fuel system maintenance activities, some fuel priming may be required. For this purpose, a manual priming pump is provided, mounted on the front of the engine (rear of the locomotive). Also at the engine front, the fuel filter is mounted transversely, high on the engine, for ease of access.

Using the engine-mounted concept, the engine lubrication system also succeeds quite well. The lube oil pump, driven from the engine geartrain, feeds the oil cooler, mounted low on the engine block. From there, the oil is sent to the oil filter, and then through the engine. The oil filter is mounted on the front of the engine, just below the fuel filter, for ease of servicing.

Traction Systems

As far as the traction systems are concerned, the transmission is largely traditional. The main generator is a KATO machine, which is connected to the DC traction motors. The same main generator is used for both model locomotives. The motors themselves are rather vanilla, by EMD locomotive standards; The GP15 uses D78B motors, rated at 1050 A continuous, while the GP20 employs D87B motors at 1200 A continuous. The motors use a series-parallel connection to the main generator, with motor transition.

The companion alternator is an 8-pole machine, which is direct-driven from the engine, along with the main generator. Thus, the maximum speed of the companion alternator is 1800rpm, yielding 220 VAC at 120Hz 3-phase for the auxiliary power converter (explained below) and other auxiliary machines.

The dynamic brake system, offered as an option on the GP20D, uses standard box-style grids and a DC blower. The system components maximize the commonality with older, established EMD dynamic brake systems.

Auxiliary Electrical Systems

With other electrical auxiliary systems, ease of maintenance is a primary driver. For instance, the batteries are located above the deck at the end of the long hood, easily accessible with entry from both the left and right sides of the locomotive.

The auxiliary generator, long a standard component in EMD locomotives, is now gone. Replacing it is a solid-state auxiliary power converter. This unit is maintenance-free and is driven directly from the companion alternator. It is rated to comfortably handle all auxiliary loads and provide voltage regulation, optimized for ambient temperature. This arrangement offers both a weight and simplicity advantage over older systems.

Trucks

Trucks used for these locomotives are also well known to those familiar with EMD locomotives. These locomotives use standard Blomberg-style trucks, newly remanufactured for switching service. Traction motors are D78 or D87, remanufactured to "B" series standards. Wheels are "Fat 40's; 41" wheels with extra tread for longer life. Braking arrangement consists of a clasp-type, double shoe configuration with 14" composition brake shoes on 9"x8" brake cylinders.

Carbody and Structures

Relative to the carbody structures, many improvements have been incorporated there, as well. Crashworthiness is paramount - the locomotive utilizes two collision posts on the short hood, integral with the short hood structure, and welded directly to the underframe. Anticlimbers are also standard, compliant with all AAR S-580 criteria.

These locomotives are configured to carry a total of 45 cu. ft. of sand, half at each end. Fillers are located at each end of the locomotive, easily accessible from the locomotive deck level.

The underframe is the main structural member of the locomotive, and is upgraded to the latest design standards at point of manufacture. Side and center sills are employed, for compatibility with the narrow long hood. In this way, service walkways are provided on both sides of the locomotive for maximum maintainability.

The long hood is bolted to the deck, so that maintenance flexibility is maximized. Side service doors are included along the length of the long hood, along with top gull-wing doors for quick access to the engine and topside components.

Impact Resistant Fuel Tank

As previously noted, the fuel tank is new, and there are a few points that are most noteworthy. First of all, this new tank is capable of holding a useable 2300 gallons of fuel, maximizing the locomotive operating range. As well, an integral 100 gallon retention tank is also included. The tank is bolted up into the underframe and remains unit replaceable. Other significant changes have been incorporated. The tank now supplied is much stronger, fully compliant with AAR RP-506 criteria as well as anticipated new FRA rules on fuel tank integrity. In addition to the added strength which makes the tank more impervious to debris damage, the bottom height is raised to keep the tank intact in the event of a derailment. Other improvements, including cross venting to minimize spillage in overturning situations, are also included.

Operator's Cab and Short Hood

As mentioned earlier, the cab is a full-vision design, allowing a 360 degree view from the operator's position. Figures 4 and 5 show the cab layout, with a standard AAR control stand supplied for bi-directional operation. All AAR clean-cab guidelines are followed, to produce a safe, ergonomic environment. The cab has ample room, and thus is equipped with three full-sized seats (operator's, helper's and observer's). Cab sound levels are greatly reduced, owing to the "isolated engine" concept employed in the design of this series of locomotives. Further crew comfort items are available optionally. For instance, air conditioning is offered as an option to either of the models.

A low short hood is provided, which is used to house ancillary locomotive control equipment and the sanding equipment for the front of the unit. The short hood is accessible from the cab only, and includes an access door, which is lockable. Space provision for an optional toilet is also included in this compartment.

Electrical Control and Display System

EMD's standard EM2000 central control computer provides all high-level locomotive control and diagnostics interfaces. Control functions are typical of EMD locomotives, including excitation, auxiliary load management and protection functions. As the engine is also microprocessor controlled, the EM2000 oversees the high level functioning of this system. As well, the EM2000 is capable of acquiring fault and diagnostic information from this, and any other installed system microprocessor used in a locomotive system.

With this series of locomotives, the EM2000 is fully intended to be used as a diagnostic tool. With the computer display located on the high voltage cabinet, the computer is set up to run test routines, identify fault conditions, and is even configured to take a "snapshot" of conditions existing just before, and during a fault event. A total of 600 fault messages can be stored on the system at one time.

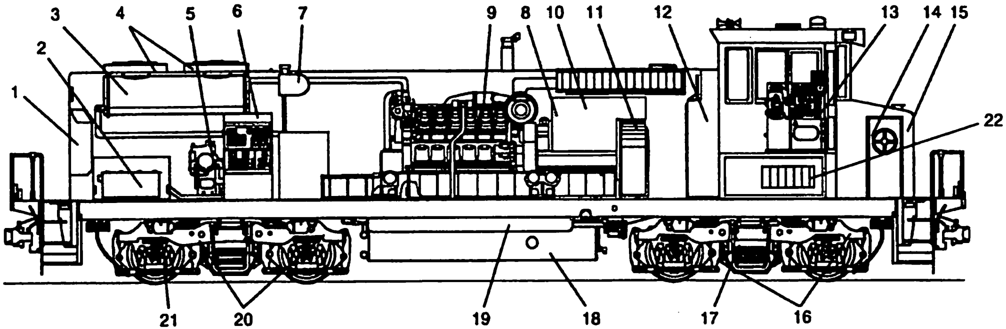
For wheel slip control, these locomotives fully utilize the capabilities of the microprocessor system. Radar ground speed sensing is employed as a primary reference to control wheel creep for maximum adhesion. A redundant speed reference is provided by axle generator, for calculation within the EM2000. Together, these elements provide a fully managed wheel creep system to maximize adhesion and minimize the use of sand throughout the full speed range of the locomotive.

Conclusion

The marketplace has been ready for an advanced switcher locomotive for some time now. With the cooperation of EMD, Boise Locomotive, and Caterpillar, there now exists a product that will offer a combination of high utility, low initial purchase price, and even lower life-cycle-costs than ever before. As customers get an opportunity to put these units "through their paces", we expect the feedback to only confirm our initial assessments. At the same time, we are eager to gain any new inputs that will make these units even more valuable as the years go by.

We are looking forward to working with our customers to explore all the possibilities of these "new" switchers, as we together look toward maintaining the rail freight industry as a leader in North America for modes of transportation.

GP15D & GP20D
Locomotive Equipment Layout



1. Sand Box
2. Batteries
3. Radiator Core
4. Cooling Fans
5. Air Compressor
6. AC Cabinet
7. Cooling System Expansion Tank
8. Companion Alternator
9. Engine
10. Traction Alternator
11. Traction Motor Blower
12. High Voltage Cabinet
13. Control Stand
14. Hand Brake
15. Sand Box
16. Traction Motors
17. 2-Axle Truck
18. Fuel Tank
19. Air Reservoir
20. Traction Motors
21. 2-Axle Truck
22. HVAC Unit (Option)

GP15D / GP20D Locomotive Right Side View (Showing Equipment)

Figure 1

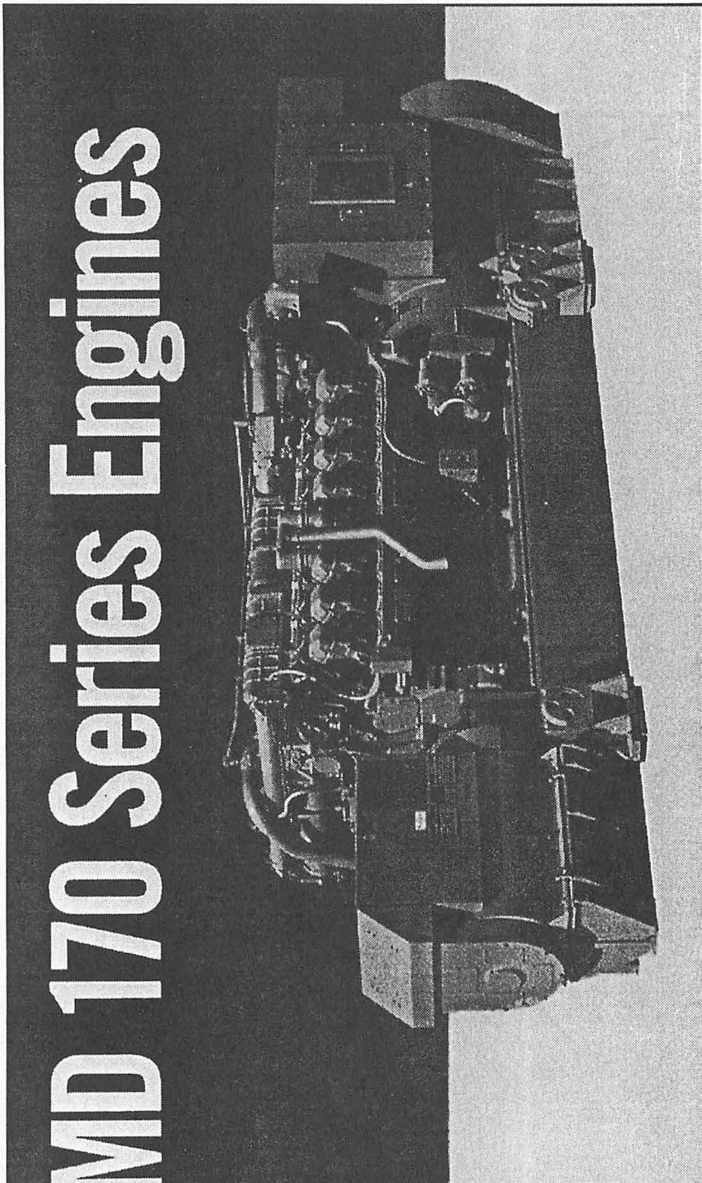


Figure 2

Fuel & Oil Filters

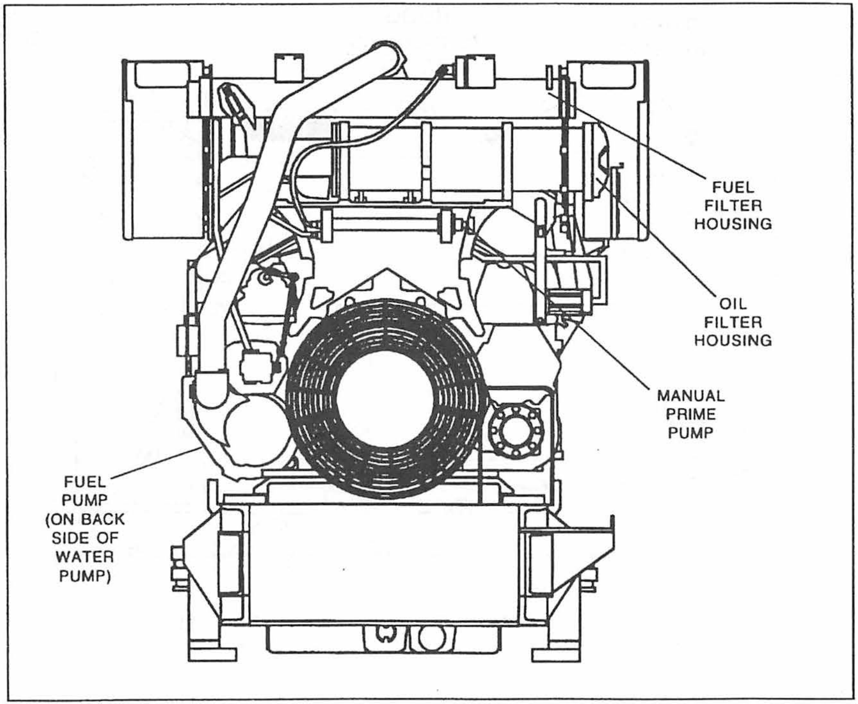


Figure 3

Cab Front View

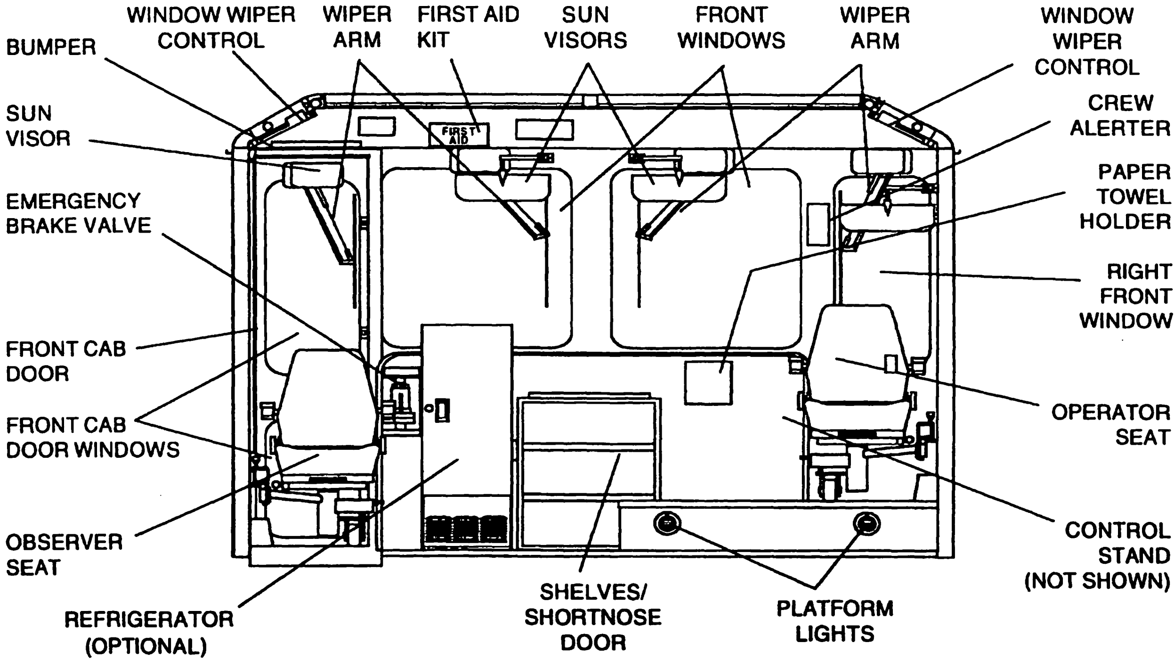


Figure 4

Cab Rear View

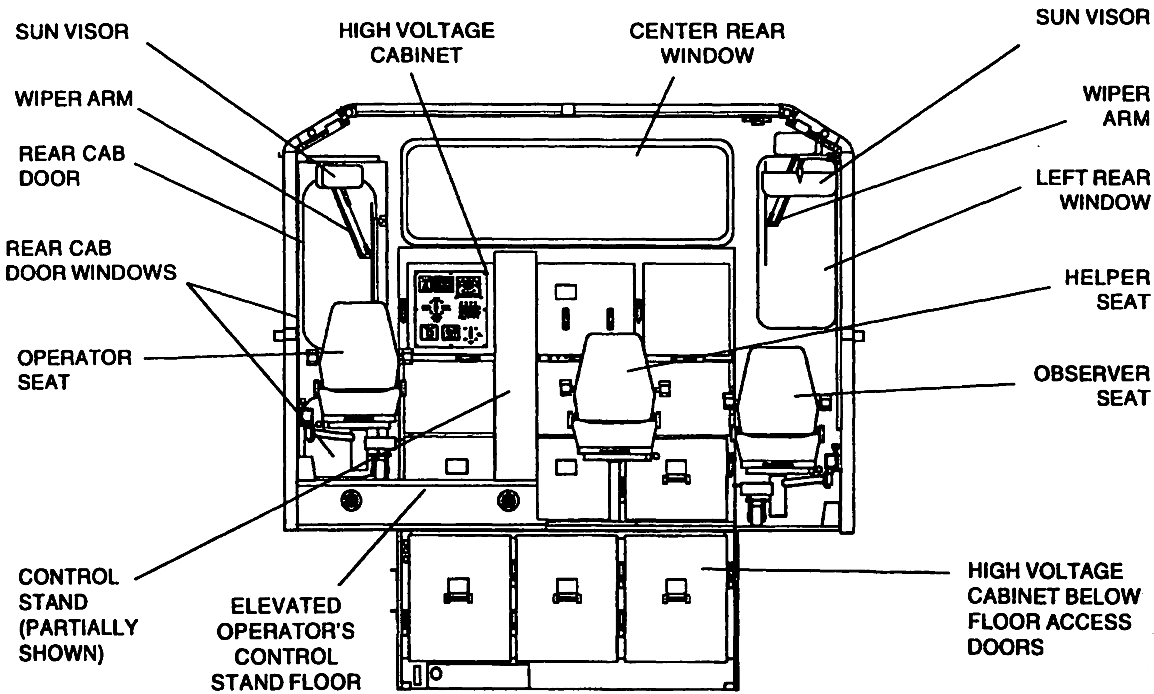
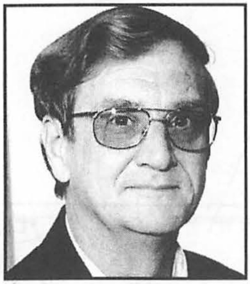


Figure 5

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

MONDAY, SEPTEMBER 20,1999
1:45 P.M.



Chairman
LES WHITE
Senior Reliability Specialist - Electrical
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Pre-Convention Presentation: Southern & Southwestern Rwy. Club

July 16, 1999
Ponte Vedra, FL

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PERSONAL HISTORY

Les White

Les was born in Montreal on Feb. 8, 1949 and began his railway career in June of 1967 as an electrical apprentice. Through his career he has worked many facets such as research and development, main shop repairs, facility maintenance, running repair including freight and passenger service. He is presently working at CN headquarters in Montreal as Senior Reliability Specialist-Electrical.

Les and his wife Lynn have two sons, Stephen and Shawn. His present hobbies are learning guitar and going to his sons Junior AA baseball games.

The LMOA Diesel Electrical Maintenance Committee *wishes to express their sincere gratitude to the Southern and Southwestern Railroad Association for hosting their preconvention presentation at Ponte Vedra, FL in July 1999.*

I. TRANSITION PANELS FOR OLDER LOCOMOTIVES

By Dave Perkins
Montana Rail Link, Inc.

Introduction

Many of the late first generation and early second generation EMD diesel electric locomotives built in the 1950's and 1960's are still on the job today. Some of these locomotives still have their original wiring and components. Others may have had one rewire or upgrade since they were built. As locomotive electrical systems and components age, they tend to lose their reliability, and shop time and repair cost increase. While the railroad industry knows that locomotives would maintain a much higher level of reliability if they were rebuilt or at least rewired every 15 to 20 years, for many reasons including economics, this does not always happen. Due to the extreme high cost of new locomotives and other economic factors, it is obvious that most of the above mentioned locomotives will remain in service for quite some time yet. So, how can railroads make some of these units more reliable with a minimal investment? Simple, install a modern Transition Control Panel (TCP).

Why Upgrade Locomotive Transition?

In a nutshell, locomotives that still have their original transition wiring can usually be upgraded for less money than maintaining the original systems. This is especially true if the existing wiring and components have been a source of unit failure and downtime. Once a new TCP is installed and "debugged", it should be trouble free for years. Here are several other reasons to upgrade to a modern TCP.

First, new solid state and microprocessor technology, that did not exist when these locomotives were first built, allows for many advantages in terms of features, cost savings and simplicity.

Second, the cost of replacement parts (if you can find them) can be quite high. Here is where the law of supply and demand comes into play. Many of the original parts, which are now obsolete, are becoming difficult to find. Once these parts are gone, they are gone for good. Even parts for some of the earlier aftermarket TCP's are over 25 years old and becoming obsolete and scarce.

Third, is the ease of installation. Because of the difficult access location of the OEM transition components and wiring, it is easier to install a new TCP as compared to troubleshooting and maintaining the old system. On many older locomotives the wiring labels are no longer readable, and in some cases the wire insulation becomes so dried and brittle, it virtually falls off if anyone attempts to even move it. Any troubleshooting in old E or EI type transition circuitry can be very time consuming and is often considered a nightmare.

Fourth, new TCP's are becoming quite generic, so one model or type of panel can apply to several models and versions of locomotives. Inventory costs and space requirements are drastically reduced.

Fifth, testing and troubleshooting have now changed from a nightmare to a breeze. With the use of a portable hand held device called a "verifier", checking the unit's operation is simple. The "verifier" is a signal generator that simulates the axle speed and provides the TCP with an input signal so the proper operation can be verified through all stages of both forward and backward transition. All this can be accomplished in minutes as compared to hours needed to set older E and EI transition.

E and EI Transition

Just the plain fact that many locomotives are still running in daily service while still equipped with the OEM E and EI style transition says it is a very proven system. However, it is quite complex and its major components which consists of two or three large relays and quite an array of larger power resistors (up to 1000 watt), take up a lot of room in the electrical cabinet. Futhermore, all these resistors can dissipate large amounts of heat which can build up in the electrical cabinet and reduce the life and reliability of all the other wiring and components in the cabinet. If any major repairs or replacements are performed on this system, then it usually requires the transition system to be recalibrated. These systems are often known to "drift" due to heat, poor resistor tap connections etc.

E and EI transition circuits use the main generator current and or voltage to trigger relays which in turn control the actual contactors that put the locomotive through its stages of transition. Even though E and EI transition systems have lasted many years, many will need major repairs or replacement soon.

Early TCP's

In the mid 1970's, a major change in the way transition was controlled took place. The "Barco" transition control panel was developed. At the time this panel was developed, it was determined that the use of track speed instead of main generator voltage and current could be used as the controlling signal source to trigger the various stages of transition. These units became quite successful and many are still in service today. Barco built approximately 2,500 TCP's between 1977 and 1991. Most of the units built were 3-step units used on GP-9's and similar units. A few hundred TCP's were built in a 9-step version to be used on SD-9's, GP-35's and other similar locomotives.

General Electric and a couple of other smaller specialty vendors also built quite a few TCP's very similar to Barco's during this same

time period.

Installation of any TCP is quite simple. For inputs, they require about 0.5 amp of 74v DC power input and a speed signal source from an axle generator or similar device.

The ouputs are wired for direct connection to control TR, FS1, FS2 & FS3 (if applicable) and WS or OS for overspeed protection.

One person can usually accomplish installation during a normal 8-hour work shift. Usually all of the old components would be removed while the unused wiring could be cut and taped.

Most of the early TCP's had to be ordered specifically for a particular locomotive. The only way to change a transition set point was to send the unit or at least some of the card inserts back to the factory for modifications. Later a new style TCP was developed with many different parameters pre-programmed into it.

A configuration plug would accompany these panels and be attached to the locomotive with a support cable so it would not get lost or mixed up with TCP plugs from other locomotives. These configuration plugs would determine the parameters at which speed the various steps of transition take place. This way, only one model unit could cover the needs of many different locomotives with different transition set points.

Today, many of the early Barco or similar TCP's are now 15 to 25 years old and are approaching the end of their useful and reliable life.

Modern Microprocessor Style TCP's

With the emphasis today on simplification and standardization, various after market manufacturers are looking into and in the process of developing microprocessor style TCP's so they would be a quick bolt-on-retrofit. They also still use a pulse signal from an axle generator to control the stages of transition like earlier TCP's. They will however be field-programmable so that transition settings can be fine tuned on board each locomotive for its specific application.

Some of the many factors to be taken into consideration when fine tuning a TCP are wheel size, gear ratio, topography and grade conditions, type of service and operating speeds. While the difference of just 2 or 3 mph in the transition set points may make little difference in some applications, it may be critical in others. Light duty road switch or yard duty will have little effect. High speed heavy drag mountain grade service, however, is a different story. In this case it is critical this locomotive be run at or near the limits of the locomotive's power curve.

Bach-Simpson 6-9 Step Microprocessor TCP

Currently Montana Rail Link is testing a new 6 through 9 step microprocessor TCP made by Bach-Simpson. This unit is currently on MRL locomotive #406 which is a GP 35 with extended range dynamics used in daily road switching service. The Bach-Simpson unit replaced a 15 to 20 year old GE card type TCP. The particular locomotive was set up with 6 step transition, so we left it that way.

Typical Transition Chart for Barco 6 Step TCP (as installed on MRL 406)

* All actions are instantaneous with

Speed	FSI	FS2	TR	OS
18	ON			
21		ON		
25	ON	ON		
28			ON*	
44	ON		ON	
54		ON	ON	
65			ON	ON

one exception, FS1 and FS2 drop 2.25 seconds after TR picks up.

This particular locomotive is in road switching service 6 days a week. It is usually run in consist with one other GP 35 unit. The two units handle a tonnage of between 1200 tons and 5000 tons. These locomotives climb grades of up to 1.8% for up to 10 continuous miles. They also operate on sections of track with a speed limit of up to 60 mph.

As with any prototype, there were a few "bugs", but I can report that so far it is very successful. All stages of transition are smooth and precise. This unit is field adjustable so deviations from the normal speed settings are very easy to make.

It is Bach-Simpson's hope to have a fully programmable TCP that can handle anywhere from 3 to 9 steps of transition in production very soon.

Conclusion

Once an older locomotive becomes a burden with a constant series of transition troubles, the owner of these locomotives has several options. The first option is simply to keep repairing the existing transition system. The next option is to install an older type, but still current production, TCP. The last option, which should soon be available, is to install a new field programmable microprocessor type TCP. This option should become very popular in the near future due to its universal application and flexiblility in programming.

II. R. S. A. C. CRASH WORTHY EVENT RECORDER UPDATE

by Robert J. Reynolds
Canadian Pacific Railway

This paper will provide an update on the Railway Safety Advisory Committee Event Recorder Working Group. This group was assigned the task of developing requirements for a locomotive crash worthy event recorder. We will be discussing the background of this development, the design discussions and our progress to date.

The Rail Safety Advisory Committee was created by the Federal Railroad Administration in 1997 and is governed with a purpose to:

a. seek agreement on facts and data underlying any real or perceived safety problems;

b. to identify cost effective solutions based on agreed upon facts; and

c. to identify regulatory options where necessary to implement those solutions.

The RSAC will provide advice and recommendations to the FRA. The committee created working groups to study key areas and make recommendations. Areas under study are locomotive cab crash worthiness, cab conditions, positive train separation and event recorder crash worthiness. We will be discussing the event recorder work.

The event recorder working group began meeting in 1997. The group is made up of representatives of the FRA, the NTSB, the AAR, US and Canadian freight railroads, short line railroads, passenger railroads and labor. The challenge of this effort were many:

- What physical force should a recorder be designed to withstand?
- At what temperature should a recorder survive?
- At what level of immersion should a recorder survive?

There are many more questions and much more work to be done. Meetings were held every few months to cover this work.

FRA Rule 229.135 was issued in 1993 to equip locomotives with an event recorder on trains operating faster than 30 mph. At that time the rule specified broad or general characteristics of the event recorder. Those requirements are as follows:

a. that lead units of a consist must be equipped,

b. the minimum parameters to be recorded such as speed, distance, throttle position, direction, air brake operations, dynamic brake operations;

c. the minimum period of time the recorder stores data; and

d. the maintenance intervals.

The requirements did not specify to what degree a recorder must be designed to withstand a railway accident. But to be fair to the FRA, this is an area that has been controversial for a long time. Canadian railways were regulated to equip trains with event recorders in 1987. Transport Canada at the time did not specify the level of protection for the recorder memory. This subject was extensively discussed in the past by recorder vendors and railways. It was always very difficult to decide how much protection was sufficient and at what cost. The original recorder model used on CPR, for example, incorporated ceramic fiber insulation to protect the memory module from fire. Later, the ceramic fiber was found to be carcinogenic and the vendor had to discontinue using it. We applied solid state recorders to our fleet of locomotives in the mid to late eighties. We had very good success with collecting data from various mishaps and even from recorders submerged in up to 30 feet of water. But there were other incidents in the industry where extreme fire destroyed recorders along with their data. This is what prompted the FRA and the NTSB to recommend improvements in fire proofing and the physical strength of recorders.

The following are the areas which were discussed at length at the working group meetings:

a. data elements to be recorded;

b. impact shock and vibration;

c. physical crush and penetration;

d. high temperature caused by fire;

e. fluid immersion and hydrostatic pressure:

f. recorder maintenance;

g. design testing including destructive testing that the recorder must pass in order for a vendor to be a certified recorder supplier.

The discussion on data elements was extensive. There were many ideas for adding a large number of data elements. We tried to focus on the essential information required to help solve the cause of train accidents. The cost of event recorders is proportional to the number of data elements and the associated sensors needed to collect information. As of this date we have added the following inputs to the basic FRA list I mentioned before. These new inputs are as follows:

a. End of train information consisting of battery status, rear BP pressure, communications status, emergency brake, armed status, marker light, valve fail and low air;

b. headlight switch position and auxiliary lights on;

c. automatic brake valve cut-in;

d. locomotive position - leading or trailing;

e. locomotive ID number or road number;

f. standard time zone using Greenwich Mean Time (although real time was on the FRA rule);

g. wheel slip condition for longer than 2 seconds.

The discussion on impact shock and vibration were also extensive. The NTSB had recommended very high levels for these. They were familiar with recorder designs for aircraft and suggested we meet those very stringent requirements. They also showed examples of earlier generation mechanical recorders that had been destroyed in severe mishaps. After much discussion and input from experts in this field we all agreed to a set of standards that will provide superior protection to the memory of an event recorder.

The memory module must survive an impact shock pulse of 193 to 290 G's for a duration of 10 to 15 milliseconds applied in the most damage-vulnerable direction.

Static crush design was another difficult standard to develop. The memory module must withstand a crush of 25,000 lbs. on each side. The location of the memory module on the locomotive was discussed; it will be located behind the collision posts and above the frame of the locomotive. Thus, we have made a quantum leap in memory protection compared to earlier designs. These high standards have created a memory module that could be located separate from the recorder by firstly providing a hardened enclosure and secondly locating it in a safer area. In the event of flying debris during a train mishap, it was necessary to incorporate a penetration protection requirement. The memory module must withstand a penetration on each side using a round cylinder whose surface area is 25% of the area of the side under test.

The specification for fire protection was brought about by researching past studies involving various equipment fires. In the seventies, many studies and destructive testing were conducted on railway tank cars. Information from this work helped to determine the expected temperature of a recorder involved in a locomotive diesel fuel fire. There were two temperature specifications created - high temperature and low temperature. The high temperature requirements calls for the recorder memory module to survive a fire producing a minimum thermal flux of 158 kilowatts per square meter or 50,000 BTU's per square foot per hour. For design testing, the entire external surface area of the memory module shall be exposed to the fire for a continuous period of 60 minutes. The flame temperature should be 1000 degrees Celsius. Shielding is not permitted.

The low temperature requirement is specified by Eurocae standard ED-56A. It is for fires that are lower temperature but last for a longer period compared to the high temperature requirement.

The recorder memory module must survive immersion in various

fluids including diesel fuel, regular and salt water, fire extinguishing agents and lubricating oils and for a period of at least 48 hours. Another requirement is for the memory module to be immersed in salt water, at a nominal temperature of 25 degrees Celsius, and at a pressure of 46.62 pounds per square inch for 48 hours. This is a equivalent to a submerged depth of 100 feet, because the AAR reported that one railroad operated adjacent to salt water with a depth of 100 feet. The AAR reported that only one railroad operates adjacent to a depth of 100 feet of sea water.

Event recorders built under these new requirements shall be painted bright orange.

The maintenance of the event recorder is very important to ensure it is functioning when it is needed most that is, at the time of a mishap or incident. The time interval between maintenace inspections is expected to be longer with the new ruggedized high performance recorder. The discussion in this area has been extensive because the maintenance inspection of this equipment is a burden on all railroads.

The initial planned maintenance interval is one year. If 95% of inspections are successful, the railroad can opt to extend the interval to three years. However, if less than 95% of inspections are successful, the railroad must perform annual inspections until the success rate is more than 95%.

The certification of event recorders requires that the design be tested in accordance with specific test proceedures. The following is a test sequence for the new design:

a. first an impact shock, then
b. a static crush test,
c. a high temperature test,
d. a low temperature test,
e. a fluid immersion test, and then,
f. a hydrostatic test.

The new requirements will result in a very robust and reliable event recorder for recording train operations. The final cost has not been added up to date, but we are a little worried about the bottom line. After all the work to create the requirements for such a device it would be very disturbing if the cost were prohibitive. There will be an effective date for the new recorder to be mandated on new locomotives. It will be far enough in the future to permit vendors to finalize their new designs and gear up for production. There will also be a phase-out period for earlier mechanical memory recorder, possibly as early as the year 2005. This has to be finalized.

A lot of work by many dedicated people went into the preparation of the specifications for a robust, reliable, crashworthy event recorder. We are very confident that the new requirements will create a recorder that will survive any incident encountered on the railroad.

III. TRACTION MOTOR SUSPENSION BEARING TEMPERATURE MONITORING SYSTEM

by Ron Bartels,
VIA Rail Canada

1. Introduction

The purposes of this paper are:

a. to present the new bearing temperature monitoring module VIA developed in cooperation with CNTC (Centre national du transport en commun, inc.) and why it was developed.

b. To give an appreciation of the scope and cost of installing a complete suspension bearing temperature monitoring system in a locomotive; and

c. to explain what actions VIA will take in the future regarding these systems.

First of all it is important to understand why a railroad would go to the expense of monitoring bearing temperatures. The answer is straightforward: to prevent deadly and costly derailments due to broken axles that are caused by overheated bearings. VIA strongly believes in bearing temperature monitoring because there are documented cases in which the monitoring system detected overheated bearings and prevented potentially catastrophic accidents.

1.1 VIA'S HISTORY OF BEARING TEMPERATURE MONITORING

Although VIA strongly believes in monitoring bearing temperatures, this safely feature did not come without its problems. In 1980, VIA started operating with on-board bearing temperature monitoring on LRC (Light, Rapid and Comfortable) trains, built by Bombardier. The wayside hot box detection technology at the time was inadequate at 100 MPH. On top of that shortcoming, the inboard journal bearings on LRC cars and the traction motor suspension bearings were, and still are, not monitored by wayside detectors.

With the on-board monitoring system that came with the trains, an unreliable "thermal fuse" technology was used at first for the sensors. The principle was simple. The circuit opened when the fuse reached a given temperature, much like a regular circuit protection fuse. This type of technology had two major weaknesses:

1. There were intermittent contact problems, which would translate into false hot bearing indications; and

2. There was no protection for a bearing if short circuit fault occurred somewhere in the circuit of a sensor and also no way of knowing, unless the sensor was unplugged.

In 1984 VIA switched to thermistor-based sensors. The resistance of thermistors varies inversely with temperature. These sensors gave an actual indication of the temperature and solved the two main problems of the thermal fuse sensors. The intermittent contact problems disappeared and short and open sensor circuits could be detected as an out-of-range temperature. To interpret the information provided by the sensors, new control boxes were designed. Once the control boxes and sensors were ready, VIA modified the entire fleet of LRC trains (at the time they were the only equipment with bearing temperature monitoring) with the new systems. Even after spending the money on improving the system, it still caused many false alarms and consequently both maintenance and operating employees doubted the reliability of the system.

1.2 VIA's Fleet equipped with Bearing Temperature Monitoring (March, 1999):

Currently, VIA operates the following equipment with bearing temperature monitoring:

- 98 LRC cars with 8 inboard wheel bearings monitored;
- 7 LRC cars with 8 suspension bearings and 8 wheel bearings monitored;
- 58 F40PH-2D locomotives with 8 suspension bearings monitored;
- and, by the end of 1999, 7 rebuilt F7 locomotives will have been retrofitted with a monitoring system with 8 suspension bearings monitored.

1.3 Maintenance Costs

The monitoring system as a whole does have maintenance costs associated with it. In a 12-month period, it costs $150,000 CAD (Canadian dollars) in material only, to monitor 1120 bearing positions. This works out to an average of $134 CAD per bearing being monitored. (Although VIA currently has more than 1120 bearings being monitored, the cost information is valid for a period of time when there were only 28 F40PH-2D locomotives equipped with the system.) It includes sensors and system specific cables, which are replaced with new only, and control boxes, which are occasionally purchased new to replenish stocks but are usually repaired. Over half of the cost is for replacement temperature sensors. The cost does not include labor and miscellaneous shop materials that are required for scheduled and unscheduled maintenance.

1.4 Objectives

Given the above-mentioned weak points of the monitoring system, as it exists at VIA, and the importance of the system as an accident prevention tool, improvements had to be made. The following objectives were established:

a. **Increase Safety.** We need to know that the bearings are being monitored accurately at all times and we need to know, for whatever reason, when they are not being monitored.

b. **Reduce or Eliminate UnnecessaryTrain Delays.** Train delays that are caused by the monitoring system occur due to equipment failure. The system must become immune to the spurious signals and be more reliable.

c. **Reduce Maintenance Costs.** The failure and repair and/or replacement cost in case of failure of the sensors, control boxes, and system specific cables are too high and must be reduced. We also have to reduce the need to take corrective action due to false alarms, which is labor-intensive and can be very time-consuming.

1.5 Actions Taken to Reach the Objectives

In the past two years, in order to help meet VIA's objectives with respect to the suspension bearing monitoring system, improvements were made in three areas on the F40PH-2D locomotives.

a. Sensor Application and wiring on traction motors: we changed the junction box design and the method of supporting and routing the sensor cables. The goal was to have fewer cable and connector failures which would lead to more reliable monitoring, fewer train delays, and fewer repairs. We already experienced the benefits of these improvements in the winter of 1998/99, during which we did not have to set off any equipment due to system failure. This is significant because it is a first for VIA. Another improvement that is currently under test is an upgraded version of the cable that links the sensor signals from the traction motor mounted junction box to the carbody wiring. It runs along the traction motor leads and is therefore exposed to debris and ice build-up. This new cable, athough actually more expensive than the previous version, is less susceptible to mechanical damage and should reduce on-line failures, train delays, and overall repair costs.

b. Suspension Bearing Temperature sensors: we updated our purchase specifications for the temperature sensors to reflect what we were actually buying and went out for quotations. The aim was to reduce the replacement cost of the sensors. The result was a 25% cost saving with the same performance.

c. Redesigned bearing monitoring module: In 1997, VIA contracted CNTC to design a new bearing monitoring module to VIA's requirements. The main purposes of having a newly designed module were: to improve the reliability of the information received from the module and of the module itself; to increase the amount of information available for diagnostics; to reduce repair costs; and to have the ablility to link up to a train monitoring and control network.

As of June, 1998, there were 35 new modules in service, in various levels of configuration. So far, they have proven to be very useful as a troubleshooting tool, when a well-trained person analyzes the alarm log. On the other hand, it is also one of the first microprocessor-based systems with diagnostics at VIA, so there have been some growing pains in encouraging the maintenance personnel to use all the available information. The new module and the system installation are the focus of the rest of this paper.

2. New Bearing Monitoring Module

The new monitoring module's features will be described in four categories: external features, hardware design, operational features, and software troubleshooting tools.

2.1 External Features

Figure 1 shows the faceplate of the new module. The most evident visual highlight is the vacuum fluorescent display. It displays the temperature of each bearing individually, in English and French, as well as any failure mode that exists.

Beside the display are the UP and DOWN buttons, that allow the operator to scroll through all the active alarms. The CLEAR button on the other side of the display erases the inactive alarm that is being displayed. The MAINTANANCE REQUIRED LED below display lights up blue whenever the module had detected a problem anywhere in the temperature monitoring system.

The center section of the faceplate contains 8 temperature sensor LED's, one for each suspension bearing temperature sensor of a 4-axle locomotive. Each one of these LED's is always illuminated and can display three different colors: green when the sensor circuit shows no defects and the associated bearing temperature is below 102°C; yellow when the temperature of the bearing is between 102°C and 121°C, or if the sensor circuit is shorted or open; and red when a bearing temperature exceeds 121°C.

On the bottom right is the self-test button which checks each sensor status and brings up its temperature on the display. It also toggles the two outputs to which the warning and danger relays are connected and checks for the proper feedback.

To the left of the self-test button is the network reset button, which has no impact during stand-alone (or non-network) operation.

Further to the left is the download/upload connector, which is used for downloading the alarm log and loading new software. When the train network is in place, plugging into this connector will also allow communication with any control/monitoring module linked to the network. The three LED's to the left of the connector only operate when the network is connected and communicating.

One feature that is not visible from the front of the module is the single connector used for power and all input and outputs. This allows for quick module changeout if it is ever required.

2.2 Hardware Design

In order to have all the diagnostic and operating features that VIA required, the new module had to be microprocessor-based. One of the microprocessor's main function is to monitor eight temperature sensor channels, one for each suspension bearing position. (Although this paper deals with traction motor suspension bearing temperature monitoring, the module was initially designed for and is also used on LRC passenger cars to monitor their inboard wheel bearings.)

The module has two inputs to continuously monitor the continuity of the "warning" and "danger" trainlines. (The meanings of "warning" and "danger" are explained in item 2.3). These two trainlines are functional in all cars and locomotives (except the rebuilt F7 locomotives, which have no communications trainline) that are equipped with bearing monitoring. They are fed with 72 volts DC at the rear of the last vehicle that is equipped with monitoring. A relay contact in each equipped vehicle maintains continuity of these trainlines to the head end of the train when there is no alarm. The system is fail-safe. The contact in each vehicle is a normally open type. A failure in the system will cause the relay to drop out. The trainline discontinuity will send a signal to the engineer of the lead locomotive on the locomotive warning panel. The module monitors these trainlines and displays an alarm only if the defect is local to the vehicle.

The first series of modules that was installed was not capable of standing up to the sometimes unfriendly electrical environment on board locomotives, so some hardware improvements were made. Power supply input/output isolation was added because certain combinations of low voltage grounds damaged some early modules. Transient and surge protection were also improved during the redesign. These changes affect one of the two printed circuit boards inside the module. Future modules will come with the improvements and earlier models will be retrofitted.

An important feature of the new module is the fact that it is designed to operate as a stand-alone module and it is also network compatible. The advantage is that, although it is designed for network use, we can install it now and benefit from all the operational and diagnostic features of the module. Once the train network is complete, we only have to connect two wires to be able to benefit from the additional advantages of the centralized information and remote communications capabilities that the network will bring.

2.3 Operation

The main purpose of the module is to detect bearing temperature abnormalities and to alert the operating crew of the train. It controls the display of bearing WARNING alarms, which make the LED at the affected bearing or circuit light up yellow. WARNING alarms are defined as a bearing temperature that is greater or equal to 102°C, a short or open sensor circuit, or an internal defect that prevents the module from monitoring bearing temperatures. It also controls the display of bearing DANGER alarms, which make the LED at the affected bearing or circuit light up red. DANGER alarms are defined as a bearing temperature that is greater than 121°C.

The module was designed to be as fail-safe as possible. A safety feature that was not present on the previous generation of control boxes is that the new module energizes two external relays, one for WARNING alarms and one for DANGER alarms. The relays must be energized to prevent an alarm from occurring. If there is a loss of power or the module is disconnected, there will be an alarm.

The module has extensive diagnostic capabilities. It continuously monitors the temperature sensor power supply and will post a WARNING alarm if it is unable to measure sensor temperatures. It monitors the status of the relays that it controls through feedback contacts and also checks for open or shorted relay coils. It detects open or shorted sensor circuits, as well as checking for grounds in the sensor circuits. One ground is not a problem because the power supply is isolated from the input, but a second one would falsify temperature readings or cause a short circuit. A ground does not post an alarm, but will light up the MAINTENANCE REQUIRED LED. Any anomaly detected by the module, including WARNING and DANGER alarms, is registered in the alarm log, which is capable of storing about 800 records.

2.4 Software Troubleshooting Tools

There are various levels of troubleshooting aids available from the new module when a portable computer is connected to it. The first one is the alarm log itself, which gives the type of defect, the time and date, duration, and a troubleshooting process.

Going one step further, to the debug screen, Figure 2, allows you to view all the information shown on the faceplate of the module, as well as real times status of each sensor and WARNING and DANGER trainline status. This screen also gives the ability to toggle the relays controlled by the module and check for the proper feedbacks. Time and date adjustments are also made on this screen.

In the case of a bearing temperature fault, the history of the bearing temperature can be viewed on the bearing temperature screen, shown in Figure 3. The module stores the bearing temperatures when either a WARNING or DANGER alarm due to temperature is posted, for 100 minutes before and after the event. The temperature trend versus time can indicate if there is a problem with a true overheated bearing, which shows up as a curve that rises steadily, or a circuit or sensor problem, which would show erratic readings.

3. Advantages

The new modules offers numerous advantages to both the Maintenance and Transportation departments.

3.1 Maintenance Department Advantages

Once all the hardware improvements are retrofitted, the new module should prove itself to be more reliable than the previous control box, at much less than 50% of the replacement cost. It should also be inexpensive to repair because it uses easily available industry standards components.

The module is easy to use as a troubleshooting tool. It monitors the whole system, not just itself. The MAINTENANCE REQUIRED LED simplifies the task: If the LED is not lit, the system is working as intended. If there is a problem, the Up/Down keys allow easy scrolling through all the active defects on the display and the alarm log lists all the faults, with the help of a portable computer. The troubleshooting guide also speeds up the process by telling the maintenance personnel where to look first.

3.2 Transportation Department Advantages

The electrically robust design of the module with its expected high reliability is also a plus for the Transportation department. It will mean fewer service interruptions. The alarm messages are shown directly on the display, which is located in front of the locomotive engineer. This, plus the fact that there is an LED for each bearing to identify a defective one, provide as clear information as possible to the operating crews, to prevent them from verifying the wrong bearing position if an alarm occurs.

False messages to the crews will also be reduced, compared to the previous control box, again reducing service interruptions. Temperature readings are filtered before they are displayed and a fault must exist for one minute before the module posts an alarm.

4. Installation

The scope and cost of a typical 4-axle locomotive installation are described below.

4.1 Installation Scope

Installing a complete suspension bearing temperature monitoring system requires making changes to the traction motors, bottom deck, short hood, and cab.

4.1.1 Traction Motors

To receive the temperature sensors, the traction motor axle bores have to be drilled at the commutator and pinion ends to a precise depth with respect to the axle centerline, and a threaded bushing is welded on top of each hole. Sensor cable support studs are welded along the edge of the frame at the axle bore. A bracket and junction box assembly, with two receptacles, one for each sensor, is bolted on top of the cable cleat assembly, making longer cleat support bolts necessary. A 4-conductor cable is spliced to the receptacles in the junction box and is clamped to the traction motor leads. (The other of this cable later plugs into a 4-pin receptacle mounted on a junction box on the underframe of the locomotive.) The sensors are then screwed into the threaded bushings, connected to the junction box receptacles, clamped to the bracket near the junction box, and clamped to the support studs.

4.1.2 Bottom Deck

Near each traditional motor cable cleat location on the underframe, a small junction box with a 4-pin receptacle is applied. Two larger junction boxes are applied, one front and one rear, near the two small ones from each truck. New conduit is run from the rear larger junction box to the front larger junction box, between the smaller junction boxes and the larger ones, and from the larger front junction box into the short hood. We used flexible polyamide tubing for ease of installation, with rigid conduit only where we had to pass through the locomotive frame. Twisted pair cables bring all the sensor signals to the short hood. Inside the four small junction boxes, where the only underframe wire connections are made, there are no terminal boards. All connections are made with environmentally sealed splices to eliminate moisture and corrosion problems.

4.1.3 Short Hood and Cab

Two relays have to be added in a protected location in the short hood, along with a terminal board. In some locomotives types, a housing or support for the module will also be needed, if it cannot be installed in the overhead console. One red and one yellow indicating light, for DANGER and WARNING alarms respectively, are applied within clear view of the locomotive engineer. Finally, the

module is installed and a prefabricated wire harness is connected to the new and existing locomotive wiring and plugged into the module. Note that this installation information applies to an application with no WARNING and DANGER communications trainlines, such as a freight locomotive or VIA's rebuilt F7's. For the complete trainlined installation, two more relays, 11 diodes, and considerably more wiring is required in the cab, short hood, and electrical cabinet.

4.2 Installation Cost

All figures are in Canadian dollars (CAD).

The traction motor frame preparation costs $450 per motor. Preparing and installing the traction motor bracket, harness, and sensors requires 6 person-hours and $650 of material per motor. The motors were removed and prepared on the bench. We found this to be more efficient and the labor hours take this into account.

The bottom deck, short hood, and cab installation requires 80 person-hours and $2,750 of material. This includes a housing for the module because in the particular application, the module could not be mounted in the overhead console.

Material and labor costs for the traction motor work are proportional to the number of traction motors. For the remainder of the work, it would be higher for a 6-axle locomotive, but not proportionally higher.

It is important to note that the module is not included in these costs. It will vary considerably based on the number of bearings monitored, special features, and quantities purchased.

5. The Future of Bearing Temperature Detection at VIA

Some system improvements still have to be made. The stainless steel braid jacket of the 4-conductor cable on each traction motor breaks easily and sometimes pierces the cable jacket and wire insulation. We have a new type of cable on test on our rebuilt F7 locomotives that is better protected and should last longer, without the disadvantages of the stainless steel braid jacket. With it, we expect to increase reliability and reduce failure-related delays.

We are in the process of reviewing our temperature sensor design. A few sensors have failed due to moisture problems and we are working with the supplier to correct the problem. At the same time some other subtle improvements are being made to increase the life of the sensors.

By far the factor that will have the biggest impact on the monitoring system, and how VIA performs maintenance in the future, is the implementation of a train network with remote communications and GPS capabilities. It will allow us to monitor and download any networked module on the entire train locally, from any other networked module on the train, or from a remote location. We will also be able to remotely download the locomotive event recorder. The GPS will give us the ability to track our trains and also provide a location stamp to any faults that may occur.

The network will include other control and monitoring systems. On locomotives that have no microprocessor control systems, the traction and dynamic brake systems will be monitored. There will also be a module to control engine cooling and loading of the air compressor. On passenger cars, there will be control modules for the heating, ventilation, and air conditioning system, door controls, and toilets, and a monitoring system for the air brakes. Although all of these systems will be connected via the network, all control and monitoring will be local and the network will be used only for sharing, and making easily available, information on all the train's monitored and controlled systems.

With all of this information, we will be able to prepare corrective actions for equipment failures before the train reaches a maintenance center and reduce out-of-service time. Eventually, we will monitor trains from the Operations Center. This will help Transportation personnel make well-informed decisions regarding train operations.

6. Conclusion

VIA has had a long history of unreliable bearing temperature monitoring. Several changes to the system have already been made to improve reliability, including some sensor and cabling improvements.

The change with the biggest impact is the new microprocessor-based monitoring module, which VIA developed with CNTC. It has extensive diagnostics capabilities and intelligent internal software to reduce false alarms, and can be linked to VIA's future train communications network. Compared to previous models, it is much less expensive and it has a robust design to give it a long reliable life.

There are still some hardware improvements to make, particularly in the cabinets and sensors and in their application, but these changes are already underway.

The train network with remote communications capabilities will also have a great impact in the future, not only on the bearing monitoring system but also on how the trains will be operated and maintained. Both the Transportation and Maintenance departments will have better and earlier information to help make informed decisions, and provide a faster turn-around of equipment.

Acknowledgements

This paper could not have been written without the help of William Barclay, Martin Gendron, and Andrè Milot of VIA Rail's Equipment Maintenance Technical Services department.

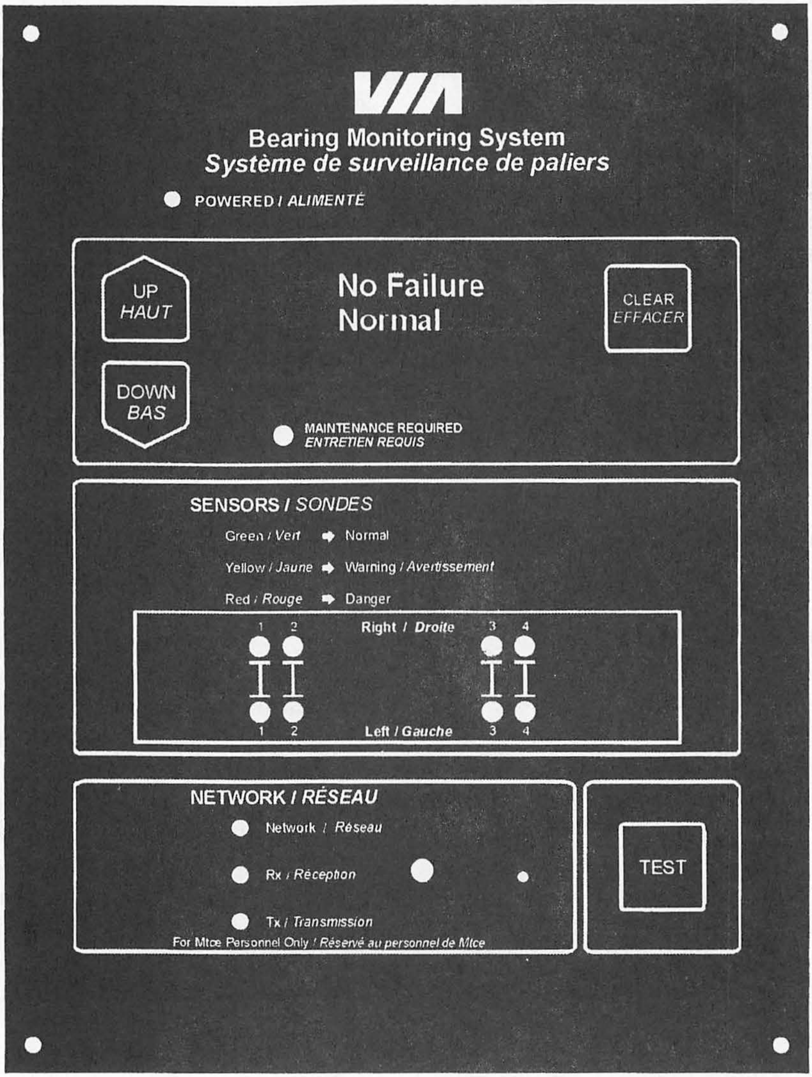


Figure 1 - Module Faceplate

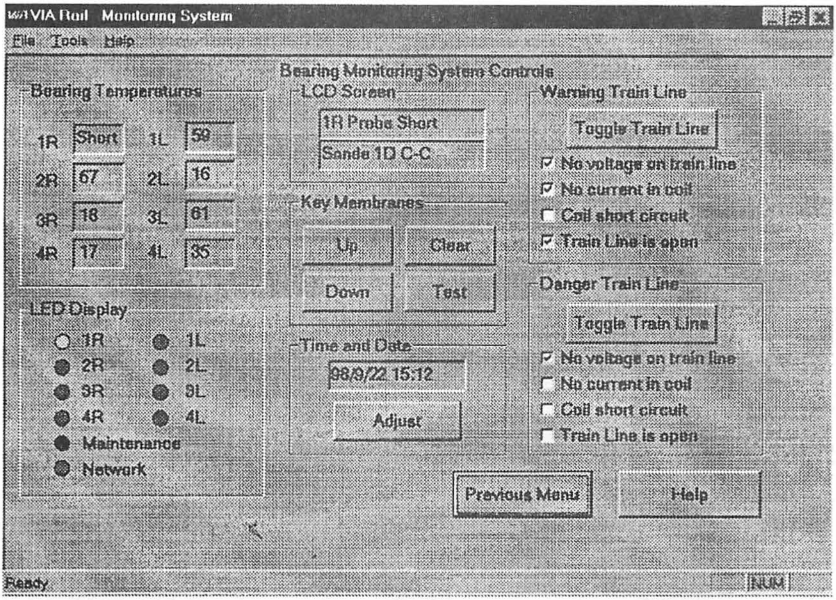


Figure 2 - Debug Screen

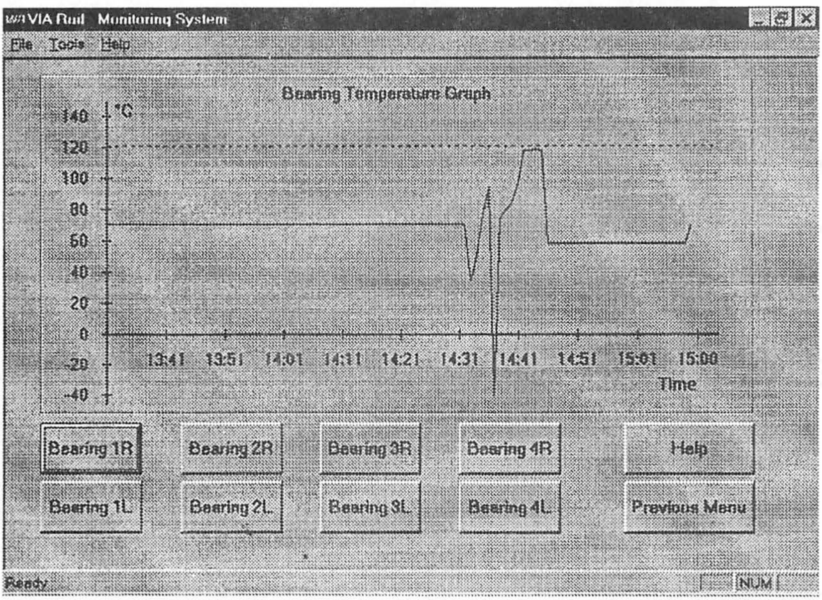
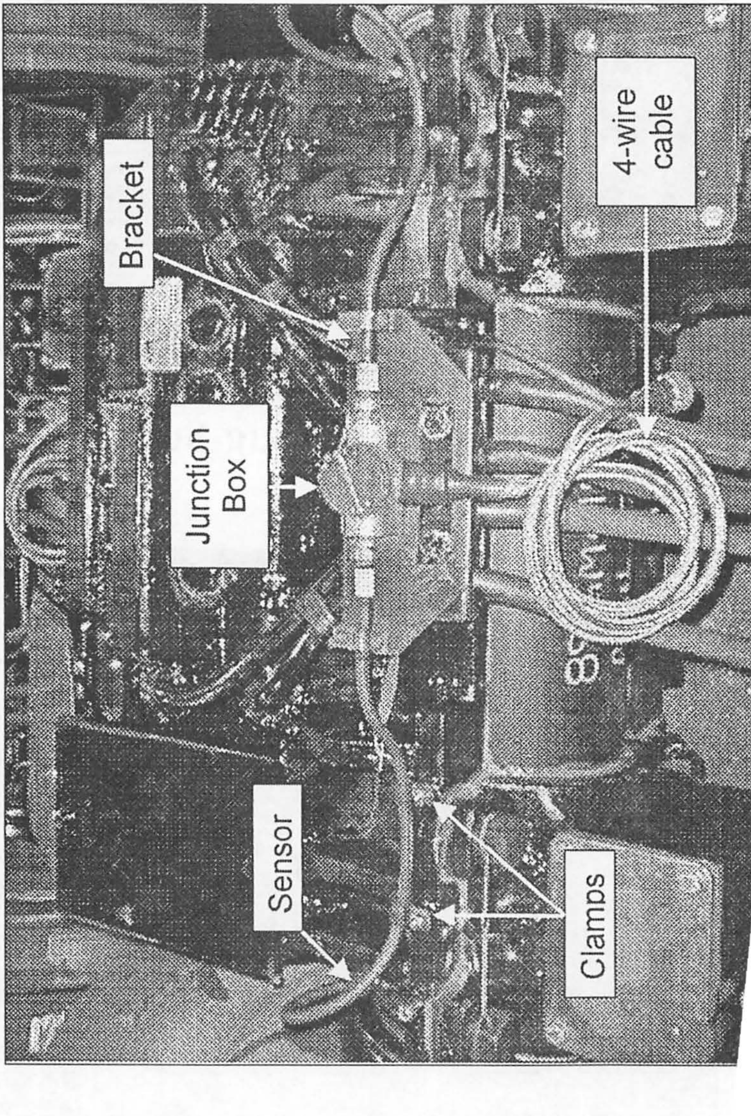


Figure 3 - Temperature Screen

Figure 4 - Traction Motor Installation

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IV. EMD SD90MAC 6000 HP LOCOMOTIVE - AN UPDATE

by Dean A. Becker
Electro-Motive Division
General Motors Corporation

The SD90MAC locomotive is EMD's latest high-performance locomotive which offers the railroad industry both high horsepower and high tractive effort. While these characteristics are important in terms of unit reduction and train dispatching, there are other aspects of the SD90MAC which have focused on maintenance and improved reliability. These items are not apparent in a photograph or on a spec sheet, but are equally important to railroads. This paper will describe the SD90MAC locomotive and focus on many of these innovations.

Overview

The SD90MAC locomotive is a culmination of many years of effort toward development of a new model. As shown in Figure 1, the SD90MAC locomotive is considered to be a "platform" locomotive, specifically developed to be the basis for all new high horsepower mainline models to come. At the center of this locomotive is EMD's new 6000 horsepower "H" engine. In conjunction with this high horsepower engine is an AC traction control system and TA20 traction alternator which work together to deliver up to 200,000 lbs of tractive effort (170,000 lbs continuous). Moreover, a high capacity dynamic brake system (115,000 lbs brake effort / 5500 kW) is provided to complement the high tractive effort. Notable here is the location of the grids at the rear of the locomotive, reducing the grid blower noise conducted into the cab and helping to retain the locomotive balance. The cab is the latest isolated cab; the EMD WhisperCab. The standard air compressor is a three cylinder unit, shaft-driven from the engine, although a motor-driven compressor can be provided as an option. Underneath the locomotive are two radial trucks equipped with AC traction motors and a newly designed fuel tank developed to be integral to the locomotive structure. Beyond the major equipment are a variety of auxilliary systems, which incidentally make increasing use of electrical technologies. A systems design approach was used when addressing auxiliary systems which has led to simple, efficient designs. EMD has given special focus to the maintainability of this locomotive model. Targeted for 122-day maintenance intervals, this offering has used the best of our design expertise and field experience to provide exceptionally long maintenance intervals. Figure 2 shows, among other details, principal maintenance access points of the locomotive. In large measure, major maintenance access points for the SD90MAC are much the same as before, with some rather minor variations. We have retained the concept of modular, removable roof hatches for easy maintenance. These include the inertial filter hatch, the turbo and generator hatch, the engine hatch, and the fan and radiator hatch. The last hatch is for the dynamic brake system. This unit is a modular but non-removable section of the carbody. This part of the long hood is permanently attached for structural purposes and to maintain the integrity of the sand boxes.

"H" Engine

At the heart of the locomotive is our new engine (Figure 3) which was designed specifically for locomotive application. This power plant carries a new designation, 16V265H, which is in keeping with the accepted metric system of the engine definition. The 16 refers to the number of cylinders, the "V" designates the cylinder arrangement, in this case a 45° Vee, the 265 is the cylinder bore in millimeters and the "H" is the EMD series designation. (The displacement criteria, in familiar units, is 1010 cubic inches per cylinder.) This engine develops 6300 brake horsepower with 6000 horsepower available for traction.

The "H" engine uses an EUI control system. This is an enabling technology which permits EMD to address the imminent governmental emission standards as well as achieve improved fuel economy. In addition, the EUI system has led to simpler maintenance practices since the engine is now easier to trouble shoot.

On the issue of periodic engine maintenance, the average shop hours will be less for this engine than comparable 710 engine (based on regular maintenance instructions). The periodic maintenance interval goal for this engine is 122 days, in support of our customers' desire to extend maintenance intervals. The major overhaul periods are new to this engine, as well. EMD has designed this engine to operate 6 years between major overhauls or 41,500 Megawatt hours.

Engine Support systems

The engine cooling system has taken great strides towards simplicity and reliablity. When used with the "H" engine, the cooling system can run with a water/anti-freeze mixture. This coolant uses a propylene glycol additive and there is no need for a separate rust inhibitor. Some of the benefits available with this change go beyond not having to worry about engine freeze. Some traditional equipment is now eliminated yielding a simpler system. For instance, there is no need for automatic drain valves and some of the shutters have been removed. Cooling fans have also become simpler. EMD has developed a more efficient two-speed fan operation that requires just two cooling fans. When this is implemented with a multi-winding motor, the number of fan contactors drops from 9 to 4. Along with 52 inch fans, the radiator area is greatly increased.

Some of the reason for the bigger radiators is not so much cooling, but to reduce engine emissions, as part of this radiator system is devoted to engine aftercooling. This, in conjunction with larger engine-mounted aftercoolers, yields a significant reduction in engine charge-air temperature, and thus the lower emissions to meet the new federal mandates for locomotive engines. Finally, electrical connections for the cooling fans have been simplified. As seen in Figure 4, flexible conduits and plugs allow for quick application.

The engine-driven primary fuel pump is another new feature for the SM90MAC. There is a priming pump that is electrically driven, but the main fuel pump is mechanical to better match fuel flow to engine speed. This will yield a longer life pump and will help reduce parasitic loads on the engine. The engine intake engine air filter is located similarly to older models. Our goal for replacement of this filter was to achieve a "no tools" method of change-out, with easy access also provided to new door-mounted inertial filters. Finally, notably absent on the SD90MAC is the traditional inertial filter compartment. Inertial filtering is still used for the engine air supply (and for filtered air to the inverter). The resulting filtration system is both simpler and easier to maintain.

Engine starting is also different. On the SD90MAC, an air-only start system is used. A dedicated air reservoir is present for this function so that if locomotive air is depleting, engine start can still be accomplished. Since electrical starting is not present, the capacity (and size) of the locomotive batteries has been reduced. The two 325 AH batteries are easier to handle when service is required.

Relative to the lube oil system, the locomotive now performs the pre-lube function as standard equipment. Controlled by the EM 2000 control computer, the pump is also used for post-lube immediately following engine shutdown.

Traction Systems

As far as traction systems are concerned, most of the AC electronic equipment remains unchanged. The traction converter cabinet (TCC), located directly behind the cab, has undergone some minor, but practical changes. A single speed motor is used to drive the TCC blower. A number of relays and contactors have been eliminated. Other TCC contactors have been relocated to the electrical control cabinet. To simplify maintenance, an emphasis was placed on quick-release covers for ease of access, and where practical, captive fasteners are used.

As with all AC traction motors, there are few maintenance parts. To continue this trend, EMD has developed a traction motor temperature simulation algorithm. Actually, the process used with EMD's DC traction motors has been expanded to include AC traction motors. The locomotive control computer (EM2000) computes a stator temperature value for each AC traction motor based upon several electrical feedback signals and the characteristics of the AC traction motors. Ultimately, this action allows the traction motors to be built without any temperature probes.

The dynamic brake system, now located in the back of the locomotive, has been developed in order to maximize the accessibility of components for ease of maintenance. The overall design is unchanged although components have been sized to support the larger 5 1/2 megawatt rating.

Auxiliary Electrical Systems

Many changes have been made to the auxiliary electrical systems. In addition to reducing the level of the auxiliary loads on the engine, maintainability has improved by making these systems simpler. There is less equipment. Remaining hardware has been made smaller and easier to handle. To illustrate this, the SD90MAC now uses three DIO modules (interface module between the 74V circuitry and the EM2000 computer) instead of four DIO modules.

The SD90MAC locomotive uses two motor-driven traction motor blowers. These blowers deliver a large volume of air while using very little power. The design has improved to the point where it now makes sense to run them full time. Contractors are no longer used. Furthermore, by using single-speed motors, the size has been reduced. Accordingly, the auxiliary loading has dropped while the resulting system is simpler.

As another step towards simplification, EMD has used the same motor/blower in multiple applications. For example, two blowers are used to provide traction motor air while a third unit provides air for the traction alternator. Also, the same motor/blower which is used for inertial filtering is used to provide the filtered TCC cooling air.

The auxiliary generator, a standard rotating machine in previous EMD locomotives, is now gone. So, too, is the DVR. Replacing them is a solid-state auxiliary power converter (APC), located behind the cab and part of the long hood. The APC (Figure 5) is rated at 30 kW for auxiliary loads, a performance upgrade from earlier 24 kW aux gens. The APC receives its power from the companion alternator. This new system is not only simpler than its predecessors, it is now maintenance-free.

Cab Structure

The traditional EMD WhisperCab™ has undergone some changes for maintenance improvements, albeit these are of a minor nature. The number boards have become fiber-optic driven, for reliability and increased brightness. Two independent light assemblies are provided for the sake of redundancy. Sand box access has changed - the fills are lowered so that sanding can be performed from the walkway in both the front and back of the locomotive. Inside the toilet area, fiberglass interior panels are used to make cleaning of the area easier.

Electrical Control and Display System

A relatively new feature on EMD locomotives is *FIRE*™ (Functionally Integrated Railroad Electronics), which is used in conjuntion with our standard EM2000 locomotive control computer. EMD has developed this system for integration of third-party cab and support electronics. The real power *FIRE*™ lies in its PC-based networked computer/display system (see Figures 6 and 7) and the integration lab which support this system. A networked system provides greater processing power, eliminates the reliance on one central computer and accommodates multi-tasking of functions. With the open architecture of *FIRE*™ and the utilization of the AAR LSI standard communications protocol, EMD is able to integrate third party functions at the software level. This means that the locomotive will provide all the functionality without the need for separate black boxes, processors and additional connections between systems. This greatly reduces the repair and maintenance for these added cab functions.

The *FIRE*™ system will include a multitude of locomotive functions. Some have been developed by EMD while others are implementations of vendor systems. In these cases, the vendor provides the software and specialty hardware (actuators, transducers, etc.). EMD integrates the function into the locomotive using the *FIRE*™ system. Examples of present and future functions are:

- Electrical Air Brakes
- ECP Brakes
- Distributed Power
- Head of Train Device
- End of Train Device
- Locomotive Control Computer (EM 2000)
- Cab Signals
- Global Positioning System
- Rail Navigation
- Fuel Gauge & Fuel Monitoring
- Mobile Communication
- Alertor
- Event Recording
- Remote Speed Indication

An important aspect of the FIRE™ system is that it represents feedback obtained directly from the customers. Shop workers as well as locomotive operators provided useful information to make the system "user friendly". For example, consistency of information (regardless of the source) was one request.

Our *Intergration Lab (I-Lab)* offers a unique cab electronics test setting. *I-Lab* consists of a full set of every cab electronics system applied to our AC locomotives today. This provides us the ability to test all cab electronics software simultaneously for proper communications as well as functionality. In this way, every cab electronics configuration can be qualified in the lab prior to production and field application, ultilmately providing higher reliability and thus greater locomotive availability. *FIRE*™ combined with *I-Lab* is just the latest example of EMD's commitment to reliability.

Conclusion

The SD90MAC locomotive offers a big jump in locomotive performance and provides it in a simpler package. EMD considers this locomotive to be the most maintainable model we have built to date. Furthermore, EMD has high hopes for this product and trusts that as customers become familiar with the SD90MAC, they'll find even more new and innovative ideas to apply to this product to best focus it for their specific needs. Indeed, we are already working with our customers to explore the many possibilities of this new design.

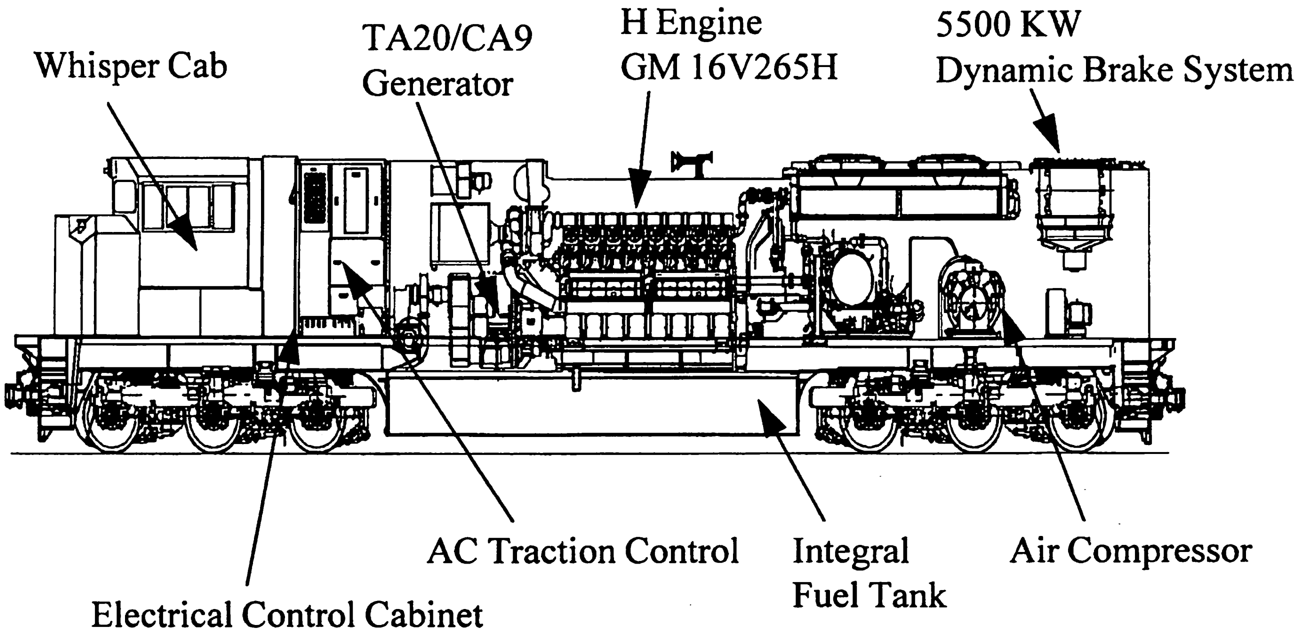


Figure 1 SD90MAC Platform Overview

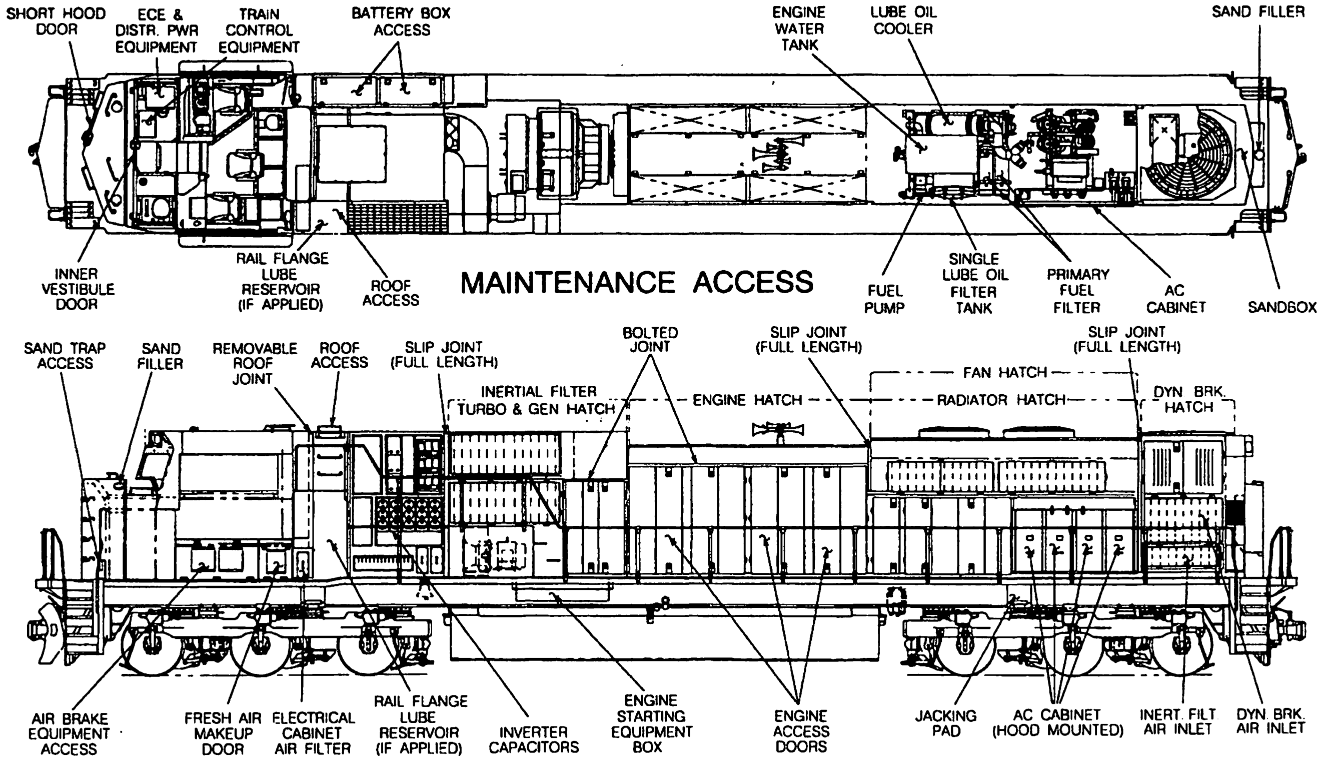


Figure 2 Maintenance Access

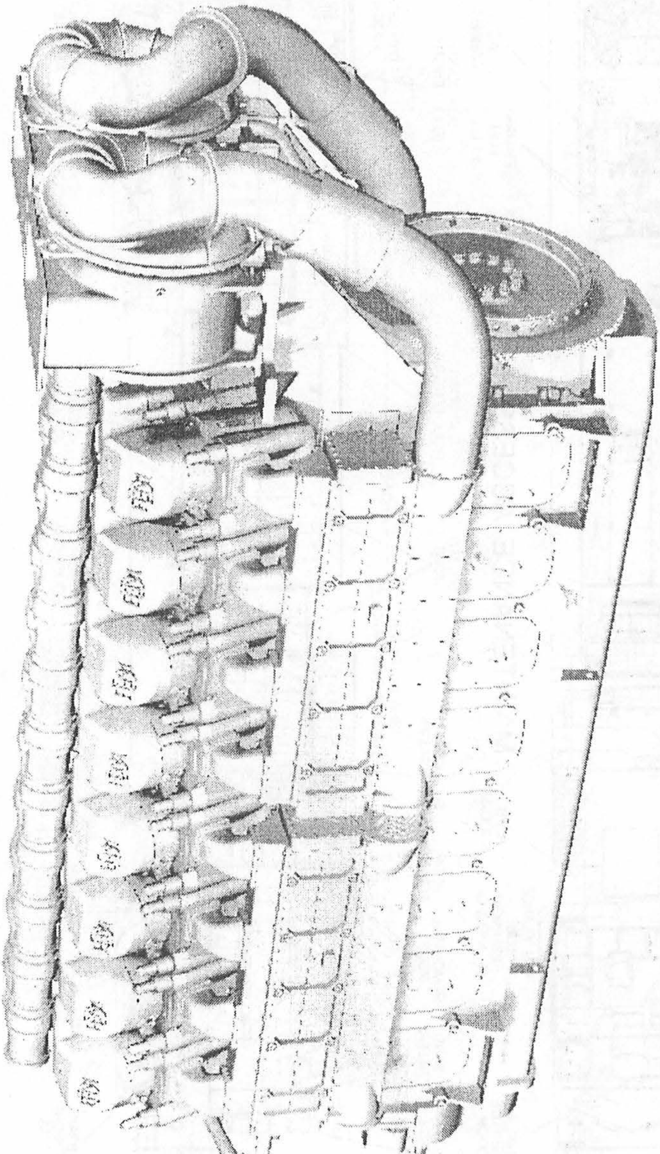


Figure 3 GMV265H 16 Cylinder Engine

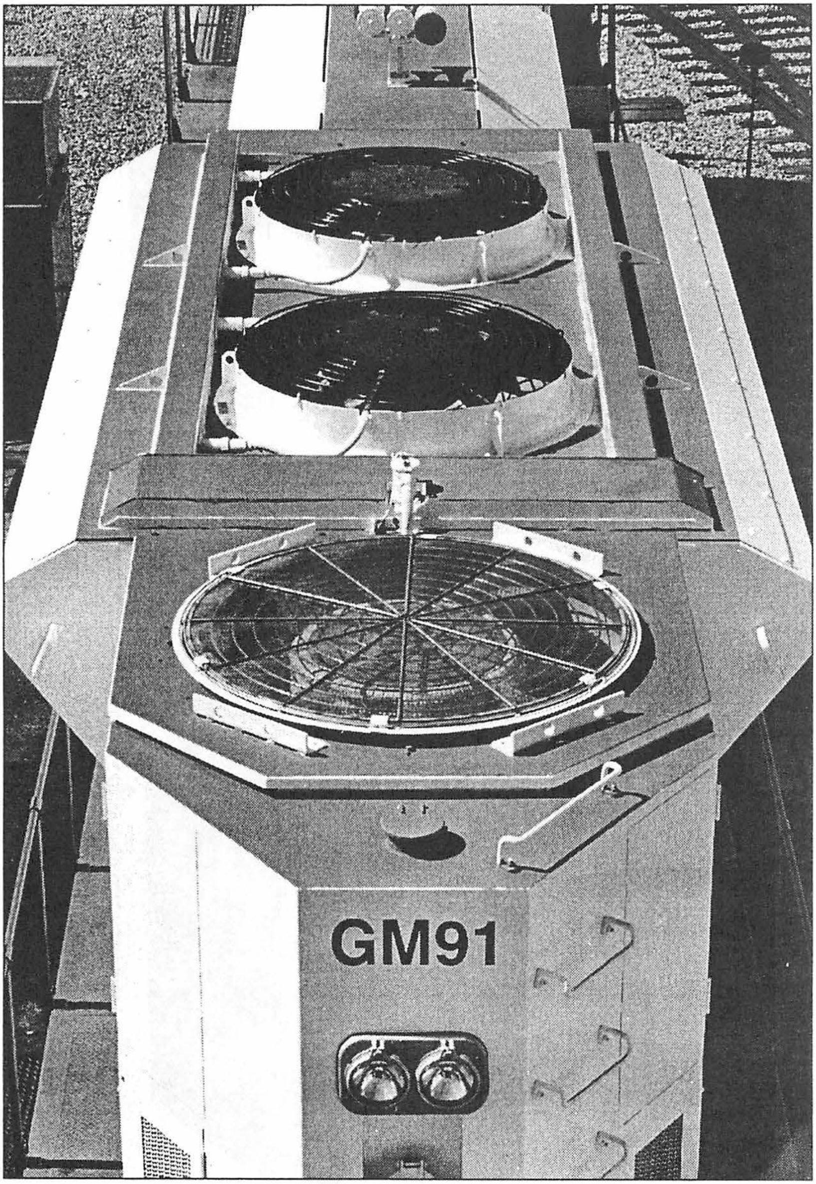


Figure 4 Cooling Fan Electrical Connections

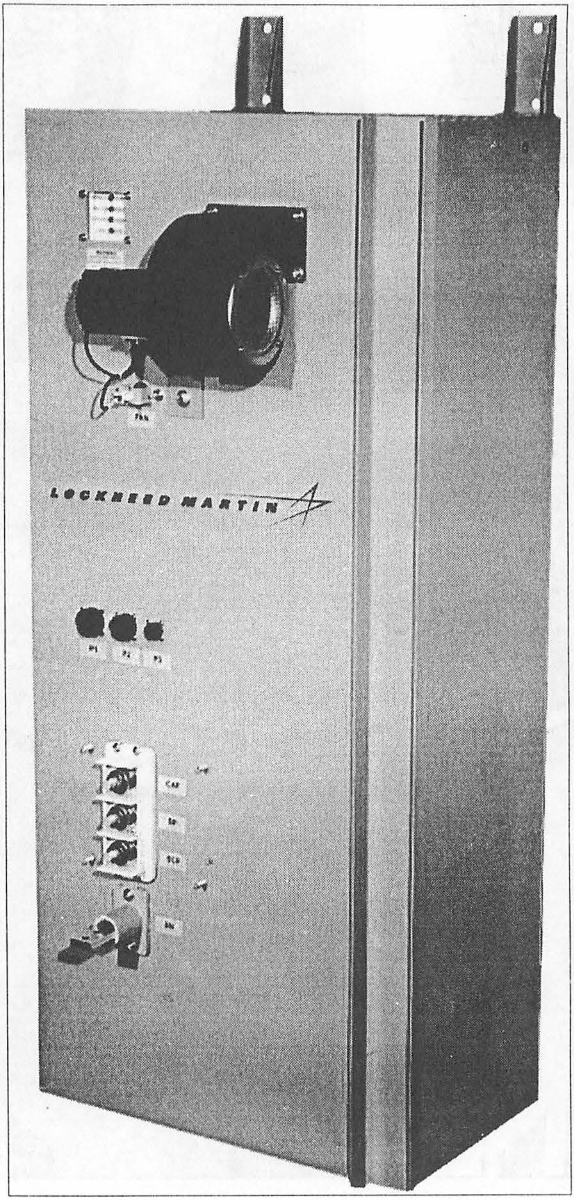


Figure 5 Auxiliary Power Converter

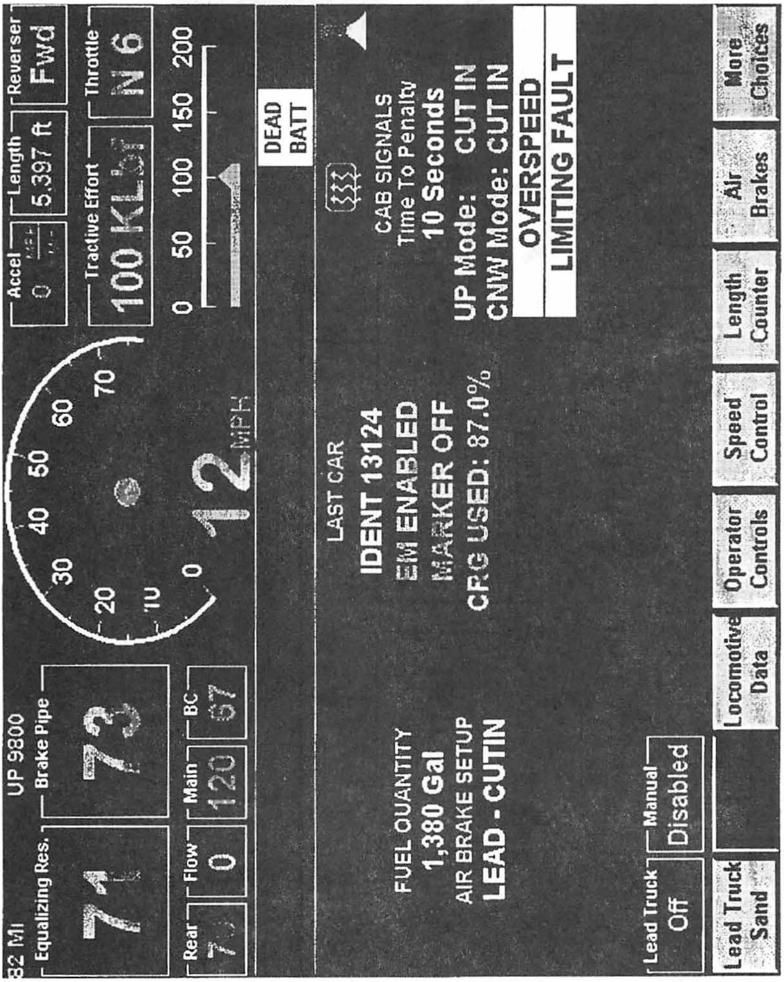


Figure 6 *FIRE*™ Display

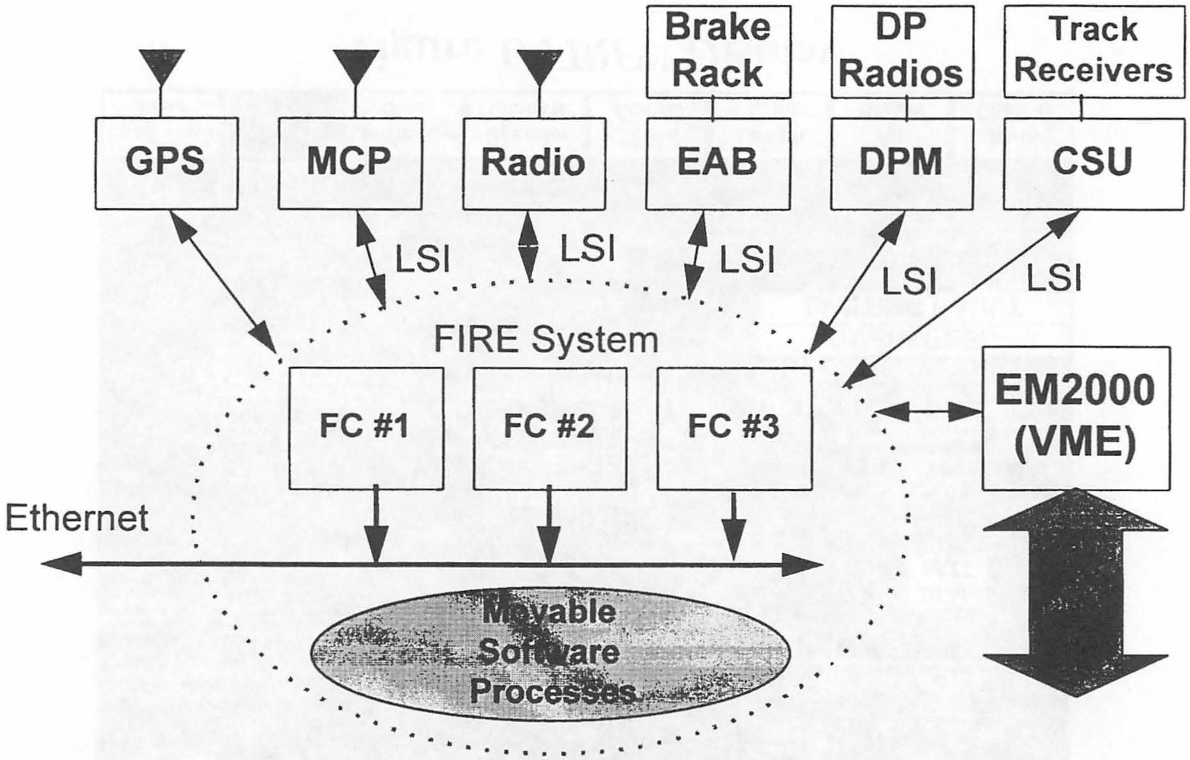


Figure 7 *FIRE*™ Network

V. IGBT-WHAT'S NEW FOR GE AC6000 LOCOMOTIVES

by John Chessario
General Electric Co.

Introduction

This paper discusses a recent product enhancement, known as IGBT, that is being installed on GE AC4400 and AC6000 locomotives. What is an IGBT? IGBT stands for "Insulated Gate Bipolar Transistor", which in English translates to a fast, high-power electrical switch. So what does it do, and why do we want it?

Background

An IGBT is a direct replacement for the GTO found in the phase module of today's AC locomotives. To understand the GTO's role in the AC propulsion system, let's recap the fundamentals of AC technology in a locomotive application. A diesel engine drives a traction alternator to produce three-phase AC output. The traction alternator ouput is converted (or rectified) to DC voltage and current. In DC locomotives the DC output is fed directly to the traction motors. In an AC system the DC output from the rectifiers is fed to a traction inverter. The inverter converts the rectified DC voltage and current to a three-phase variable voltage and frequency supply that is fed directly to the traction motors. Traction motor speed is controlled by varying the frequency and voltage outputs of the inverter. In GE locomotives each traction motor has its own dedicated inverter which affords greater control for wheel-slip and tractive effort.

What Does A GTO Or IGBT Do?

An essential component of the inverter is the GTO, or gate turn-off thyristor. The GTO turns current on and off in response to propulsion control system commands from the gate driver. The switching activity alternates the flow of current through the motor windings to power the traction motor. GE AC4400 and AC6000 locomotives built from 1994 through 1999 use GTOs in the phase modules of the traction motor inverter. The GTO switching function can be accomplished with an IGBT - the next generation of a power semi-conductor that offers many advantages over the present day GTO and gate driver.

Why Change To IGBT?

Why use an IGBT instead of a GTO? It is just one part of GE's on-going commitment to improve locomotive reliability. The GTO technology has matured to the limit of its capability. To make a quantum leap forward in reliability requires a technology transition in the power electronics area. GETS strategy was to facilitate the development of a single reliable IGBT module that would directly replace the GTO. IGBTs use a different technology than a GTO to reduce the total number of parts required. Snubber elimination and a simplified gate driver reduce parts count and allow the IGBT to be more robust than the GTO. The reliability of the IGBT and its associated gate driver will initially be better than the current GTO design. Reliability growth over time will continue the trend towards improved performance. Another primary advantage is maintainability. The modular design continues GE's "Ready Track" serviceable maintenance philosophy.

Why Are They More Reliable?

The IGBT has the same performance and functionality as the GTO, but it uses far fewer components to operate. There are no snubber capacitors, and over 5000 electronic components per locomotive were eliminated due to a simplified gate driver design. Snubber-less operation eliminated another 144 power components and 400 electrical connections. The power to run the IGBT gate driver has been reduced from 3600 Watts to 300 Watts per locomotive. IGBT technology also has the capability for short circuit protection.

Initially these features will translate into 20% reliability improvement versus the GTO design. The design has gone through the rigors of functional qualification testing (FQT), environmental qualification testing (EQT), reliability growth testing (RGT) and extensive field testing. FQT ensures that the system performs the functions for which it was designed. EQT ensures that the design will survive the environmental extremes within which it must live-ranging from- 40 degrees C in Northern Canada up to 131 degrees F in the Pilbara of Western Australia. RGT utilizes long-term life testing to facilitate lower rates through design maturity.

What Are The Maintenance Advantages?

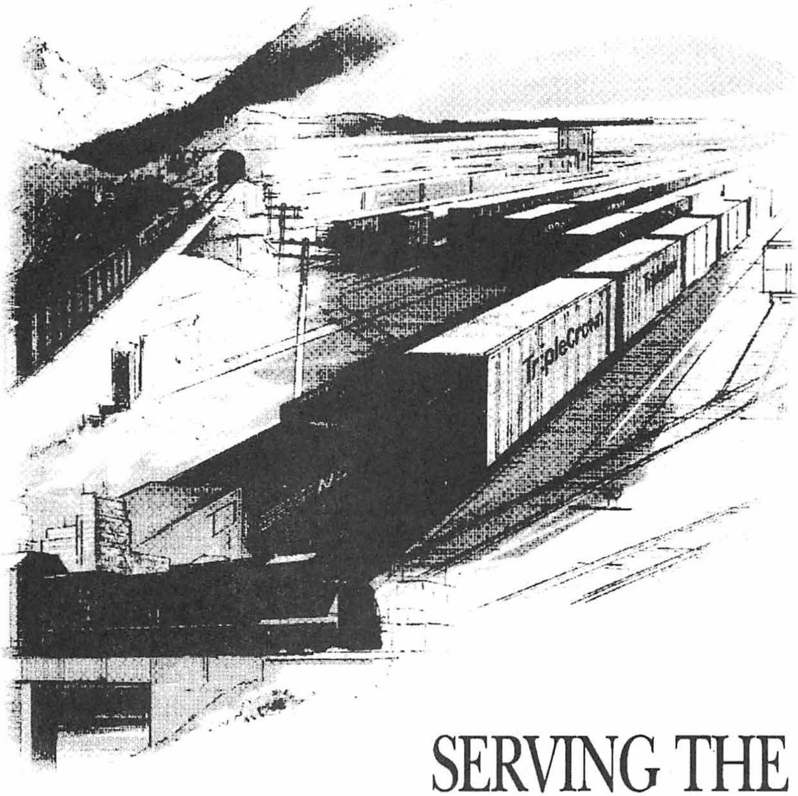
The primary maintenance advantage stems from increased reliability (reducing failures means fewer shopping and component change outs). If an IGBT does need to be replaced, the maintainer will appreciate its lighter weight and size. An IGBT phase module is 12 pounds lighter than the 68 pound GTO phase module it replaces. The decrease in size also means more room in the auxiliary cab, resulting in improved access. The capacitors have been removed from behind the phase module stack and are located underneath it-further improving access for maintenance personnel. In addition, moving the capacitors inboard reduces wayside damage in the event that an inverter compartment is sideswiped.

Why Are We Using Them Now?

IGBTs have been around since 1994 and have been used in other applications such as transit cars. They have only recently reached the power levels and reliability rates suitable for heavy-haul freight locomotive applications.

What Changes?

First, let's discuss what stays the same in the locomotive configuration. The alternator, rectifier, traction motor, control hardware, sensors, software,


TripleCrown

performance, functionality, diagnostics and troubleshooting all remain the same. So does GE's time- and service-proven 1400-volt insulation systems, highly reliable air cooling system and inverter per axle control strategy. Unique to the IGBT are new bus bars with low DC link inductance to permit snubberless operation and new fuses. The IGBT itself is lighter and smaller and is installed with four mounting bolts, four electrical connectors and three fasteners.

Other key elements of the design that are retained are the safety mechanisms to discharge stored electrical energy in the Link Capacitors. As with all GE AC freight locomotives, there are three paths available to discharge the stored energy. The first method is manual and involves raising the barrier bar to connect the capacitors to the discharge resistors in under 30 seconds. There are also two automatic modes. The first connects the link capacitors to the dynamic braking circuit to initiate a quick discharge in 4 seconds or less. The other automatic mode allows the link capacitors to discharge in approximately 20 minutes through a bleed-off resistor. These are discussed in detail in the GETS presentation from the 1996 LMOA Diesel Electrical proceedings.

Testing and Validation

In 1996 the design was finalized using Design for Six Sigma processes. A GEB 13 traction motor was tested in GE Transportation Systems' Erie labs beginning in July 1997, and a single axle was powered on a GE test locomotive in December that same year. In July 1998 three CP and three CSX AC4400 units were modified to IGBT on one axle. December 1998 saw the first two locomotive applications-one CP and one CSX AC4400 locomotive. In March of 1999 the first AC6000 with IGBT was produced for CSX; and, an additional four CSX units were produced in April along with five UP AC4400s. These units bring the total number of pre-production locomotives in service today to twelve. Full production is scheduled to commence in the second half of 1999.

Summary

Through technology advances IGBT's are now capable of reliable operation on GE freight locomotives. Direct functional replacement of a single GTO with an IGBT maintains GE's single inverter per axle advantage in wheel-slip and adhesion control. The initial failure rates for an IGBT are lower than the GTO at introduction, and they will improve over time. IGBT's offer simple gate driver, snubberless design in an air-cooled package. Simple mounting, smaller size and lighter weight translate directly into enhanced maintenance ergonomics and maintain the "Ready Track" serviceable philosophy.

GE recognizes the successful partnership in developing the IGBT and thanks Canadian Pacific, CSX and Union Pacific for their contributions.

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

MONDAY, SEPTEMBER 20, 1999
3:45 P.M.

Chairman
J. BRAWLEY
Director-Material Control
Amtrak
Beech Grove, IN

Vice Chairman
J. Minnie
Manager - Materials
BNSF Rwy
W. Burlington, IA

COMMITTEE MEMBERS

R. Brandt	Director-Materials	VMV Enterprises	Paducah, KY
A. Chapman	Senior Mgr. of Materials	CSX Transportation	Waycross, GA
R. Florczyk	Mgr.-Loco. Parts Sales	General Electric	Philadelphia, PA
B. Girard	Sr. Materials Supply Spec.	CP Rail	Calgary, AB
B. Graham	Material Manager	Montana Rail Link	Livingston, MT
J. Hartwell	V.P. Sales	Progress Rail Svcs.	Green Cove Springs, FL
B. Harvilla	Sales Mgr.	Standard Car Loco.	Bensenville, IL
D. Rhyne	Senor Matls. Analyst	Electro Motive	La Grange, IL

Note: Guest speaker J. Dillon, Railpro, Inc.

PERSONAL HISTORY

John Brawley

John Brawley is the Director of Materials Management at the Beech Grove, Indiana Maintenance Facility with over 22 years of experience in the rail industry. His responsibilities include Beech Grove, Chicago, Miami, Sanford and New Orleans.

He began his career with Amtrak in 1977 in the mechanical department at the New York Maintenance Facility (Sunnyside Yards) as an electrician. His responsibilities included turn around service, special projects and for 3 1/2 years he was in charge of metroliner service.

In 1984 he was promoted to General Supervisor Material Control, New York where he headed up the Materials Department in support of the New York Operations.

In 1986 he became Manager Materials Disposal located at 30th Street Station, Philadelphia. In this position he was responsible for managing and controlling the sale of all corporate assets throughout the Amtrak system.

In 1991, he was appointed Manager Material Control, Beech Grove, Indiana, which is the largest facility in the Amtrak system. Its prime responsibility is to overhaul passenger cars and locomotives. It is also a distribution center for all the outlying points throughout the Amtrak system.

He has 3 children and 2 grandchildren. One of his children, Paul, is currently a junior at Ball State University. Another, Christine, graduated from Indiana Wesleyan University and recently got married (July 1999).

I. COMPOSITE FLOORS AND DOORS FOR LOCOMOTIVES

Prepared by
Jack Dillon, Railpro, Inc.

Agenda

For those of you who do not like detail, but prefer the bottom line, we have decided to present our conclusion first. Following that, we will briefly discuss the history of floors and doors and their associated problems, the properties of composite materials with specific reference to a new design with which we are very familiar. Finally, we will list the advantage of composites.

Conclusion

The use of composite materials in the railroad industry is here to stay. Functionality, longevity and costs can be controlled by the proper selection of the right combination of composite materials coupled with proper design.

Barring catastrophies, composite materials can easily outlast the life of the locomotive on which they are applied. This will make the life cycle costs extremely beneficial.

Objectives

If we accomplish nothing more than increasing our industry's awarness of the merits of the use of composite materials for specific applications, then we have achieved our goal today.

History

Flooring and doors are not, and never have been, critical areas when it comes to operating a locomotive. Consequently, there has been little advancement in their development. They, and their problems, have just been accepted over the years.

The Ideal Locomotive Floor

- Provide a good gripping surface - anti-skid (safety), be "easy on the feet" and have a good appearance.
- Lightweight with the strength to support loads, i.e. seats, control modules.
- Sound deadening and insulating qualities.
- Moisture resistant - will not swell up due to moisture.
- Chemical resistant - grease, fuel, cleaning compounds.
- Flexible with ability to withstand vibration, shock and severe dynamic loads associated with locomotive operation.
- Fire resistant - self extinguishing.
- Easy to clean and maintain.
- Easy to install; easy to remove and re-install.
- Long life - life of the locomotive.
- Repairable.
- Low cost.

Unit

We like to consider a locomotive floor as a unit, like a wheel and the rail are a unit. This unit is the sub-floor, the top floor and the cab wall. Each is dependent on the other for top performance.

Current Floor Designs

Most sub-floors in current use are made from plywood, Benelux, presswood or sometimes steel or aluminum sheeting.

The top coat is normally a vinyl type material like linoleum or rubber matting.

These sub-floors are subject to deteriorating due to rotting, rusting and delaminating caused by moisture. Some moisture is introduced at the top surface from cleaning, precipitation entering through open windows and also comes directly from underneath the floor during cleaning and operating in wet and humid conditions. Moisture also comes from condensation caused by temperature changes. This is particularly prevalent on locomotives that travel from humid to dry climates and from warm to cold climates, especially during winter.

Aluminum sheeting, although strong and lightweight, can corrode and is subject to denting and disorientation. Aluminum sheeting also conducts heat, burns through easily and is prone to point load failure.

With plywood, the thickness and the type of wood used affect strength. The thicker the plywood, the greater the impact resistance. There is a jump from 3/8" (3-ply) to 5/8" (5-ply), but there is also a significant increase in weight.

Vinyl material used in top floors has a limited life and is easily damaged and difficult to repair.

Most floors are not manufactured for removal and re-installation.

Cab Wall: Locomotives have a history of rusting at the interface of the sub-floor and the wall. This is mainly due to the sub-floor retaining moisture which increases the oxidation process.

Why A Composite Floor?

A compostite floor with a topcoat will provide all the qualities of the ideal floor and can "mate" with the cab wall to complete the unit.

A composite normally consists of five sections:

- Top Skin
- Bonding Agent
- Core
- Bonding Agent
- Bottom Skin

The core, which can be made of more than one component, is the heart of the composite, but the overall structure is only as strong as its weakest component. Ideally, all five will fail at the same time, but practically there is the need to balance the desired properties - strength, weight, etc. - to meet cost objectives.

The core should provide strength, be lower cost than a "solid" (plywood or metal), provide sound deadening, vibration absorption, and thermal, fatigue and fire resistance and absorb impact energy.

The skin should provide rigidity and additional strength.

Most composites have either a foam or balsa core. Closed cell foam is lower cost than balsa and can provide all the desired properties. Foam is normally one-third lighter than wood.

Linear closed cell foams are more resilient than cross linked types, provide superior resistance and bond better to skins.

New Design Composite Floor

A new design composite locomotive floor has a multiple part core consisting of a foam, glass and synthetic material core. The synthetic material also serves as the bottom skin. The topcoat, which includes the anti-skid material, is the top skin. The top coat enhances and strengthens the sub-floor. It is seamless, chemically resistant, resists chipping, sealing and cracking, cleans easily and is long life. It is also easily repaired if damaged and the repair blends completely with the surface.

Additionally, corporate logos and caution stripes/wording can be imbedded into the surface.

All mounting holes are sealed to prevent moisture penetration into the side walls or sub-floor.

This floor has excellent compression strength and all the other properties of the ideal floor.

The floor top coat can also be used in shops, warehouses and freight and passenger cars.

The Ideal Locomotive Floor

We believe this new composite flooring meets all the requirements for an ideal locomotive floor discussed earlier.

Technical Data

The sub-floor properties include:

Tensile Strength	
Lengthwise	22,900 psi
Crossway	15,200 psi
Flexible Strength	
Lenghtwise	32,900 psi
Crossway	25,600 psi
Compressive Strength	
Lengthwise	19,400 psi
Crossway	17,200 psi
Impact Resistance	24 inch. lbs.

Low Cost Alternative

If you have a plywood sub-floor still in good condition, its life can be extended by the use of the topcoat material over the plywood. For best results using this method, the plywood should be "surround coated" to reduce moisture penetration.

Current Composite Floor Applications

- Jet transport and passenger aircraft. The floors on passenger planes face damage from foot traffic - particularly high heels - carts and chemicals in galleys and toilets.
- Corvette C-5
- Montreal Subway Cars

Composite Doors

Locomotive doors made from composites are also coming into use. Many of the properties found in a composite floor are incorporated in a composite door.

Weight reduction, sound

deadening, insultation and long life are among the major benefits of a composite door.

New skin material being used provides seven to ten times the impact resistance over previous products.

Other properties include:

Heat resistance

Softening point - 190° F/11lb. Load

Continuous Operating Temps. - 180° F

- Water Absorption - 0.4% (weight gain in 24 hr. Immersion)
- Tensile Strength - 5500 psi
- Elongation at break point - 50%
- Flexible strength - 10,300 psi
- Rockwell hardness - 45
- Chemical resistance - Good

Other Railway Composite Applications

- Locomotive nose sections:
- Pendolino S220 train manufactured by Fiat and Transtech
- TGV New Generation
- Seats on the Danish S Train. Provides a 44% weight reduction over standard type seats.
- Rail Cars on Swiss Railroad
- Shuttle cars at the Delta Airlines Cincinnati terminal

Other High Performance Composite Applications

Marine

- Energy absorbing ship fenders
- High speed racing boats

Helicopter Rotor Blades providing 10,000 hours life, which is ten times greater than metal.

II. PACKAGING STANDARDS

By Jim Hartwell
Progress Rail Services

Packaging standards are an important and integrated part of the entire locomotive component supply chain process. Although the products in the packaging are considered more important than the packaging, the packaging plays an important silent role in the success of the reliability of the components shipped in them and this does not exclude our locomotives.

Packaging is a $100 billion dollar business that effects everyone's daily life. Some packaging is more critical than others depending on the application, however all packaging should be designed for the product that it intends to be shipped in it. Packaging is as simple as a box of cereal and as our lives. Even seatbelts are a form of packaging, and probably the most critical packaging application in our family's day to day lives.

Webster defines packing as "Material in which something is packed, to prevent seepage or breakage". I think we need to define packaging in much broader details as it relates to our locomotive and components business.

Our locomotive components may not be as high tech as the shuttle components but are every bit as critical to the performance and reliability of the locomotives that pull our freight cars and bring revenues and profit to the bottom line. Poor packaging can cost millions of dollars to the railroads and suppliers of the components. Poor packaging and material handling will substantially increase the maintenance budget for increased freight costs. When a component is damaged during shipment the product is shipped twice, going back and forth from the supplier to the railroad and back again to the supplier. This is a waste of everyone's time and adds substantial and unnecessary cost to get the component to the locomotive.

Poorly packed products increase pool requirements in order to support locomotive maintenance programs. Poorly packed products also create loss of the products as well, material left at a freight carrier due to improper packaging and labeling, broken products, and cost of down time waiting for locomotive parts to be delivered all contribute to increased locomotive maintenance cost. This is not a good utilization of your locomotive assets waiting for new material because the first shipment was poorly packaged.

Packaging is a critical link between the supplier and the railroad that is typically not noticed until there is a problem with the product when it arrives. In most cases unless the damage is visible the unforeseen damaged product is not noticed until it is on the locomotive and labor dollars have been expended. Poor packaging causes extensive administrative efforts. Everyone who reads this probably has been through the process. The tracking alone for the return of the new part is a nightmare and adds a whole support staff in order to track the components through the process.

Even though the product may appear to be shipped in a proper package, if it is not anchored properly the part may lose a significant part of its overall life cycle without anyone detecting a problem after the warranty has expired. Suppliers and railroad material groups should pay close attention to their component packaging to make sure that their parts are being shipped safely and in proper shipping containers for the particular part's intended use and to the satisfaction of the end users.

Safety is major concern for good packaging design. Railroad yards are a tough environment in which to work. Our components are big, heavy and cost a great deal of money. The personnel that use the parts are technically qualified to perform the change outs of the components and we as suppliers and railroaders owe it to these technicians to give them the safest packaging possible. There are about 22,000 parts on a locomotive and although you don't purchase every part during the life of a locomotive you certainly replace a lot of them during normal maintenance and major overhaul programs. It is important that the end user know that the part will be shipped and delivered in a safe manner.

Because of the many different types of parts and shipments made to the railroad along with the many different ways of handling material, (by hand, forklift, jib crane and full overhead crane) it is critical that we know what will happen at the other end of the shipment. It is estimated that 20-25% of all occupational injuries are related to material handling. This causes enormous stress on the cost of running the business from loss of an employee, productivity, increased health insurance, cost for repair of the damaged part, but most importantly the pain being suffered by the employee and his family. Packaging is an important part of our lives and the environment in which we live.

Suppliers and the railroad should look at packaging as a proactive way of increasing the life of the components, the safe delivery of the components and the reduction in locomotive maintenance cost. These are benefits of good packaging. David B. Lansdale in his book "The Vital Signs of Effective Packaging Management", believes some questions should be reviewed when you are looking at an effective packaging management program. They are as follows:

1. Is there a plan for packaging activities and is it compatible with the firm's goals? I would extend this and ask if it is compatible with the end user and or customer goals for packaging.


New And Remanufactured Water Pumps

served by the function within the firm known and carried out?

3. Are the packaging environment hazards known and acknowledged?
4. Is there a system of quality control for packaging?
5. Are the internal and external lines of communication regarding packaging kept open and used aggressively? I would extend this to know the customers environment and needs.
6. Is the interface of packaging functions with other departments known and understood?
7. Is there a formal process available and known to all of those concerned for the updating of packaging technology?
8. Is there a policy of packaging exploration and development for the future?

In our locomotive business, due to the nature of the unit exchange and repair and return of components, there is an extensive use of reusable packaging and containers. Just about every major component is shipped back and forth between supplier and railroads. Returnable containers, if properly designed, can save the suppliers and the railroads millions of dollars per year in their material costs. They can be an effective tool for both the supplier and the railroad. The up front money spent on the more substantial reusable containers is more than repaid over time considering the cost of safety, replacement, and damaged goods.

Some other questions you may want to ask are:

1. Does the function and design of the package or container meet the needs of the product, the supplier and the customer?
2. Does the packaging or container meet regulatory and environmental guidelines?
3. Is the reusable container an economical solution for the product shipments?
4. Is the packaging or container safe for the product and those that will be handling the container?
5. Would a reusable packaging or container better fit the application component?
6. How many reusable containers will be needed in order to support the shipping patterns of the components? Are there enough containers to support the material requirements of the end users? What locations will need to be served?
7. Can the reusable containers be easily transported to and from the suppliers and customers locations?

In an effort to have some standardized method of packaging for the railroads and their suppliers, the NAPM (National Association of Purchasing Management) in conjunction with the RIF (Rail Industry Forum) and key suppliers put together a "Packaging Standards Subcommittee". The Packaging Standards Subcommittee developed and generated guidelines for shipping rail components.

We will take a few minutes and walk you through the highlights of this book. Until recently I never knew the book existed but I have found it to be great reading. Here are some highlights of the book. I suggest if you supply components to the rail industry you should make sure you get a copy for your review.

The Book

Development of the Rail Packaging Guidelines and Standards was generated by the following rail related companies:

- Class 1 Railroads - BNSF, CN, CP Rail, UP, CSX, NS and their merging railroads
- Suppliers - EMD, GE, Gunderson, Johnstown America, National Steel Car, Thrall Car Manufacturing and many other industry suppliers.

The Purpose

Per the Packaging and Standards Subcommittee, "The purpose of these standards is to provide packaging guidelines to railroad industry suppliers and will meet certain criteria. The criteria by which these standards are developed include safety, regulation, environmental impact, customer satisfaction, distribution and warehousing impact as well as cost".

Contents of the Book

- Standards compliance and packaging guidelines
- Definitions
- Packaging materials and specifications
- Drawings and applications for the following rail components:

  -Locomotive

  -Freight car

  -Maintenance of Way Equipment

  -MRO

  -Signal & Communication

  -Track Components.

The Standards book goes into substantial details in the following areas:

- Compliance (regulatory, NAPM & RIF)
- Environmental packaging considerations
- General packaging considerations
- Handling & ergonomics
- Bar code symbology and labeling requirements

We will concentrate specifically on locomotive applications. These will give you some idea of what the book has to offer and what level the supplier needs to develop for its railroad components packaging.

Some locomotive applications:

- EMD 4 pack - power pack shipping containers
- GE single and double reusable containers for power assemblies
- Locomotive gear cases
  - -Individual
  - -Multiple 5-pack
- Lube filter
- Bag filter
- Hand brake
- Injectors
  - -Single
  - -4-pack
  - -8-pack
- GE U-tube

The illustrations show different, packaging, shipping and material containers used by different railroads that help reduce maintenance dollars, increase the life of the part and provide safe and effective methods of shipping.

I appreciate the opportunity of presenting this paper to you. Should anyone have any additional comments or ideas for the book please contact the NAPM or RIF and I'm sure they will appreciate any additional comments you may have for their book.

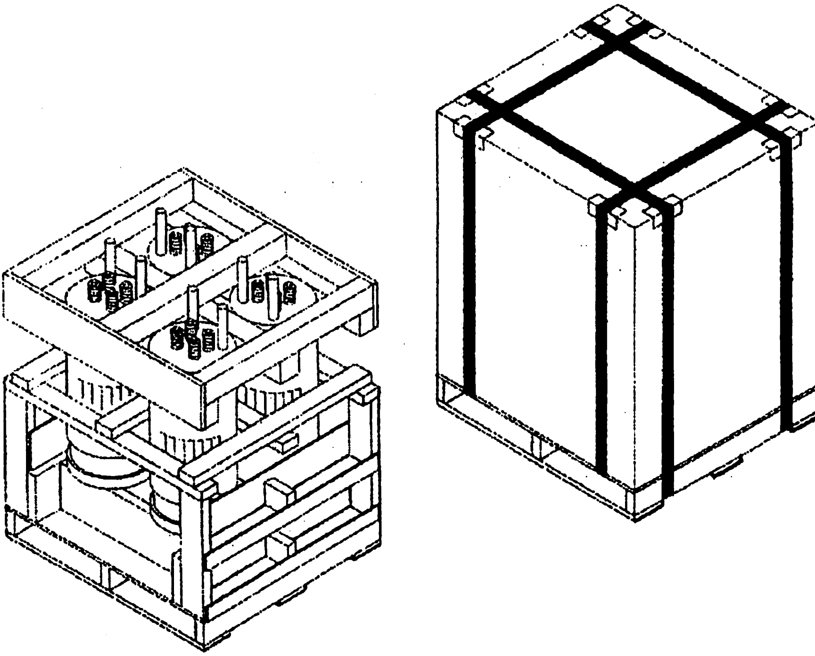
I would like to thank Alan Chapman from CSX and the entire Materials Committee for their support of this paper.

National Association of Purchasing Management

Rail Industry Forum

Packaging Standards Subcommittee

NAPM National Association of Purchasing Management **RIF** Rail Industry Forum **PSS** Packaging Standards Subcommittee



PACKAGING DESCRIPTION:

Place 4 assemblies in a crate and cover with a corrugated tube. Use four 1¼" steel bands and 8 edge protectors to affix to the pallet. Each container consists of 1 base, 1 top, 4 blocks (1½" x ¾" x 7"), 4 bolts (3/8" x 12") and 1 HSC 35 7/8" x 33½" x 46" 350# D/W Clay White Printed. Each set should be unitized by: banding the 3 bases together, banding the sleeves on the pallet, banding the tops together and bolting the blocks in the container.

MATERIALS:

Item	Description	Qty
1	Base, ½" CDX 32¾" x 35⅞"	1
2	Base, 1½" x 3½" x 33¾"	5
3	Base, ¾" x 3½" x 35½"	3
4	Base, 1½" x 4" x 18¾"	4
5	Base, 1½" x 7¼" x 24½"	4
6	Base, 1½" x 7¼" x 32¾"	2

Container: SPECIAL

DIMENSIONS (INCHES):

Height:	Width:	Length:
50 3/8	35⅞	32¾

Std. Qty..	Gross Weight (Pounds):
4	2500

PACKAGING STANDARD FOR:

ASSEMBLY, EMD POWER

Date	Packaging Standard Number	Revision
10/96	ASY-30, sht. 1	

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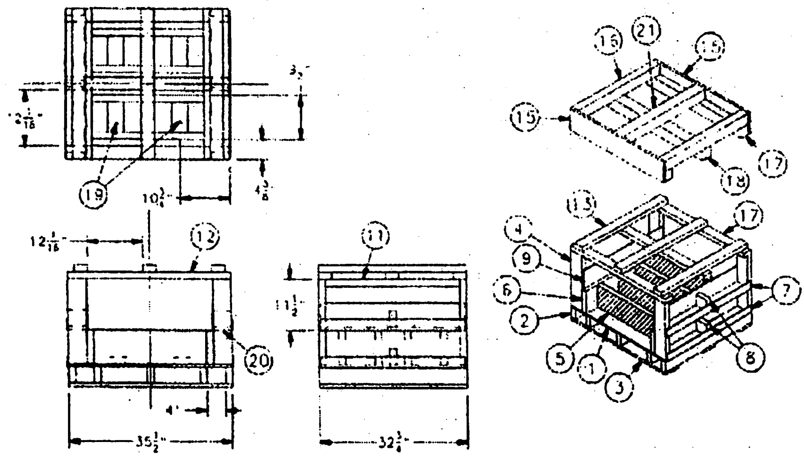

BASE DETAILS

MATERIALS:

Item	Description	Qty
7	Base, ¾" CDX 2¼" x 31 7/8"	
8	Base, 1½" x 3½" x 4"	4
9	Base, ¾" CDX 5 7/8" x 31 7/8"	2
10	Intentionally left blank	n/a
11	Base, 1½" x 3½" x 29¾"	2
12	Base, 1½" x 2 7/8" x 35½"	3
13	Base, 1½" x 2 7/8" x 32¾"	5
14	Intentionally left blank	n/a
15	Top, ¾" x 7¼" x 35½"	2
16	Top, 2½" x 3½" x 31¾"	2
17	Top, 2½" x 3½" x 35½"	2
18	Top, 3½" x 3½" x 35½"	1
19	Base, 1½" x 3½" x 6½"	4
20	Base, ¾" x 3½" x 29¾"	2
21	Top, 3½" x 3½" x 31¾"	1

Container: **SPECIAL**

DIMENSIONS (INCHES):

Height:	Width:	Length:
50 3/8	35½	32¾

Std. Qty.: 4

Gross Weight (Pounds): 2500

PACKAGING STANDARD FOR:

ASSEMBLY, EMD POWER

Date	Packaging Standard Number	Revision
10/96	**ASY-30, sht. 2**	

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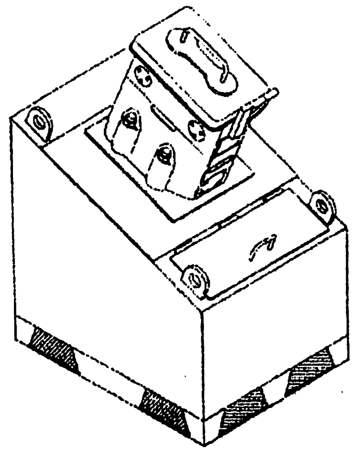
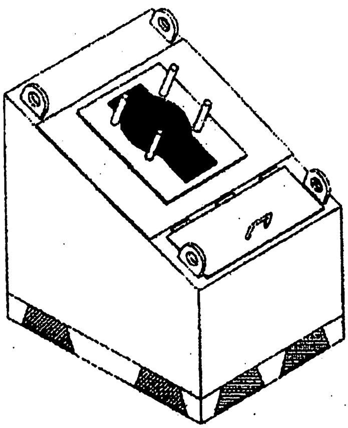




PACKAGING DESCRIPTION:

Place 1 assembly in the custom built steel container and bolt down to the four threaded studs. The empty container measures 34¼" x 44". It is 45" high at the back and 26½" high in the front. The container top measures 34¼" x 47½" and slopes from back to front at a 67° angle. The storage door opening in the front part of the container measures 9¼" x 27¼" x 9¼" deep.

Container: **RETURNABLE**

DIMENSIONS (INCHES):

Height:	Width:	Length:
67	34¼	44

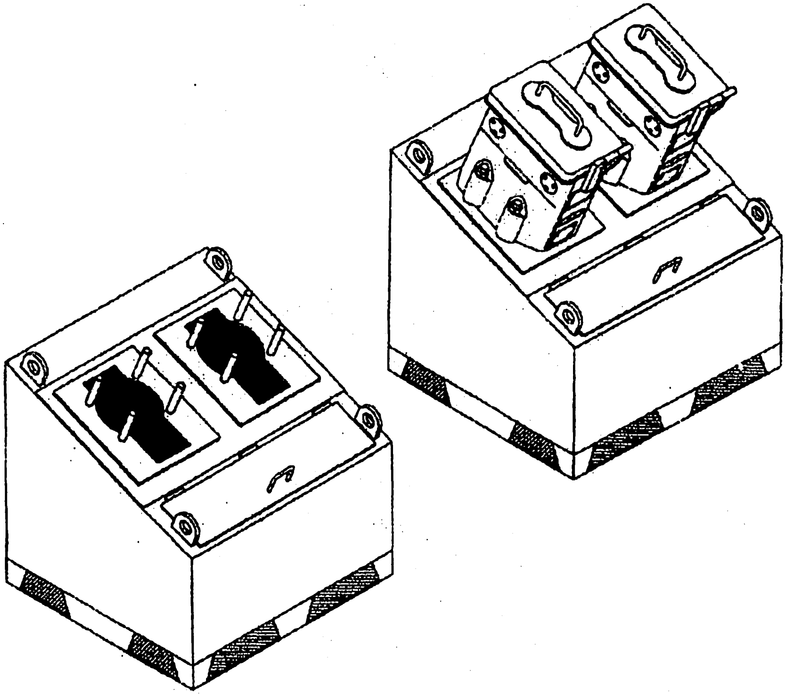
Std. Qty.:	Gross Weight (Pounds):
1	1700

PACKAGING STANDARD FOR:

ASSEMBLY, GE RETURNABLE POWER

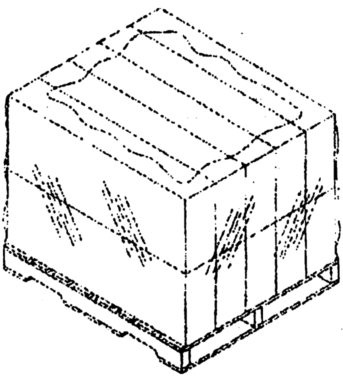
Date	Packaging Standard Number	Revision
3/97	ASY-31	

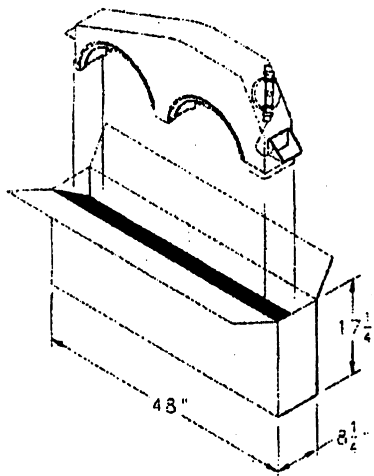
NAPM National Association of Purchasing Management RIF Rail Industry Forum PSS Packaging Standards Subcommittee



PACKAGING DESCRIPTION:	DIMENSIONS (INCHES):
Place 2 assemblies in the custom built steel container and bolt each down to the four threaded studs. The empty container measures 48" x 44". It is 45" high at the back and 26½" high in the front. The container top measures 48" x 47½" and slopes from back to front at a 67° angle. The storage door opening in the front part of the container measures 9¼" x 42" x 9¼" deep.	Height: 67 / Width: 48 / Length: 44 Std. Qty.: 2 / Gross Weight (Pounds): 2700
	PACKAGING STANDARD FOR: ASSEMBLY, GE RETURNABLE POWER
Container: RETURNABLE	Date 3/97 / Packaging Standard Number ASY-32 / Revision

NAPM National Association of Purchasing Management RIF Rail Industry Forum PSS Packaging Standards Subcommittee





PACKAGING DESCRIPTION:	DIMENSIONS (INCHES):		
Place each gear case in its own individual carton and seal the flaps. Five boxes are placed in each of two layers on the pallet for a total of ten gear cases. The load is secured to the pallet with stretch wrap.	Height: 40	Width: 42	Length: 48
	Std. Qty.: 10	Gross Weight (Pounds): 490	

PACKAGING STANDARD FOR:

CASE, EMD METAL GEAR

Date	Packaging Standard Number	Revision
10/96	CAS-30	

Pallet: PAL-5 Box: BOX-1

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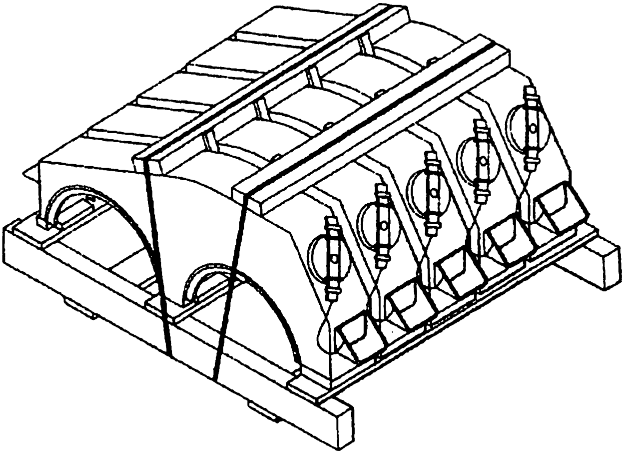

PACKAGING DESCRIPTION:	DIMENSIONS (INCHES):
Place five gear cases with open ends facing down on a special pallet consisting of two 2" x 4" x 52" runners, two 1" x 4" stringers and three 1" x 4" deck boards. Two 2" x 4" x 42" boards are placed across the top of the gear cases. Two 1" x 2" x 20" spacer strips are attached to the top boards and the middle deck board between each gear case for a total of eight spacers. Two ¾" steel bands are placed over the top boards to secure the gear cases to the pallet. Pallet: SPECIAL	Height: 25¾ Width: 46 Length: 52 Std. Qty.: 5 Gross Weight (Pounds): 295 PACKAGING STANDARD FOR: CASE, GE METAL GEAR Date: 10/96 | Packaging Standard Number: CAS-31 | Revision:

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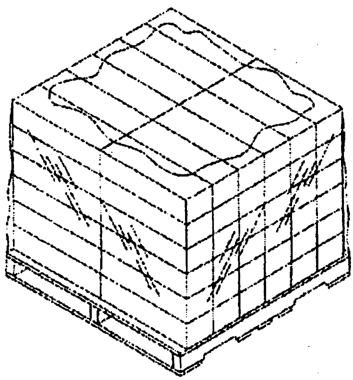

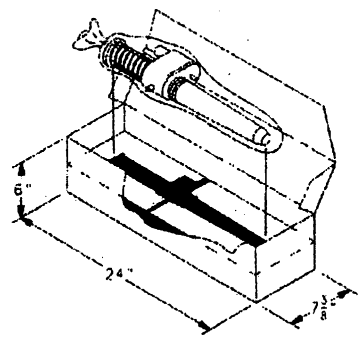

PACKAGING DESCRIPTION:	DIMENSIONS (INCHES):
Place each fuel injector in its own blended resin bag and then into an individual carton with die-cut form to stabilize it within the box. Twelve boxes are placed in each of six layers on the pallet for a total of 72 injectors per package. The load is secured to the pallet with stretch wrap. Pallet: PAL-6 Box: SPECIAL Bag: BAG-2	Height: 41½ Width: 48 Length: 48 Std. Qty.: 72 Gross Weight (Pounds): 700 PACKAGING STANDARD FOR: INJECTOR, EMD FUEL (QTY 1) Date: 10/96 — Packaging Standard Number: INJ-30 — Revision: 3/97

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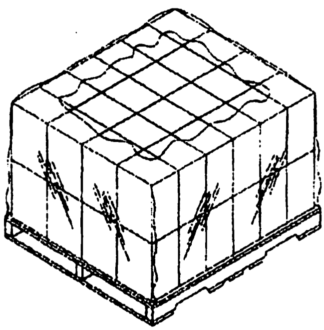

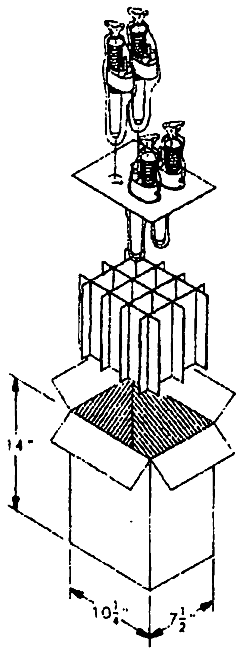

PACKAGING DESCRIPTION:	DIMENSIONS (INCHES):
Place each fuel injector in its own blended resin bag and then into an individual cell made of corrugated partitions and a die-cut, four position slot to stabilize them within the box. The four outer cells accept the injectors while the two inner cells are left empty (total of six cells). The gross measurements of the partition are 8" high x 7¼" wide x 9¾" long. The die-cut corrugated, slotted form is folded to offer double strength. It measures 7¼" x 9¾". Twenty-four boxes are placed in each of two layers on the pallet for a total of forty-eight boxes and 192 total injectors per package. The load is secured to the pallet with stretch wrap. Pallet: **PAL-5** Box: **SPECIAL** Partitions: **PAR-1** Bag: **BAG-2**	Height: 33⅛ Width: 42 Length: 48 Std. Qty.: 24 cases Gross Weight (Pounds): 1500 **PACKAGING STANDARD FOR:** **INJECTOR, EMD FUEL (QTY 4)** Date: 3/97 — Packaging Standard Number: **INJ-32** — Revision: **10/97**

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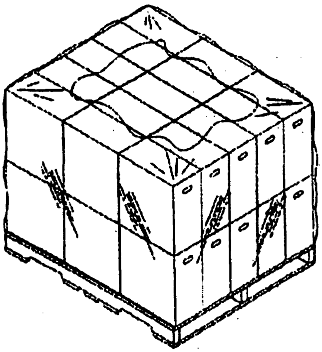
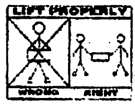
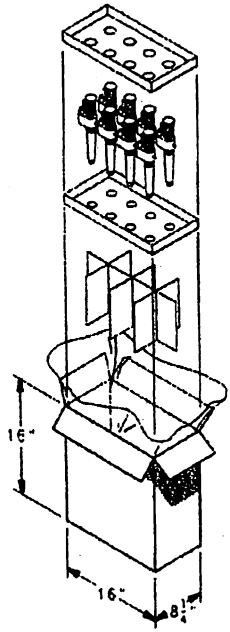






PACKAGING DESCRIPTION:

Place each fuel injector in its own individual cell made of corrugated partitions and 2 die-cut forms to stabilize them within the bi-wall corrugated box. Each of the 8 cells is filled with an injector. The gross measurements of the partitions are 8" high x 7 1/8" wide x 15 1/2" long. The two separate die-cut corrugated forms measure 7 1/8" x 15 1/8". The entire contents of the box are placed within a single blended resin bag sized to suit. On the ends toward the top of the box are hand-hold cut-outs. The box must not be lifted by only one person. Labels appearing on the box must warn against such handling.

Fifteen boxes are placed in each of two layers on a pallet for a total of thirty boxes containing and 240 injectors per package. Stretch wrap is used to secure the package.

Pallet: PAL-5

Box: SPECIAL Partitions: PAR-1 Bag: BAG-2

DIMENSIONS (INCHES):

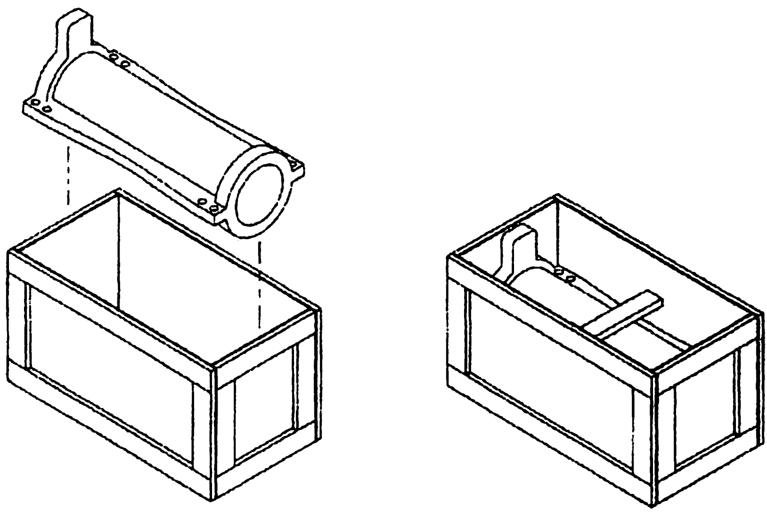
Height:	Width:	Length:
37 1/8	42	48
Std. Qty.:	Gross Weight (Pounds):	
30 cases	1800	

PACKAGING STANDARD FOR:

INJECTOR, EMD FUEL (QTY 8)

Date	Packaging Standard Number	Revision
3/97	INJ-33	10/97

NAPM National Association of Purchasing Management RIF Rail Industry Forum PSS Packaging Standards Subcommittee



PACKAGING DESCRIPTION:	DIMENSIONS (INCHES):
U-Tubes are individually packaged in specially designed wooden crates with outer dimensions (OD) of 45½" x 25" x 29". In order to stabilize the U-Tube, two L-shaped cradles made of a 2" x 6" x 22¼" and a 2" x 4" x 22¼" are placed together on edge inside the crate. The crate is constructed of plywood and framed with 1" x 4" lumber. Three 3" x 4" runners are applied to the outside bottom of the crate. After the U-Tube has been put into the crate on the cradles, a 2" x 4" x 22¼" board is placed inside and over the U-Tube and is attached to the side walls of the crate. This will provide additional integrity to the package. Crate: SPECIAL	Height: 29 · Width: 25 · Length: 45½ Std. Qty.: 1 · Gross Weight (Pounds): 600 PACKAGING STANDARD FOR: **U-TUBE, GE LARGE LOCOMOTIVE TRACTION MOTOR** Date: 10/97 · Packaging Standard Number: **TUB-32** · Revision:

REPORT OF THE COMMITTEE ON MECHANICAL MAINTENANCE

TUESDAY, SEPTEMBER 21, 1999 9:00 A.M.

Pre-Convention Presentation: Hosted by Engine Systems, Simmons Machine Tool and Amtrak

Jay Holley, Chairman
Director Mechanical Operations
CSX Transportation

Albany, NY
May 25, 1999

Vice Chairman
Rick P. Gates
General Equipment Supvr.
BN SF Railway

COMMITTEE MEMBERS

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J. Richardson	Ass't Chief Mechanical Off.	Montana Rail Link	Missoula, MT
J. Sadler P.E.	Manager - Loco Shop	Canadian National	Winnipeg, MB

PERSONAL HISTORY

Jay J. Holley

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

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

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

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

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

Jay and his wife Candy have been married for 35 years and reside in Jacksonville. They have 2 children, Jeff and Amy.

The LMOA Diesel Mechanical Maintenance Committee *wishes to express their sincere gratitude to Engine Systems, Simmons Machine Tool and Amtrak for hosting their preconvention presentation at Albany, NY in May 1999.*

I. VIBRATION ANALYSIS

by Dennis L. Nott
Boise Locomotive

Condition Assessment Through Non-intrusive Testing

Vibration analysis is a real benefit today because it gives you the ability to see what's going on inside a piece of equipment without interrupting its process in any way. This non-destructive method is a good tool for predictive maintenance of machinery.

What defects can be detected: imbalance, misalignment, bent shaft, bearing shift, bearing defects, bearing looseness, loose mounting, structural looseness, resonance, gear wear, gear misalignment, cracked gear teeth, cavitation and oil whirl.

What is vibration: vibration is the movement of an object about its reference position. Vibration occurs because of an excitation force that causes motion.

This force may be externally applied to all objects, or it may originate inside the object. It will be seen later that the rate (frequency) and the magnitude of the vibration of a given object is completely determined by the excitation force, direction, and frequency. This is the reason that vibration analysis can determine the excitation forces at work in a machine. These forces are dependent upon the machine condition, and a knowlege of their characteristics and interactions allow one to diagnose a machine problem.

The vibratory motion of an object can be completely described as a combination of individual motions of six different types. These are translations in the three orthogonal directions known as X, Y, Z and rotation around the X, Y, Z axis. Any complex motion of an object can be broken down into a combination of these six degrees of freedom, as shown in Figures A through F. For instance a ship can move in a vertical direction; surge (Figure A), fore and aft direction; heave (Figure B), and port and starboard direction; sway (Figure C). It can rotate lengthwise; roll (Figure D), rotate around the vertical axis; yaw (Figure E), and rotate about the port and starboard axis; pitch (Figure F).

The simplest possible vibratory motion that can exist is the movement in one direction of an object controlled by a spring. Such a mechanical system is called a single degree of freedom system. If the object is displaced a certain distance (X) from the equilibrium point then released, the spring will return it to equilibrium, but then the mass will have kinetic energy and will overshoot the rest position and deflect the spring in the opposite direction. It will then decelerate to stop at the other extreme of its displacement (-X) where again the spring force will pull it back again and again.

A machine with imbalance has an excitation force that is a sine wave at 1X, or once per revolution. If the machine were perfectly linear in response, the resulting vibration would be a pure sine wave like the one shown in Figure 1.

The most common way to look at this information in the past was a wave form (Figure 2).

Through a process known as a fast fouier transform you can view this as a spectrum (Figure 3).

In many poorly balanced machines, the wave form does not resemble a sine wave, and there is a large vibration peak in the spectrum at 1X, or one order.

What tools are needed to perform vibration analysis?

Vibration Analyzer (Figure 4): You must have a machine that will read more than overall levels of the vibration signature. It has to have the ability to read, store and compare spectra for detailed analysis as well as trending. The ability to divide the overall value into select frequency bands for more discrete alarming and analysis provides a powerful tool.

Vibration Transducer: A good transducer should convert mechanical vibration into an analog electrical signal. The various types of transducers are: **Displacement Transducer, Velocity Probes, Seismic Velocity Transducer, Accelerometer and Piezovelocity Transducer.**

The accelerometer is the type of transducer most common to our application (Figure 5).

This transducer generates an electrical charge proportional to acceleration by stressing piezoelectric crystals. These transducers possess a broad frequency range, are very rugged, need no external conditioning, are easily mounted with stud, adhesives or magnet mounts.

Computer based software is essential to store (archive) all readings, trending, report generation, frequency calculation, fault analysis and diagnostic to develop base line data.

To understand the readings we must understand the X and Y axis (Figure 6).

The X-Axis is the time or frequency of a given event. This can be described as the number of cycles per minute (CPM) or cycles per second (CPS), but the most common unit of measurement for time is in Hertz (Hz). This is especially true when viewing the information as a spectrum.

60 cycles/minute = 1 cycle/sec
60CPM
60RPM - 1 HERTZ (Hz)

To convert Hertz to CPM, multiply the value of Hertz times 60. 20 Hz x 60 = 1200 CPM (RPM).

The Y-Axis is the amplitude or magnitude of the defect. This is measured in various ways. Displacement or distance of travel which is measured in mils (Pk -Pk) or microns. Velocity or speed of movement measured in in/sec

(Pk). Acceleration which is the max force where it changes direction, is measured in G's.

The shaded area on Figure 7 indicates normal operating speed range for industrial machines.

What does all this mean in the real world? Let's take a look at a few examples of common problems that could be encountered.

The examples in figures 8-18 are the worst and best case scenarios. The third U-tube assembly (Figure 18) has worn out one wheel set. While not as good as new, it falls into the criteria set forth by GE that says, overall vibration levels can not exceed 0.15. The assembly with new bearings had an overall reading of .0229 The second example with bad bearings had a reading of .6115. The used bearings had a reading of .0653, which is well within tolerance of 0.15.

Railroad suppliers are successfully using vibration analysis to improve the products we purchase. A leading supplier of turbochargers test all units prior to delivery (Figure 19). The components tested during vibration analysis are: rotor assembly (Figure 20), idler and carrier gear bearings (Figure 21), idler and carrier gears (Figure 22), planetary gears (figure 23), turbine blades (Figure 24), impellers (Figure 25).

With the use of vibration analysis this company has been able to boast of several success stories; the ability to determine an alignment table out of calibration, gear incompatibility from various vendors, rotating assembly imbalance and oil contamination that caused planetary gear system failure. With the use of vibration analysis these defects were corrected prior to shipment. Of equal importance is the fact that they were able to improve their processes to eliminate the reoccurrence. Figure 26 shows the location of the accelerators at the test stage.

One of their railroad customers that uses vibration analysis as a predictive maintenance tool has asked that mounting pads be permanently mounted to the turbo at the time of overhaul. This ensures consistent readings everytime (Figure 27).

Currently, the railroad industry is performing vibration analysis on the following components; air compressors, turbos, cooling fans and main generators/alternators. Vibration sampling is done on a periodic basis. Traction motors are also being done only on initial run in.

The OEM's are also performing vibration sampling on all major electrical and mechanical rotating equipment, such as generators, a/c motors, traction motors, dynamic brake fans, cooling fans, turbos, locomotive engine, and the entire locomotive during final testing. This sampling is done after final assembly as part of one of the many quality pocesses.

Additional OEM testing of locomotive components varies according to the application, and also by the category of equipment.

Rotating equipment is subjected to periodic testing in accordance with the IEEE11 specification for transportation equipment (electrical and thermal characteristics). In addition, rotating equipment is also subjected to a commercial test, involving tests for vibration, overspeed, and magnetic characteristics.

Micro-electronic panels and power electric panels and devices are given environmental qualification tests whenever their design is changed or when the particular application is an unproven one. Such tests involve response to temperature extremes, vibration, shock, and EMI, as well as measurement of how much EMI the device generates. "Third party boxes" are also subjected to the same type of qualification. Where possible, test levels are based upon actual environmental measurements on that part of a similar locomotive where the subject panel will be located in service.

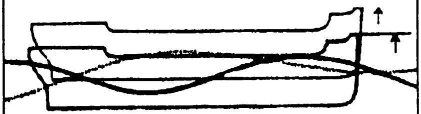
Environmental measurements on locomotives for specification purposes include vibration of truck-mouted devices as well as those mounted on the platform and in the cabs at many locations. Recorded 3-axis vibration data are then reduced and displayed in environmental specifications as power spectral densities.

Engine components and engine-mounted devices (such as turbochargers) are tested in conjunction with an engine that is under test in a test cell or on a test locomotive. Vibration measurements are sometimes taken in such cases, particularly if characterizing an engineering change that was made. Such tests are often run simultaneously with other engine tests, such as those for specific fuel consumption.

Some engine-mounted devices (e.g. mufflers) can be vibration tested on electronically controlled "shaker tables" for qualification tests.

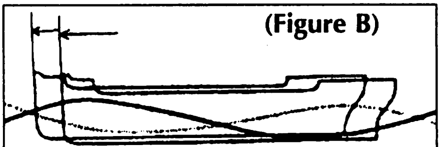
Heavy-capacity vibration testing equipment makes it possible to test larger and larger pieces of equipment, and some OEMs are moving to this type of testing. To do this the OEM must either invest in larger test sets in-house, or utilize suppliers of testing services. (This paper was co-authored by Dave Plumb, formerly of Conrail, and Carlo Gatewood of Union Pacific.)

(Figure A)



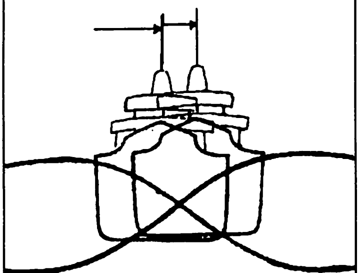
Surge

(Figure B)



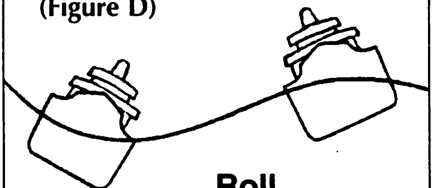
Heave

(Figure C)



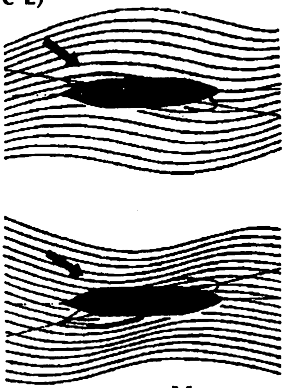
Sway

(Figure D)



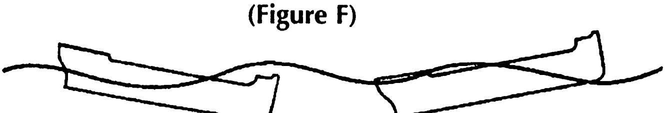
Roll

(Figure E)



Yaw

(Figure F)

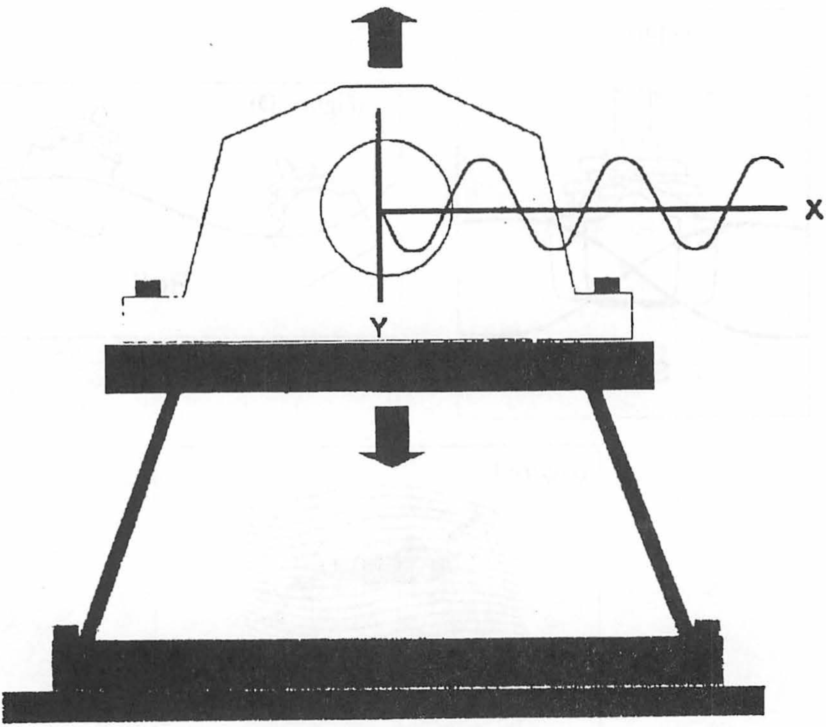


Pitch

Legend

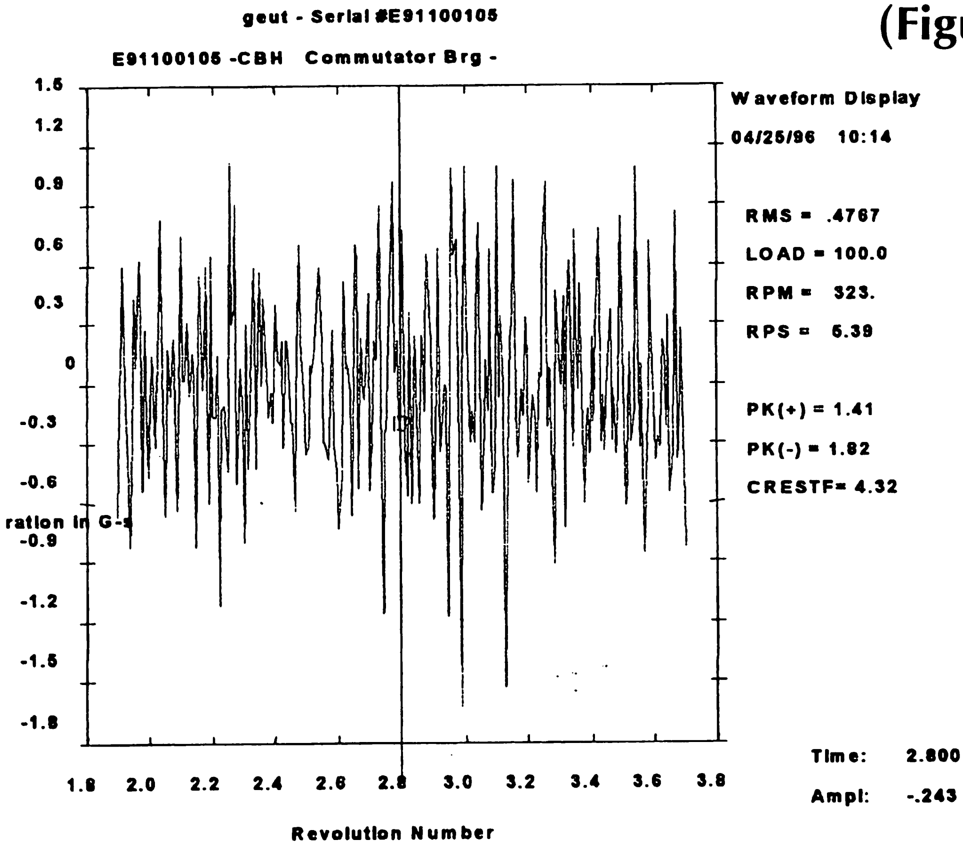
X - Amplitude

Y - Time



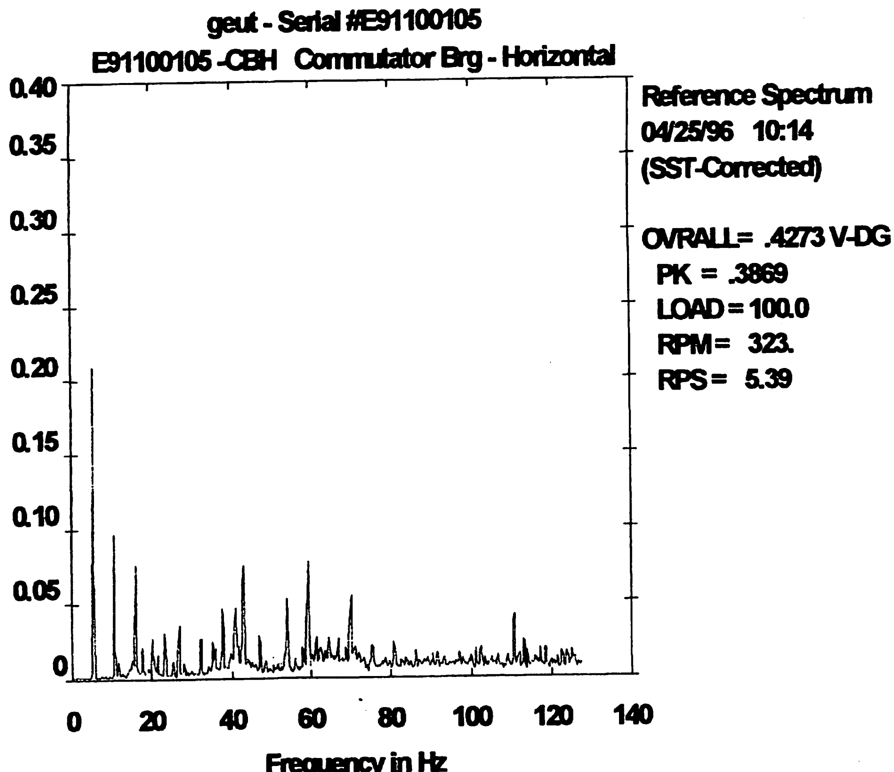
(Figure 1)

(Figure 2)

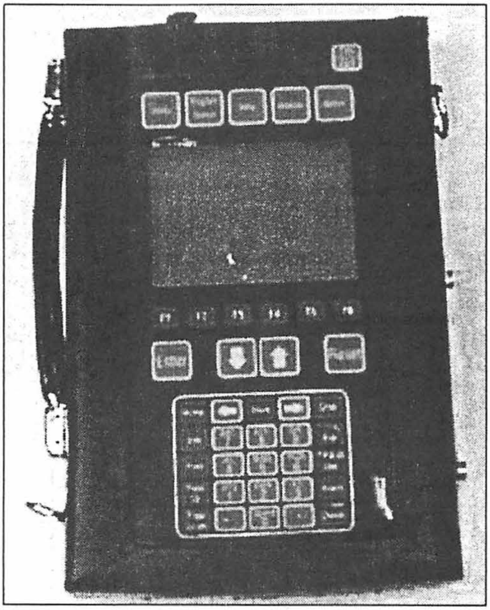


geut - Serial #E91100105
E91100105 -CBH Commutator Brg -
Waveform Display
04/25/96 10:14
RMS = .4767
LOAD = 100.0
RPM = 323.
RPS = 5.39
PK(+) = 1.41
PK(-) = 1.82
CRESTF= 4.32
Time: 2.800
Ampl: -.243
ration in G-s
1.5
1.2
0.9
0.6
0.3
0
-0.3
-0.6
-0.9
-1.2
-1.5
-1.8
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
Revolution Number

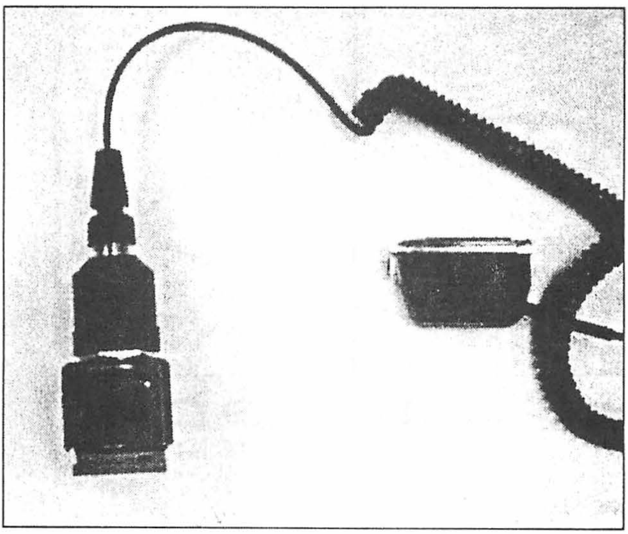
(Figure 3)

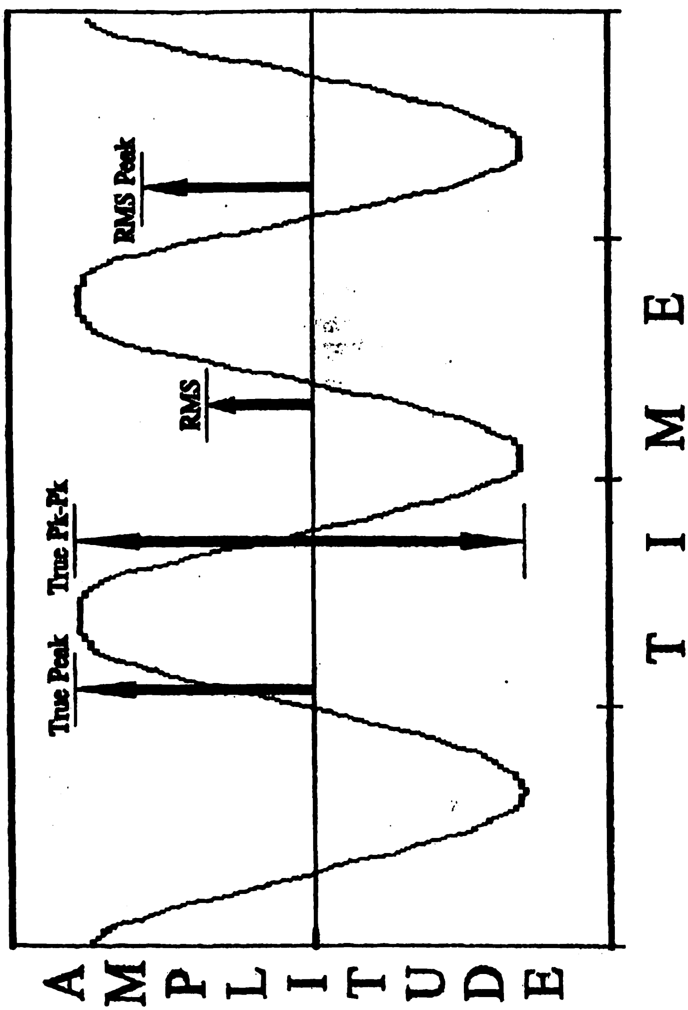

geut - Serial #E91100105
E91100105 -CBH Commutator Brg - Horizontal
Reference Spectrum
04/25/96 10:14
(SST-Corrected)
OVRALL= .4273 V-DG
PK = .3869
LOAD = 100.0
RPM = 323.
RPS = 5.39
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
20
40
60
80
100
120
140
Frequency in Hz

(Figure 4)



(Figure 5)



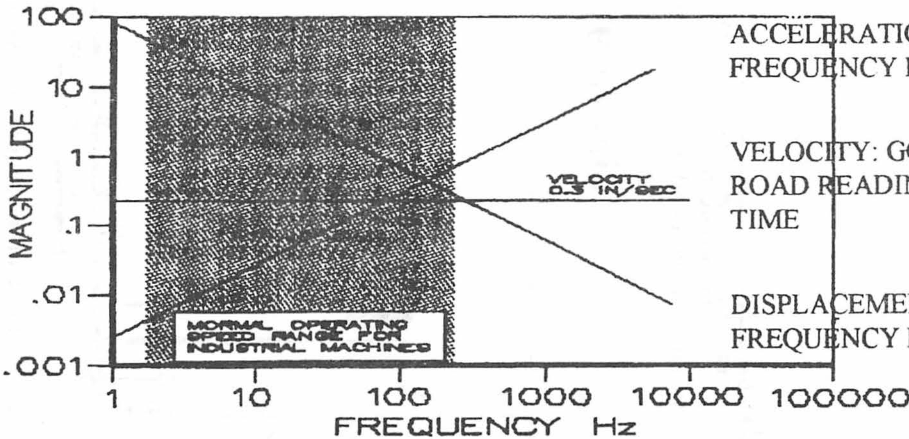


(Figure 6) MEASUREMENTS

(Figure 7)

Relationship Among
Displacement, Velocity, and Acceleration

RELATIONSHIP OF THE VIBRATION PARAMETERS VS FREQUENCY



ACCELERATION: GOOD FOR HIGH FREQUENCY EVALUATION

VELOCITY: GOOD MIDDLE OF THE ROAD READINGS. USED 95% OF TIME

DISPLACEMENT: GOOD FOR LOW FREQUENCY EVALUATION

(Figure 8)

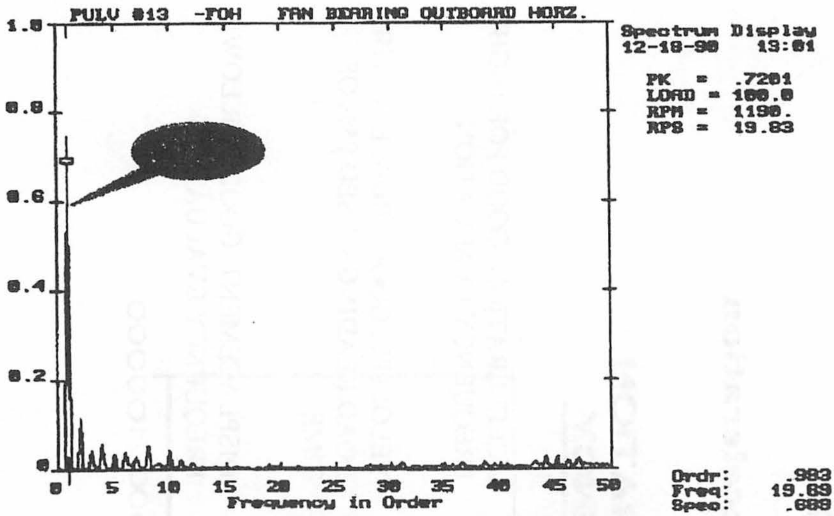


Figure 8 is an unbalanced condition. Note the high 1XTS.

(Figure 9)

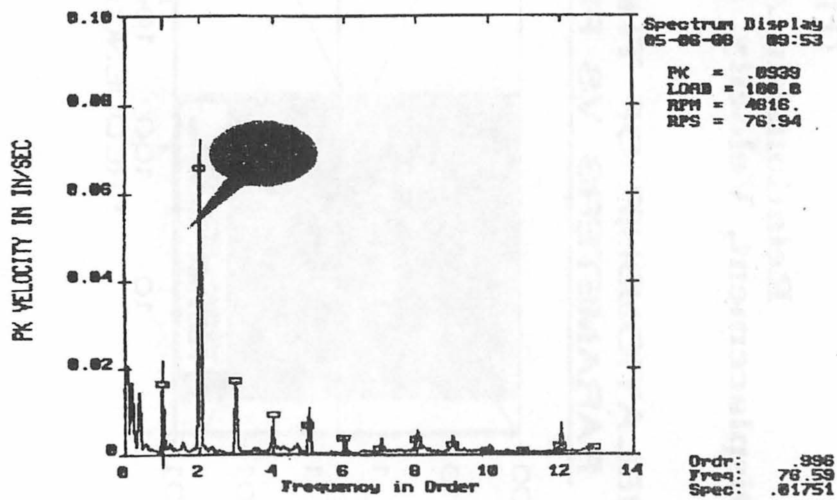
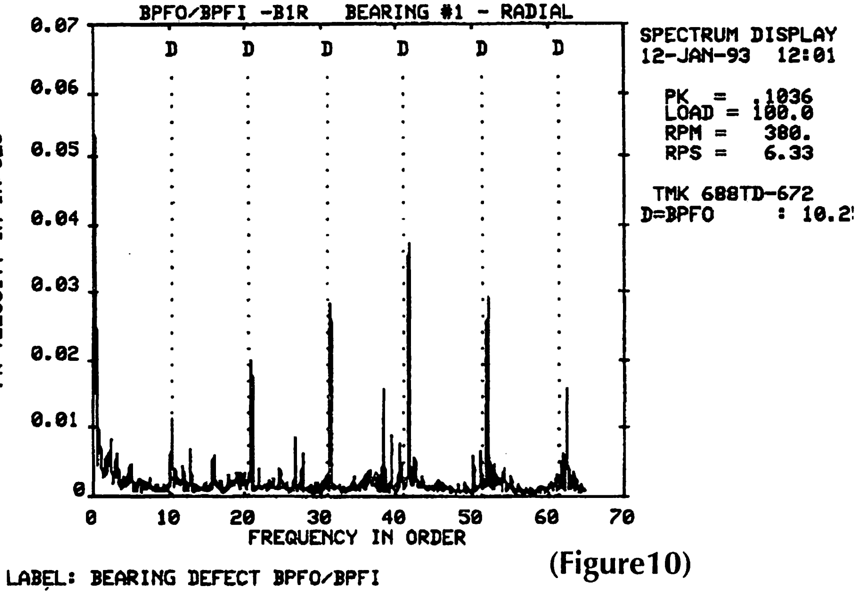


Figure 9 is an example of misalignment. As with the previous unbalance condition this is a synchronous defect. The big difference is that this occurs at 2XTS.

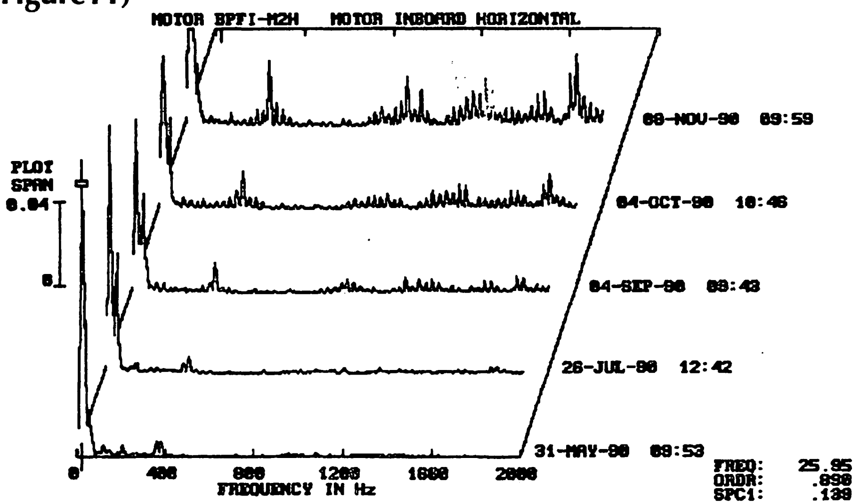
BEARING DEFECTS SHOW UP AS NONSYNCHRONOUS. THAT MEANS THEY ARE NOT AN INTEGER OF TURN SPEED. BELOW IS AN OUTER RACE DEFECT.



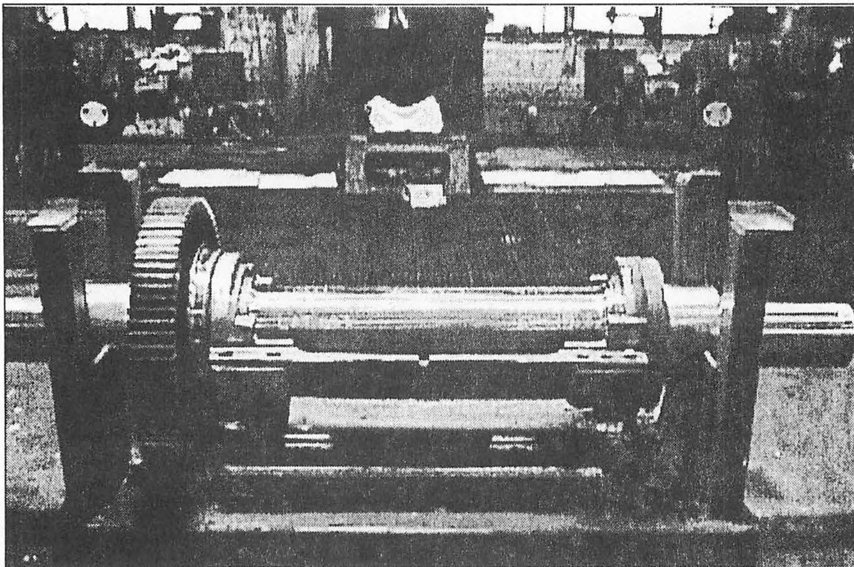
(Figure10)

TYPICALLY YOU WOULD LIKE TO SEE TRENDS DEVELOP THAT ALLOWS YOU TO PREDICT FAILURE BEFORE IT HAPPENS BUT ALLOWS YOU TO OPERATE THE MACHINE THROUGH ITS USEFUL LIFE.

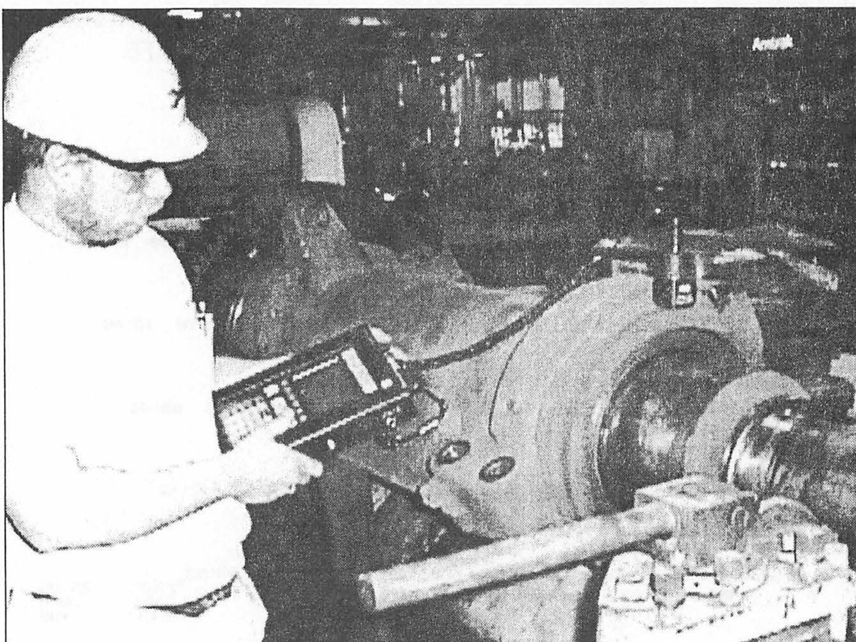
(Figure11)



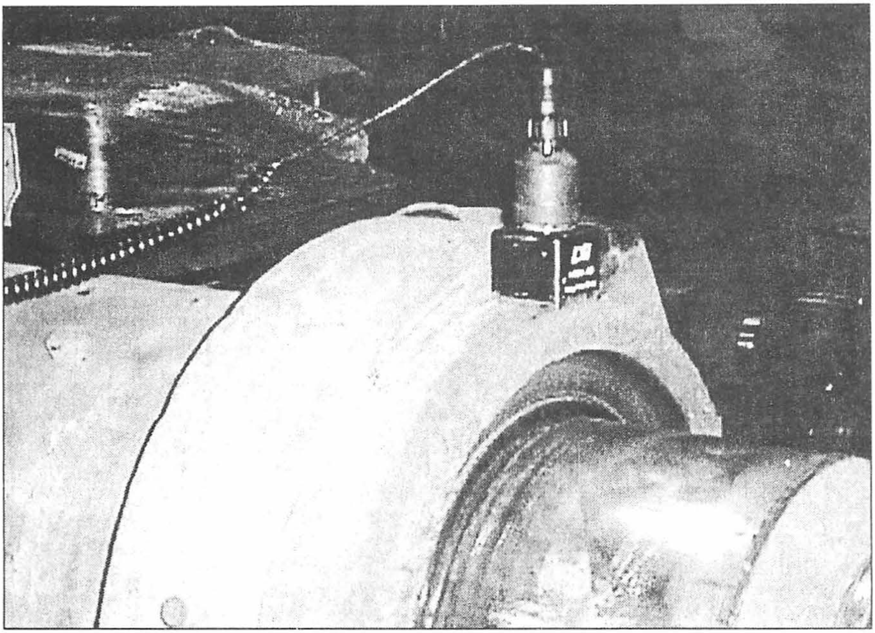
AMTRAK IS USING VIBRATION ANALYSIS TO DETERMINE THE CONDITION OF THE ROLLER TYPE MOTOR SUPPORT BEARINGS USED ON GE 752-AH TRACTION MOTORS. (Figure 12)



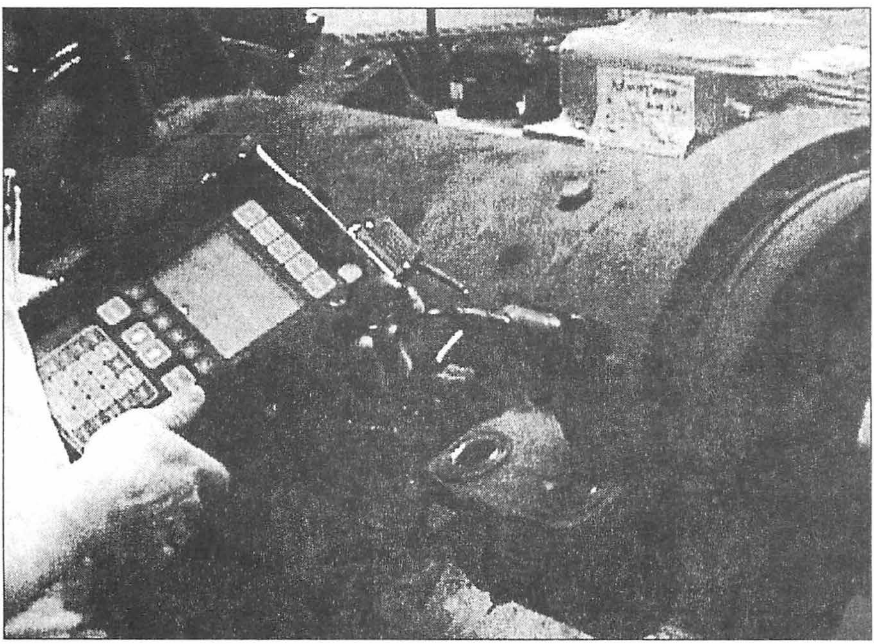
THE MEASUREMENTS ARE TAKEN AT SIX LOCATIONS WHILE MOUNTED IN A LATHE WITH A TURN SPEED OF 300 RPM (FIGURE 13, 14 AND15) (Figure 13, Below)



(Figure 14)

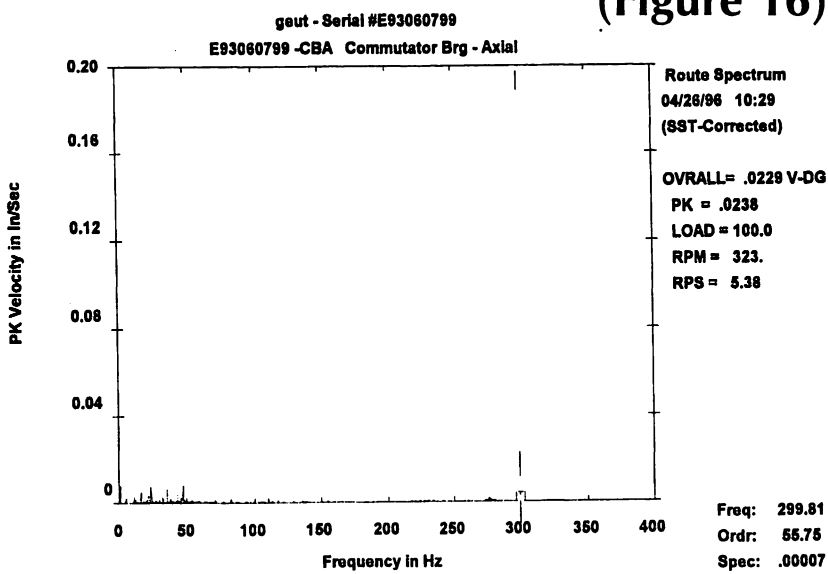


(Figure 15)



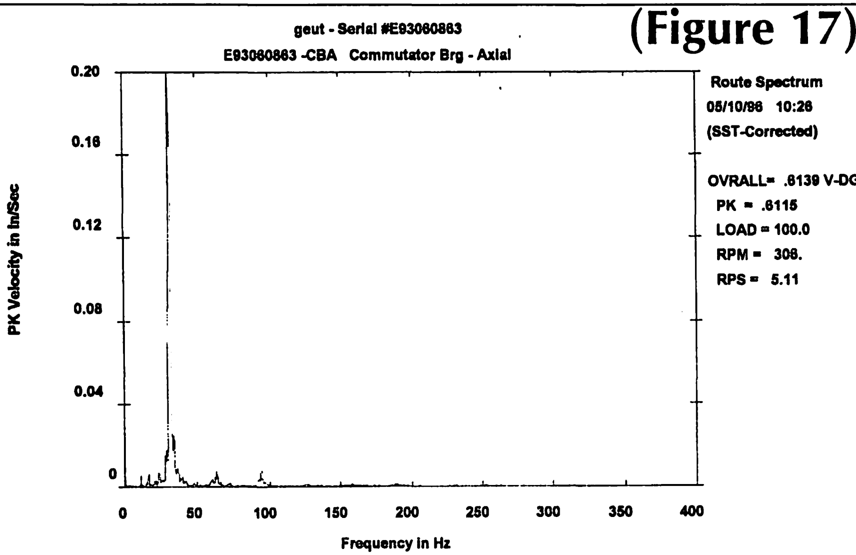
THE SPECTRUM OF A NEW U-TUBE ASSEMBLY
NOTICE THE LOW AMPLITUDES AT ALL FREQUENCIES.

(Figure 16)

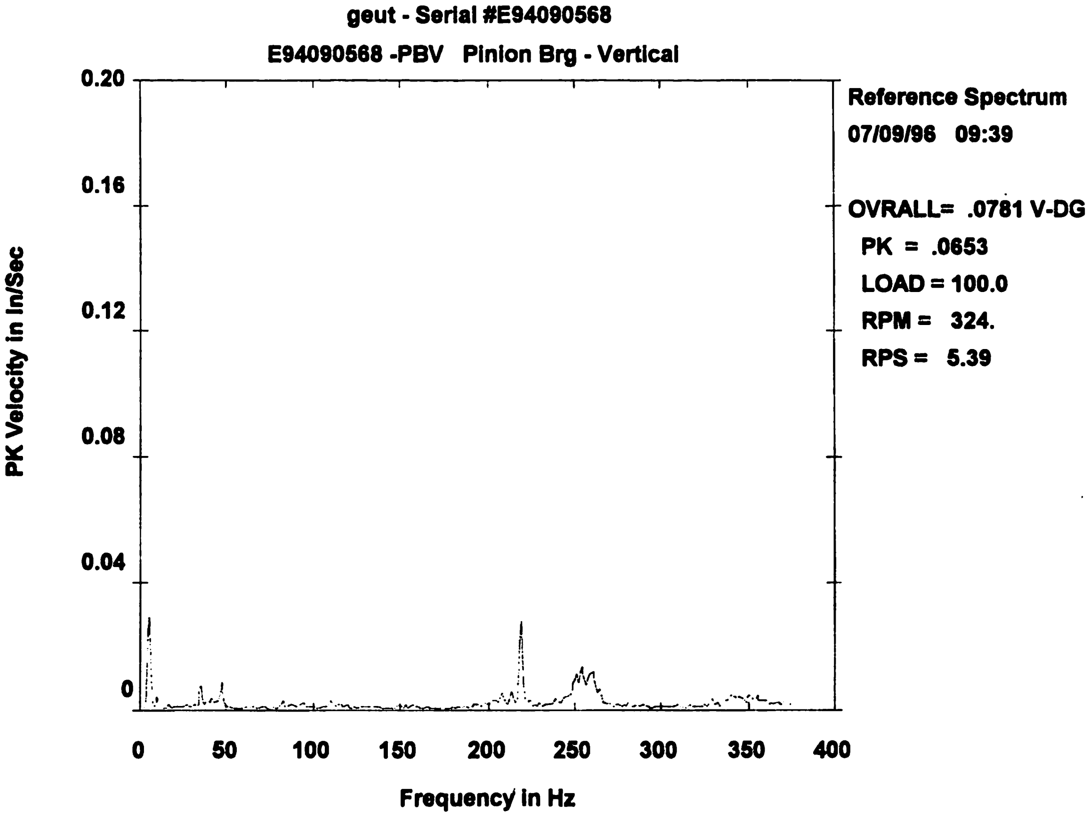


THE NEXT EXAMPLE SHOWS A KNOWN BAD BEARING.
NOTICE THE HIGH READINGS ON THE Y-AXIS. A TEAR DOWN INDICATED WATER ETCHING.

(Figure 17)

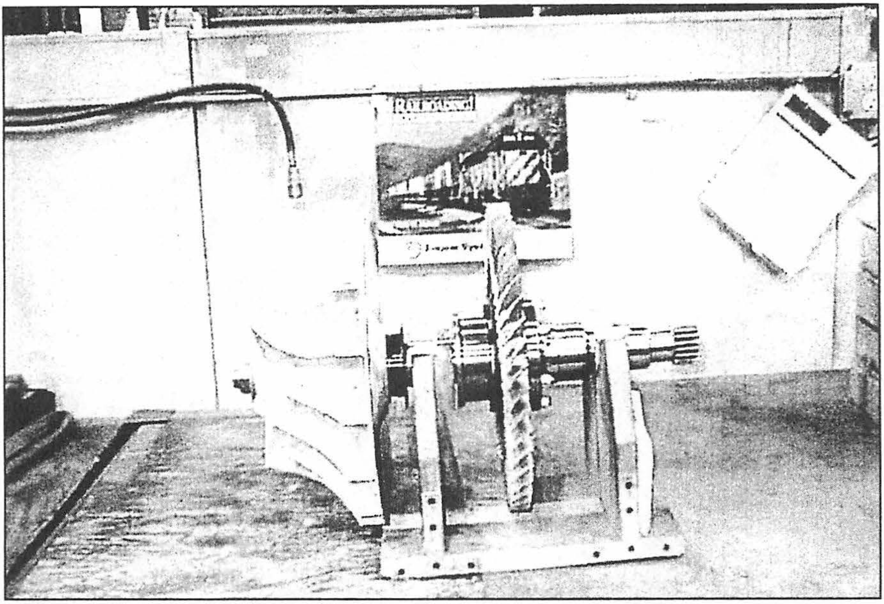


(Figure 18)

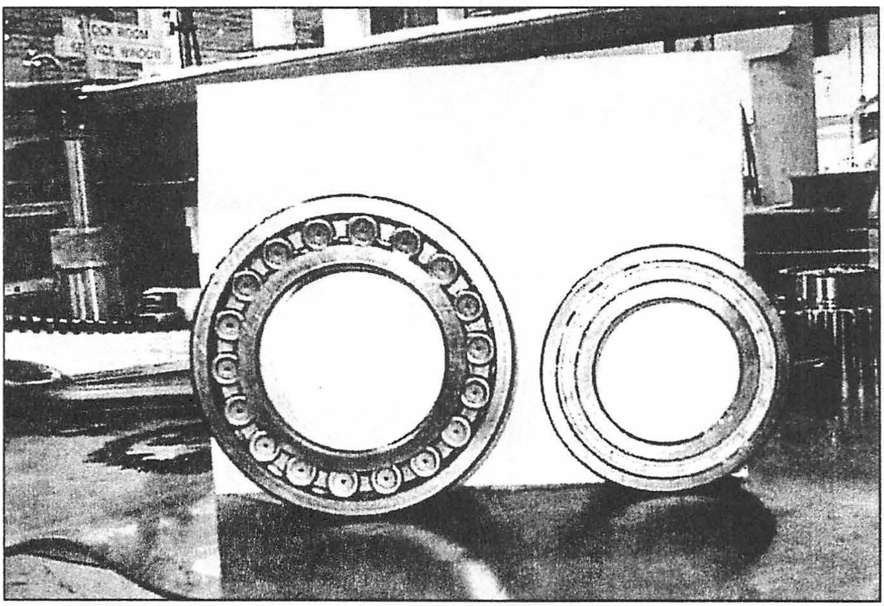

geut - Serial #E94090568
E94090568 -PBV   Pinion Brg - Vertical
PK Velocity in In/Sec
0.20
0.16
0.12
0.08
0.04
0
0
50
100
150
200
250
300
350
400
Frequency in Hz
Reference Spectrum
07/09/96   09:39
OVRALL= .0781 V-DG
PK = .0653
LOAD = 100.0
RPM =   324.
RPS =   5.39

(Figure 19)

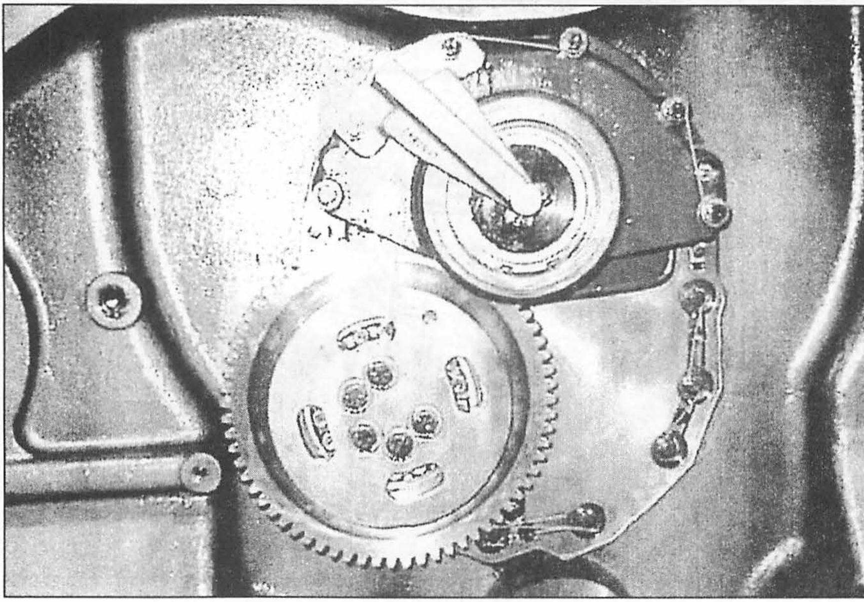
(FIGURE 20)
ROTOR ASSEMBLY



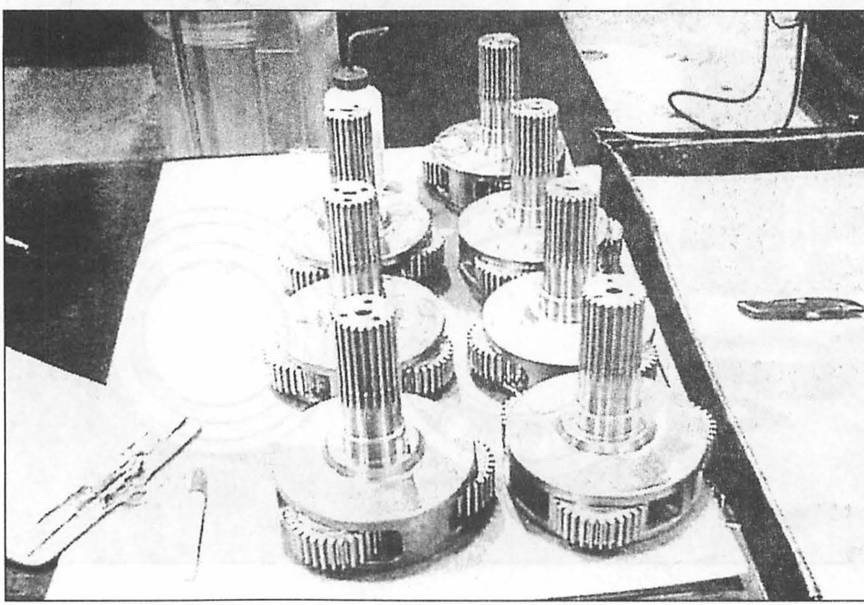
(FIGURE 21)
IDLE AND CARRIER GEAR BEARINGS



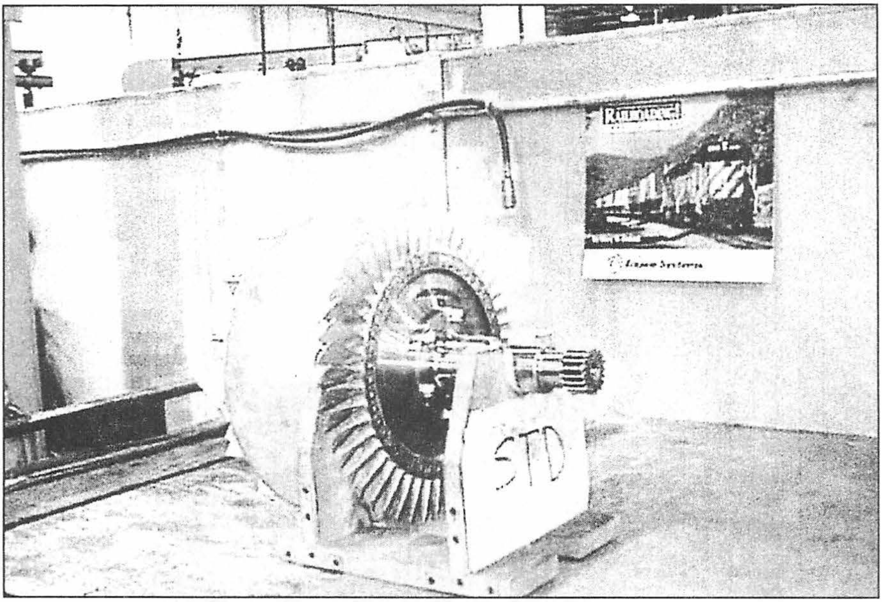
(FIGURE 22)
IDLE AND CARRIER GEARS



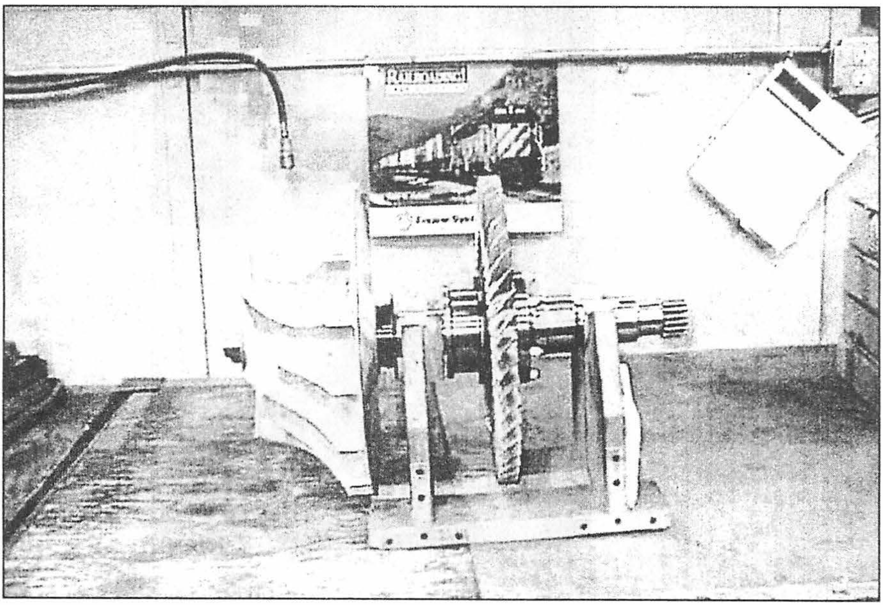
(FIGURE 23)
PLANETARY GEARS

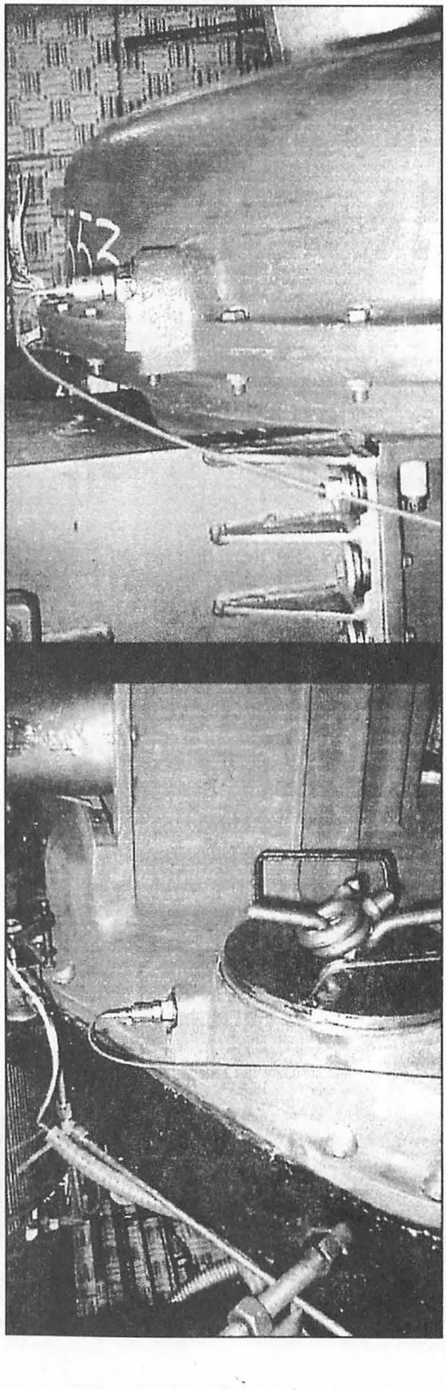


(FIGURE 24)
TURBINE BLADES



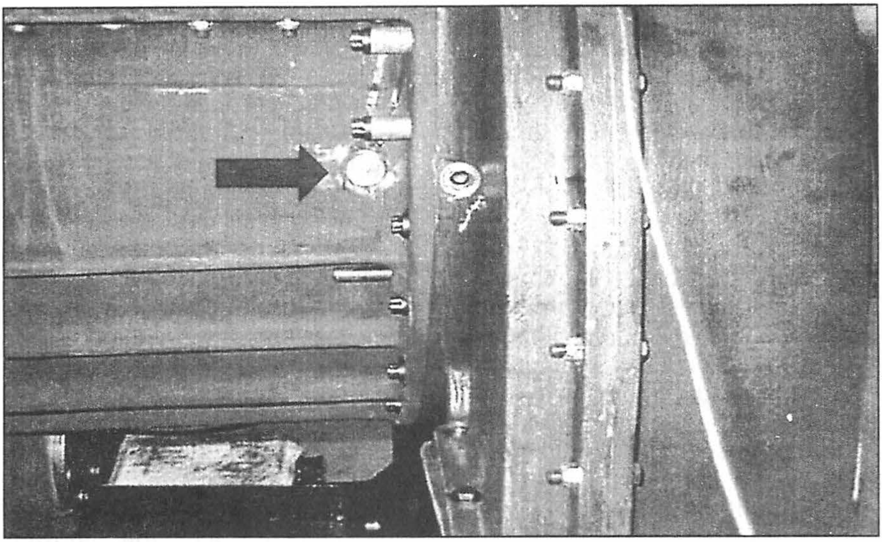
(FIGURE 25)
IMPELLERS





(FIGURE 26)

(FIGURE 27)



Best Practices
II. EMD POWER ASSEMBLIES CHANGE OUT PRACTICES FOR REGIONAL AND SHORT LINE RAILROADS

by Joaquin Flores
Illinois Central

The goal of all railroads is to have reliable locomotives at the lowest cost possible. For some railroads the ideal strategy would be for components to fail by normal wear in conjunction with periodic inspections. For others a disciplined scheduled change-out of components measured either by mileage, age or fuel consumption is the ideal solution to prevent road failures.

Power assemblies could very well be the components that are changed out the most often on any locomotive.

We decided to look at different practices and different specifications for different railroads to see what kind of results they were getting. The data we compiled are strictly raw data. There are many components and/or practices that would effect the life of a power assembly, for example:

- Type of lube oil
- Injector
- Lash adjusters
- Condition of the camshaft
- Condition of the rocker arm rollers
- Proper flow of the coolant
- Use of the locomotive. (Pulling one ton per HP?)
- Perhaps the most important is proper installation.

Some of the practices were clearly developed with the intent to minimize or eliminate any road failures caused by power assemblies, others are intended to minimize the cost of the replacement part, knowing that their practices increase the risk of road failures related to power assemblies. Others are trying to obtain both benefits of low cost and no road failures.

We hope that you can use some of these data to help you on your search for the most effective practices for your operation.

Railroad "A"

This railroad's strategy is to equip its locomotives with OEM components and to shop the locomotives every 800,000 miles to change all the power assemblies. The mileage is usually reached in eight years.

Specifications

Head: New Diamond 6 with new valves, springs and keepers.
Liners: New hub liners.
Pistons: New with hardened top ring groove.
Tin plated piston skirt.
Pre-stressed stainless steel piston ring.
New thrust washer.
New carrier assembly.
New insert bearing.
New connecting rods.

82% of the original power assemblies remain working until the next scheduled change-out, which is about eight years.

The average service is 7 years, 4 months.

The average current life of

power assemblies currently in service is 5 years, 5 months.

A visual inspection without water pressure of the power assemblies is done on every 92-day inspection.

They change the injector, lash adjuster and connecting rod bearing when they change the power assembly.

Ring land, lead readings and pressurizing of the engine are done every 12 months.

Railroad "B"

This railroad only change those power assemblies that have failed or are found to show some signs of premature wear or some defects which are only going to contribute to premature failure of the power assembly.

Specifications

- New hub liner
- Diamond 5 Clark head or Diamond 6 or 7 EMD or Hatch & Kirk with new valves, springs, locks, keepers, and rocker arm studs.
- Piston with tin plated skirt.
- New carrier insert.
- Pre-stressed stainless steel piston rings (Kaydon or EMD).
- All new basket bolts must be supplied with each assembly.
- New rod to piston pin bolts.

The following components shall be new or reconditioned:

- Carrier
- Piston pin
- Carrier thrust washer
- Qualified rod less than ten years old or remanufactured.
- Rod with new basket remanufactured by Throjan.
- Hollow pin dowels installed in fork rod.
- Qualified snap ring.

The average service life of the power assemblies is eight years.

The average current life of the power assemblies currently in service is 4 years, 9 months.

The injectors, lash adjusters, piston cooling pipe and connecting rod bearings are changed when the power assembly is changed out.

A visual inspection without water pressure of the power assemblies is done on 92-day inspections and every six months 20 lbs. of water pressure is applied to the locomotive.

Every 24-month inspection the ring land and lead readings are recorded.

Condemning limits are ring land .022 and lead readings .068 or higher but it should also have an increased reading of .038 from the previous reading.

Railroad "C"

This railroad replaces power assemblies that fail. It uses rebuilt power assemblies and pays attention to the cost of the component.

Specifications

- Requalified or new Diamond 4 or better head.
- Requalified valves, springs, guides, etc.
- Reconditioned pattern "A" chrome liner.

- Tin plated piston, by EMD specifications.
- No oversize ring grooves allowed.
- Maximum wear step of .0002".
- Requalified piston pin.
- New silver inserts.
- Kaydon rings.
- Qualified rod less than 25 years old.

The average service of life of the power assemblies is 2 years, 11 months.

The power assemblies are inspected thoroughly every 92 days, including water pressure, and ring land readings (.025).

Lead readings are recorded every 12 months.

Railroad "D"

This railroad has a unique way to keep track of the age of the power assemblies.

It's locomotives are scheduled to have all their power assemblies changed out when the locomotive uses one million gallons of diesel fuel, which by its estimates takes about nine years.

It uses two different specifications on its power assemblies; one for the assemblies that are applied to the locomotive during the scheduled change out, the other is to replace the new power assemblies that fail.

New Assemblies

- #4 heads, new or requalified.
- Everything new on heads.
- New cast iron liners.
- New piston.
- Kaydon rings.
- Requalified pin.
- New rods.
- New rod to piston bolts.
- Silver plated insert bearing.
- Requalified thrust washer.

Replacement Assemblies

- Reconditioned #4 head or better.
- New valve guides.
- Requalified valves, springs, etc.
- Reconditioned liners.
- Reconditioned piston.
- New Kaydon rings.
- Requalified pin.
- Requalified rod.
- Requalified thrust washer.

The reconditioned power assemblies come from their own pool from the new power assemblies that are changed out due either to schedule or failure.

62% of the power assemblies last the duration of the schedule, which is one million gallons of fuel or approximately nine years.

Their average useful life is 7 years, 4 months.

The average current life of the power assemblies in service is 4 years, 6 months.

The power assemblies are inspected on every periodic inspection, no water pressure is applied to the locomotive and no ring land and lead readings are taken.

On annual inspections only, they pressurize the engine, record lead readings and record land reading.

This railroad maximizes the life of the power assemblies by using

its own discretion to condemn power assemblies on locomotives that are scheduled for assembly change outs in the near future. This extends the life of some power assemblies, which would be changed out if there were no schedule in place.

Railroad "E"

This railroad's policy is to change the power assemblies that fail; it does not have a scheduled change out in place.

It overhauled a large number of prime movers in 1990 and it reports that this was a wise move. It decreased the number of road failures that were related to power assemblies considerably, and by having all new power assemblies the engine ran better and it extended the life of the power assemblies.

Specifications

- The power assemblies are from EMD.
- Diamond 5 head.
- Requalified springs, valves, guides, etc.
- Iron liner.
- Standard piston.
- Prestressed stainless steel ring set.
- New silver plated insert bearing.
- Qualified pin.
- Qualified rod.

Most of the failed power assemblies were changed out within the first two years. The power assemblies lasted an average of 7 years, 8 months. The power assemblies are not looked at during the quarterly inspections, only every six months, and the ring land and lead readings are recorded every 24-month inspection.

Railroad "F"

This railroad has been maintaining historical data since 1995.

The power assemblies are replaced when they fail.

Specifications

The following components shall be new or reconditioned and meet OEM specifications:

- Chromium liner.
- Diamond 4 or 5 head with qualified valves, springs, and new keepers and keeper seats.
- Piston with laser hardened ring land and tin flash coating.
- New carrier insert bearing.
- Ring set from EMD or Kaydon.
- Qualified carrier.
- Qualified piston pin.
- Qualified carrier thrust washer.
- Qualified rod less than 20 years old with follow pin dowels in fork rod.
- Qualified rod to piston pin bolts.
- Two year warranty. Counted from the date assembly is put in service.

The average service life of the power assemblies that have failed and were installed since 1995 is 21 months.

The average current life of the power assemblies currently in service which were changed out since 1995 is 20 months.

The power assemblies are inspected every six months with water pressure.

The ring lands and lead readings are recorded every 12 months.

Railroad "G"

This railroad did not have any historical data on power assemblies at the time that these specifications were being put together but it is sharing its specifications with us.

It changes the power assemblies when they fail.

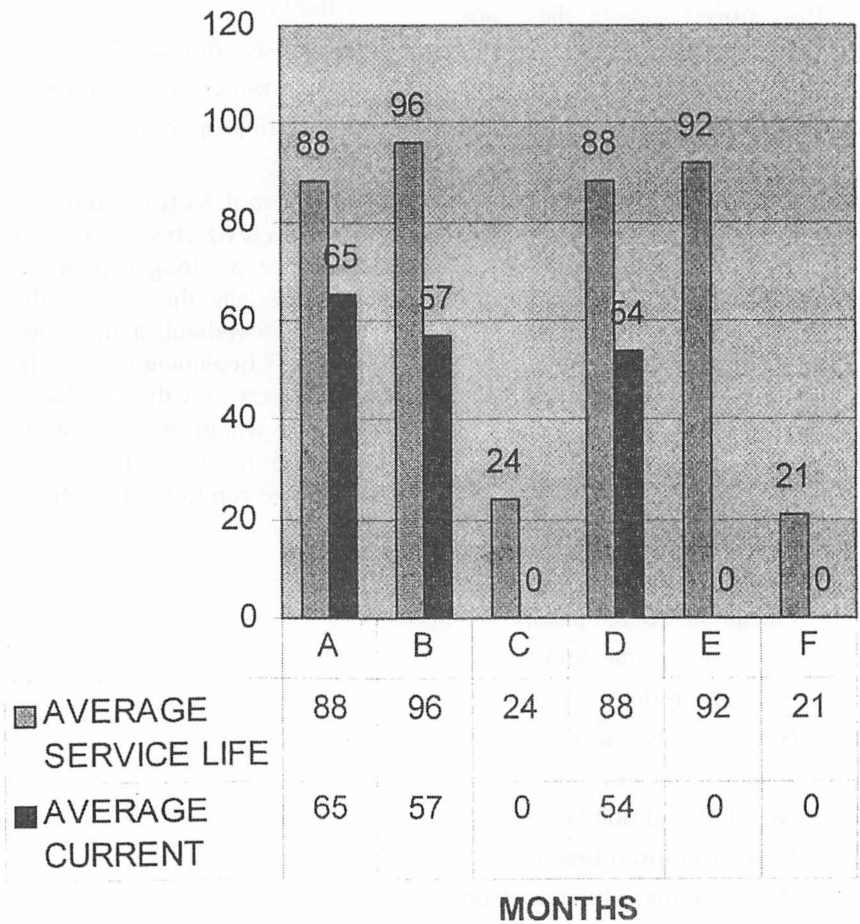
Specifications

- Diamond 4 head or better, no welded/Jones process.
- Pattern "A" chrome liner.
- Phosphate coated piston.
- New valve guides/locks.
- New piston rings.
- New thrust washers.
- New gaskets and seals.
- New fork rod bolt kit.
- New silver insert bearing.
- All other material should be qualified.

All the railroads that we talked to change the power assemblies for the following defects:

- Water leak
- Cracked head
- Broken valve
- Excessively worn valve guides*
- Scored piston
- Scored liner
- Worn or slick rings*
- Bent rod
- Excessive ring land*
- Wrist pin or bearing wear*
- Lack of proper compression*

- The above defects marked "*" are defects which some railroads tolerate for a longer period of time, especially the ones with a scheduled overhaul; if the power assembly is beginning to develop these defects and the overhaul is scheduled within less than a year they tend to allow that power assembly to run until the overhaul.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MONTHS

III. IMPROVED ACCESS TO GE7FDL ENGINE INTAKE MANIFOLD FOR CYLINDER INLET PORT CLEANING

by Darlene Kisko, General Electric And Jack Kuhns, Hadady

Abstract

The scope of this paper documents the importance of diesel engine maintenance for optimum performance of a locomotive. One process for maintaining the engine is the removal of carbon build-up in cylinder inlet ports. Over the years, maintainers have successfully used several methods for inlet port carbon cleaning. Today, railroads need to realize lower operating costs; and one way to decrease costs is to increase productivity. A new method for cleaning cylinder intake ports has been developed. The use of air manifold access covers and dry ice provides a maintainer with a faster, simpler, and more economical way of cleaning inlet ports.

Introduction

On modern, high horsepower diesel-electric locomotives, it is essential that all aspects of maintenance (which maintain "as-new" performance levels) be identified and fully implemented. A shortfall in any area of builder-recommended maintenance can result in reduced locomotive availablility and higher operating costs. It is true that modern locomotives, and diesel engines which power them, are highly developed machines designed to be self-protecting against many failure modes. It is also true that modern locomotives will still operate with maintenance neglect, but this practice will result in higher operating costs and reduced component life.

Railroads generally recognize that deferred maintenance leads to long-term and costly problems. At the same time, it is realized that locomotives offered by the major builders have slightly differing maintenance requirements as a result of basic design differences. Railroad maintenance personnel, familiar with each builder's technology, have assisted the builders in identifying those areas where maintenance practices support locomotives in delivering all of the performance and operating cost efficiencies inherent in their basic designs.

The most economical combustion of #2 diesel, a fossil fuel of varying characteristics and levels of impurity, demands its own science. A critical part of this science is to maintain the diesel engine for minimum fuel consumption while providing full performance. The fuel and air systems of the diesel engine are <u>the</u> prime areas where degredation can and will occur.

Intake Port Carbon - A Definition (Figure 1)

Optimum diesel engine performance and economy are achievable only with the optimum combustion of a precise combination of fuel and air mixture and with the ease of entry and exit of the mixture through the combustion process and into the exhaust system. Any restriction of fuel and/or air will degrade performance and increase component temperatures. On a four-stroke cycle GE7FDL engine, the presence of carbon in cylinder inlet ports can negatively impact diesel engine fuel consumption and horsepower.

Just what is "port carbon", and why and where does it occur (Fig. 2)? Inlet port carbon is a combination of coke and products of the engine combustion process. Coke is formed as a result of lubricating oil that is exposed to high heat. Since no combustion process is 100% efficient, there are combustion by-products that develop as a result of the combustion process itself. The coexistence of coke and the combustion products is defined as carbon. Its existence in the intake port area of modern four stroke cycle diesel engines is a result of engine valve overlap, that is, periods when both the intake and exhaust valves are open at the same time for scavenging products of combustion. Port carbon is aggravated by those operations that result in the intake manifold pressure being lower than the exhaust pressure, such as engines idling for long periods of time and for high performance engines which are lightly loaded. Locomotive operational features also contribute to this engine problem. For example, use of notch 8 engine speed for grid cooling in dynamic braking on older GE locomotives results in lower inlet air manifold pressure which promotes inlet port carbon deposits.

A Historical Perspective (Fig. 3)

GE was aware of the detrimental effects of excess inlet port carbon to FDL engine performance before 1966. A GE GEMS article, published January, 1979, re-confirmed the implications of operating engines with excessive inlet port carbon deposits. A one-quarter inch carbon deposit in an inlet port decreased the inlet area of the cylinder by 30 to 40 percent. This decrease in inlet area resulted in an increase in pre-turbine temperature by up to 200°F. Piston crown temperature increase measured 77 degrees, and there were higher temperatures recorded over the entire piston area, as well as in the upper combustion zone of the cylinder and at the head-to-liner seal. These temperature increases also contribute to increased incidents of turbo surging under some altitude and temperature conditions.

By the end of 1970, GE was considering several maintenance processes to remove port carbon. This effort extended to contacting other GE product departments, notably GE jet engine, to determine what technology and processes were available.

By April, 1971, GE Product Service Bulletin #113 announced the availability of an inlet port carbon cleaning device (Fig. 4), consisting of an air blast apparatus which used crushed walnut shells as the cleaning media and a vacuum system for debris recovery. MIL spec. G-5634C outlined the general requirements for the walnut shells and included additional choices of cleaning media, including apricot pits, corn cobs, and peacon shells. The only medium GE ever tried was walnut shells.

There were a few drawbacks with the use of this system. First, an extensive cleanup was required, despite the fact that the vacuum apparatus was designed to recover the spent shells. Secondly, it took workers about eight hours per engine to perform this job. A second-generation walnut blaster, which was introduced in an August, 1981, GEMS article, allowed one operator to safely use the system (Fig. 5).

By November 1981, GE announced a change in the inlet port carbon cleaning process. A western railroad had experimented with the use of hot water under high pressure to clean inlet ports of GE engines, and GE adopted this as the preferred method.

The "HOTSY" kit (Fig. 6) is now the preferred GE method of cleaning engine inlet ports. The principal advantage of the HOTSY over the use of walnut shells has been time savings and lower cost.

In 1981, diesel fuel costs approached $1.00 per gallon. GE reiterated the importance of maintaining FDL engines to remove inlet port carbon on a scheduled basis. A GE laboratory test confirmed that a 40% reduction in the inlet port area due to carbon build up would reduce fuel efficiency as much as 1.5% on a duty cycle basis. At that time, GE recommended annual cleaning of inlet ports.

Recent Builder Developments

What has changed? The answer is "a lot!" The introduction of electronic fuel injection systems, that are microprocessor controlled, permitted systemic improvements to the entire fuel intake and combustion process. Current GE technology for EFI permits a high performance FDL engine with even greater horsepower along with further reductions in fuel consumption and less sensitivity to partial load operation.

Extensive time in idle, formerly a major contributor to the formation of inlet port carbon, was significantly improved with more precise metering of fuel at the low notches. Additional engine changes to the cooling system, the turbocharger and the camshaft provided a reduction in the time of inlet port carbon formation. The net result of these changes increases the time interval 50% before inlet port cleaning is required. For railroads, the resulting benefits include lower life cycle fuel consumption, extended component life, reduced emissions,

and a reduced need to shop the locomotive to restore its original performance, thus increasing availability.

New Cleaning Method

For older GE locomotives that are governor equipped and use a mechanical injection system, there is another change on the horizon; and it is both a money saver and a time saver.

One major eastern railroad is successfully using dry ice in a blasting type application to clean carbon build up in the ports and on the intake valves. An inlet air manifold with a port opening has been designed to provide access to each cylinder. One engine bank at a time is cleaned. Remarkably, the cleaning is accomplished with the engine idling! Dry ice changes directly to carbon dioxide. Since there is no water phase, water handling equipment is not required. Port carbon is exhausted through the exhaust stack, so there is very little cleanup. This process is more efficient than previous methods and is expected to reduce the time to clean intake ports. With the modified manifold sections applied the railroad hopes to reduce the current 16 man-hours down to two.

Figure 7 shows a Durox modified air manifold with access port. This design cover is easy to install and remove, but still must be torqued to insure a proper seal on the gasket.

Figure 8 shows a dry ice pellet blasting machine.

Figure 9 is a photo of the dry ice machine being loaded with dry ice pellets. Dry ice is a solid phase of dry ice gas. The solid phase temperature is -109°F, Dry ice is not harmful unless it is misused or misapplied. Figure 10 is a photo of inlet port being cleaned. Figure 11 shows inlet port carbon before and after dry ice cleaning.

New Program Discussion

The original program goal was to provide a cost-effective solution to the recurring high labor costs associated with the traditional methods of port cleaning. A goal was established to restore the individual components' service lives to precondition expectations. These goals have been met with the latest system maintenance requirement - the adoption of this cleaning process.

At this time on CSX, 150 plus locomotives have been equipped with the modified manifolds and quick access covers. The approximate initial cost per locomotive is $1500 which includes modifying the manifolds and purchasing the sixteen port access covers. The cost of the dry ice pellet blasting machine is around $15,000. The normal consumption of dry ice is about 50 pounds per engine; and the current price is $.35 per pound (approximately $17.50 of product cost per engine).

CSX incorporated numerous other work station improvements to facilitate this program and "customize" it specifically for this program. The design of the entire program, which includes the design of the individual components, as well as the design of the modified work station, was the cooperative result of CSX locomotive and facilities engineering staffs and the skilled shopcraft employees of CSX's Waycross, Georgia heavy repair shops. An in-depth analysis of the equipment and the workstation design will be covered by the Shop Equipment Committee's presentation on this topic.

It should be understood that the initial cleaning process with the dry ice pellets takes approximately the same amount of time as other cleaning methods and other similarities include manifold removal, cleaning, and reapplication to establish a baseline. (The existing buildup is generally hand scraped to remove the heaviest deposits to speed up the cleaning process.) The new process eliminates post cleanup time associated with waterborne systems and solid particle systems such as the walnut shell blast. The initial dry ice cleaning is performed with the engine at idle power. The cleaning station also remains very clean without the need for post-process cleanup. Without the modification, port cleaning will usually require two mechanics approximately one shift or 16 man-hours to complete the inlet air manifold disassembly and re-assembly process which includes the systematic pushrod removal and engine barring over procedure required for cleaning each cylinder. Once modified, the savings stand out very clearly.

With the modified intakes, the process could reduce the cleaning time significantly to complete (1-2 hours) by simply removing the access cover, cleaning the port, then reapplying the cover. Again, this process is done with the engine at idle. Ideally, this would be scheduled annually during routine locomotive 92-day service or washing.

The entire cleaning and modification process was successfully demonstrated by modifying a locomotive (that had approximately one-year buildup) with the port access system, then timing the cleaning process. The documentation of this step demonstrates the program's success. Currently, it appears that with the simplicity of this system, a one-year interval between cleanings will be desirable to maintain the engine's performance.

Another critical part of the program evaluation was to perform a tear down of an engine that had undergone the cleaning procedure and then return it to service. This tear down was performed to determine if there were any negative effects of the intake deposits passing through the cylinders and possibly scoring the cylinder walls. There were none found. Additionally, the valves, the exhaust system, and the turbocharger inlet and turbine wheel were inspected. The tear down also revealed no negative effects of the debris ingestion on any of the components.

At this time, benefits to over all locomotive performance continue to be collected; however, the reduction in reported "black smoke" and "reduced loading" line of road failures are observable. The measured individual benefits related to components are available; that is, returning power assembly life expectancy, as well as returning extended turbocharger life with an associated reduction in the possiblilty of overheat/overspeed failures. All these benefits point towards a reduction in fuel consumption, due to maintaining the optimum fuel/air ratio.

Additional Applications of Access Covers

At the beginning of this year, Union Pacific Railroad began testing a locomotive equipped with modified manifolds with quick access covers. For an added measurable dimension, these covers are being endurance tested for extreme altitudes and temperature conditions.

Also, GE has designed and is testing a new cast manifold with an access cut-out which allows for a convenient way to inspect and clean the intake and exhaust valve without the need to remove the manifold body. Two CSX locomotives were equipped with these prototype manifolds in late May of this year.

Conclusion

Maintenance continues to play a large role in optimum performance of railroad assets. The enhancement of current maintenance practices and the development of new processes provide the railroad industry with a trend for sustained growth in terms of productivity. Additionally, future regulatory requirements (exhaust emissions) are to be considered in each enhancement and/or development. The modified manifolds and the dry ice process consider these factors and continues the productivity trend.

Acknowledgements

The author gratefully appreciates the contributions of time and expertise . of the following individuals: Jack Kuhns, co-author; Donna Perino and Tom Gerbracht, GE Transportation Systems; the Shop Equipment and Processes Committee in its joint effort with this paper, and special recognition to the CSXT team.

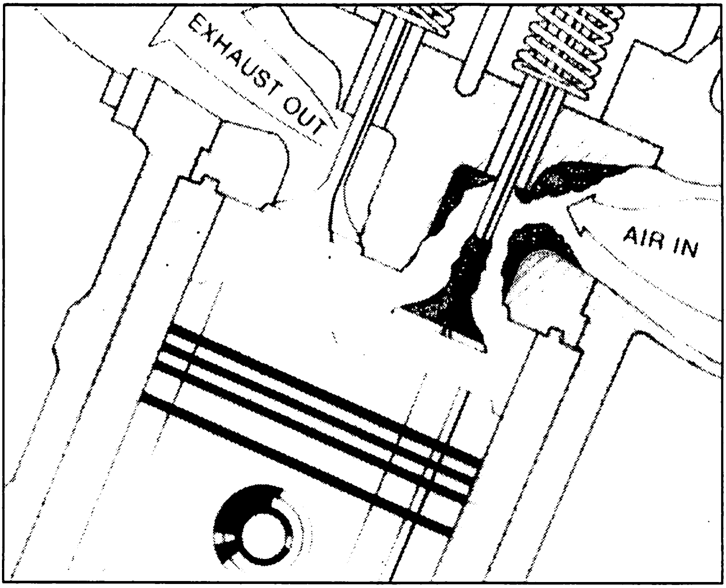


Figure 1

Port carbon builds up on the walls of the air inlet passage and on the inlet valves, restricting the passageway. This affects the air-fuel ratio unfavorably and also increases temperatures. (Figure 1, above)

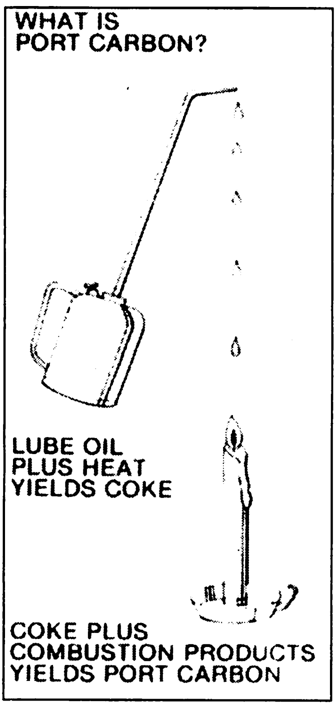


Figure 2

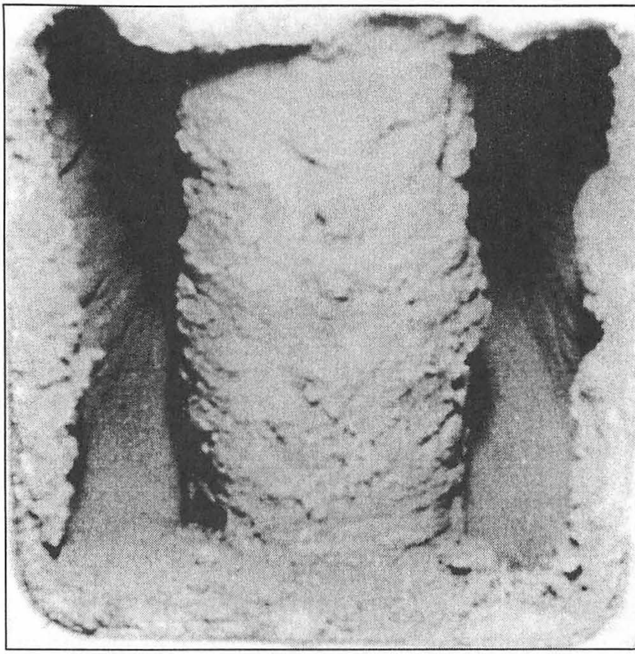


Figure 3

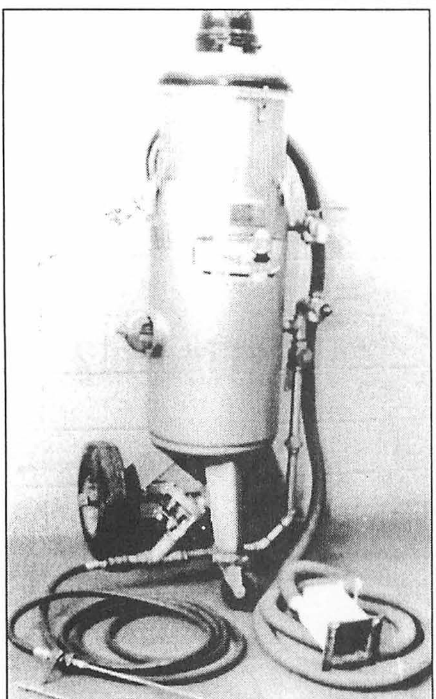


Figure 4

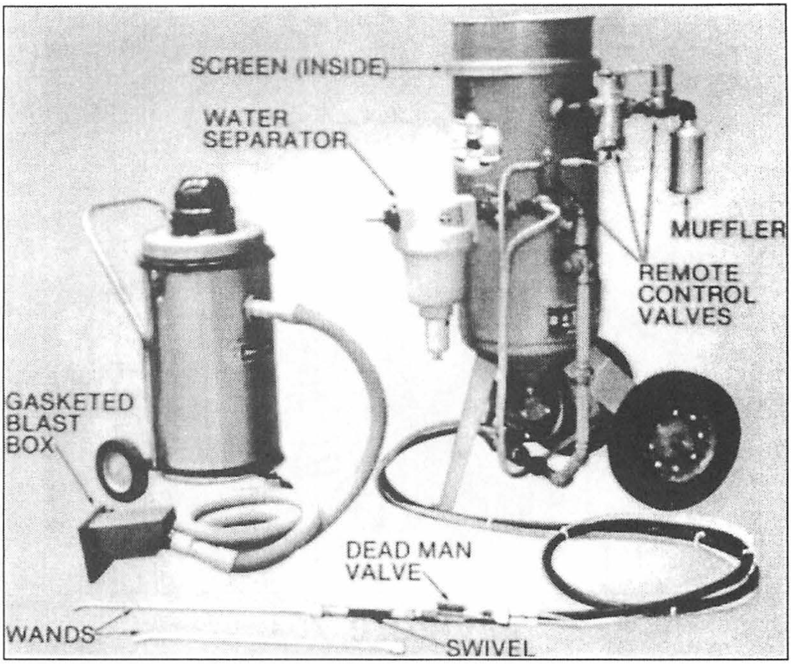
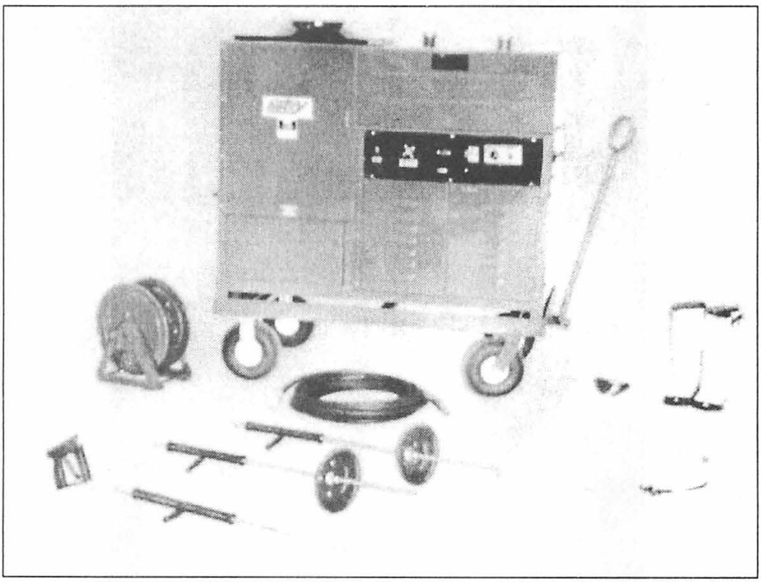

SCREEN (INSIDE)
WATER SEPARATOR
MUFFLER
REMOTE CONTROL VALVES
GASKETED BLAST BOX
DEAD MAN VALVE
WANDS
SWIVEL

Figure 5



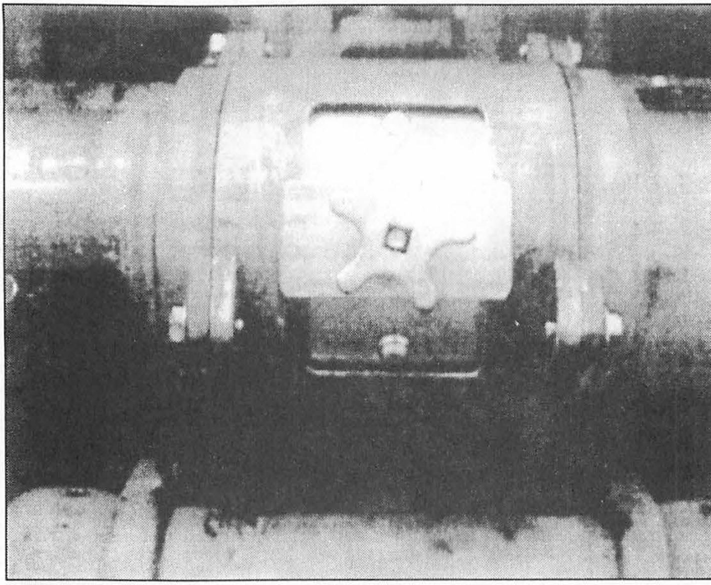


Figure 7

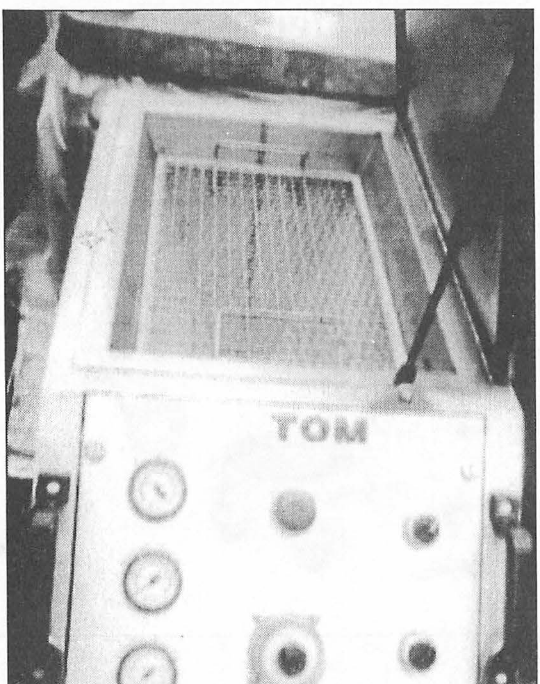


Figure 8

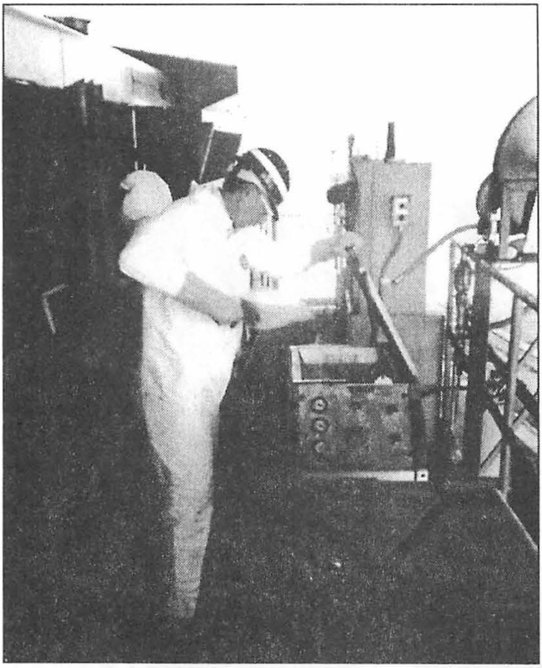


Figure 9

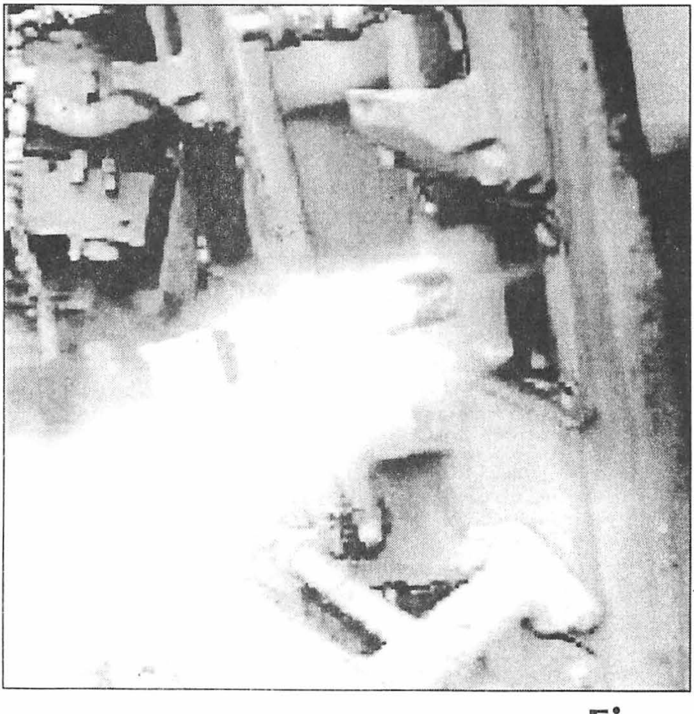


Figure 10

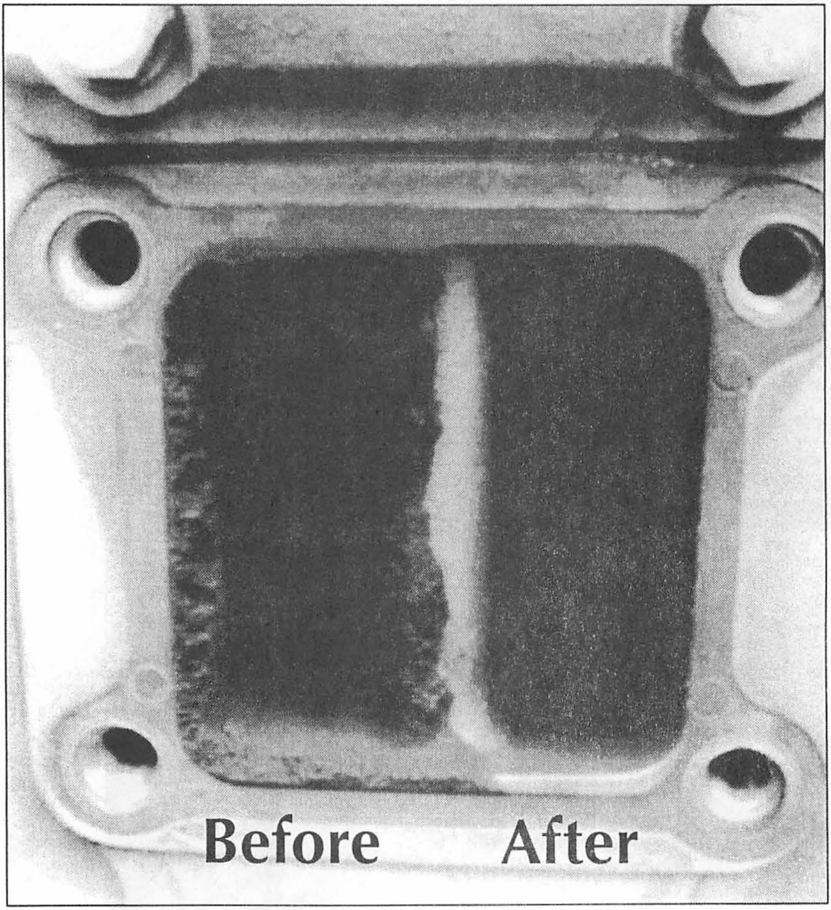


Figure 11

IV. WHATS AHEAD IN PLASTICS FOR LOCOMOTIVE APPLICATIONS

by Stan Houston, P.E.
Houston Polymers

Plastic has enjoyed many successes in the locomotive industry and the ever increasing applications plastic will address in the future will continue to promote cost savings through extended locomotive component service life. Plastics are not only here to stay, they are a viable cost savings tool we now must all learn to exploit.

With this as a background, this paper will cover a very brief history of materials and applications, the new plastics on the horizon, and finally, some of the environmental issues surrounding plastics.

Starting in 1956 three plastic resins were introduced as materials suitable for locomotive products; and they stayed the dominant resins of choice up until 1975: These three plastics were thermoset polyesters, phenolics, and cast nylons. These resins were used in the manufacture of the very first plastic locomotive products: In the cab and topside of the engine, some electrical panels were formed from thermoset polyester sheet. The locomotive truck saw center plate liners and a few other miscellaneous wear plates, which were cast from thermoset phenolics and nylons. Both the carbody and cab structure saw virtually no plastic products in those early years.

Twenty years later, in the middle 1970's, several new plastic resins became available for both new and old locomotive component applications. Along with these new resins, variations to the original three became available as well. Since the middle 1970's, continued growth in polymer science has brought us to where we are today: with a varied mix of tough, high heat resistant, and flexible polymer resins.

Today, thermoset polyesters and phenolics are alloyed with other ingredients making them tougher and with higher heat capacities than those offered in the sixties and seventies. Nylons are now available in injection molding grades which offer 3-4 times greater impact and fatigue strengths than earlier versions. Acetals, more widely recognized by the names Delrin and Celcon, came on stream in the late 70's offering superior wear properties to those of most nylons in medium load bearing applications. Urethanes are now available that can be both cast and injection molded for a variety of cushioning and dampening products. Besides these, a host of exotic materials have begun to see their way into all transportation markets: resins such as Vespel from Du Pont, Ultem from GE and Torlon from Amoco, all began addressing potential locomotive products in the 1980's. And finally, the introduction of the flouroplastic family of resins brought us Teflon, again from Du Pont.

Since their introduction, these new resins have been used in the following product applications: In electrical applications such as brake-grid and related electrical panels, thermoset polyesters are now the norm. In the engine, individual power assembly covers for EMD 645 engines are made from thermoset polyester alloy. Valve umbrellas on GE engines are made from both Teflon and Ultem. Locomotive trucks are now dressed-out in full battle armor using both cast and injection molding grades of nylon for all types of impact/wear plates. Additionally, thermoplastic polyurethanes are being added as support architechure for certain nylon wear plates. The combination of nylon and urethane in certain applications is proving a worthwhile addition in the battle against abrasive wear to the truck. The carbody itself has implemented changes such as plastic inspection door hinges and pins made from nylon alloys and acetals. In the cab, reverser and brake handles and entire engineer consoles have successfully been molded from thermoplastic nylon alloys, and thermoset polyesters.

Now, as we approach plastic's 50th year in the railroad market, we must acknowledge a few of the recent discoveries in polymer science that will soon find applications in the locomotive environment: Bearing grades of plastics which can live in high-hydrocarbon - high-heat applications such as in the engine environment, are off the drawing board and well into long term testing. Many of these plastics are true composites and contain high-tensile fibers such as Kevlar, metals such as bronze and silver, and lubricants such as Teflon and silicone oils. Plastics that can survive high heat and flexural fatigue are available for substitution of some 'older' rubber materials. Rubber hoses and pipe joints, for instance, currently made from material such as Viton rubber, can be successfully replaced by material such as molded Teflon. Polymers which dissipate static electricity are a reality as are those composites which provide for greater than 99% conductivity in low voltage applications. And, plastics are replacing brass components in air brake valves, thereby extending the valve's service life.

Are we better off than we were 50 years ago? With almost 50 years of using plastics behind us, its safe to say we are better off today than we were a half century ago. The need for reduced maintenance and rebuild costs will continue to spearhead the drive towards newer and improved plastic products. As an example, plastic components that replaced metal parts also replace a lot of the welding and special tools necessary for applying those metal parts. Newer plastic components have, in some cases, replaced some

metal multi-piece assemblies with homogenous one-piece designs. Plastics have shown superior performance in wear and impact fatigue when compared with the low carbon or manganese steel products they replaced: thus providing productivity gains in higher mileage between rebuilds. Plastic wear components have proven a secondary benefit in long term maintenance in that they can be engineered to eliminate the wear on the metal surfaces upon which they are housed. This is reducing some of the massive welding and grinding to truck frames the industry practiced for so many years.

So the question begs: What's ahead of us for potential applications? In the engine, certain plastics have shown their potential in bearing applications. Fuel delivery systems with flexible plastic arteries and connectors are now available. Coolant line connectors with inherent flexibility are under development. High clarity plastics with extreme temperature ratings are now available for products we'd like to 'see through'. In the cab, plastics will continue to offer soft step safety flooring, ergonomic engineer consoles, and bulkheads which insulate the cab from both heat and noise. At the carbody, hinges and doors which don't rust and don't require painting will be gradually introduced. On the truck, more multi component based materials will act as dampening and wear products, and products which now bolt on will gradually develop into snap-on and press-fit products that will further reduce assembly time. Pins and bushings now made from steel will be made from polymeric materials, eliminating the rebuild of bushing pockets and sleeves. Air brake valve bodies and their internal components will continue to see a change from cast or machined metal to plastic. And finally, dynamic housings such as traction motor gear cases that don't leak, don't break, and don't require repairs will be available.

Besides reducing labor costs associated with rebuilding, a potential problem plastics may seem to help abate is of an environmental concern. Certain metals are under attack from the EPA. The most obvious of these, are metals employing lead - such as those used in engine and traction motor bearings. A few new plastic resins have been developed to address high speed - high load bearing applications within the engine and motor environments. Having a solution to the EPA's lead concerns now may squash any rash action a few years from now. Testing products made from these new materials now is timely and practical. The first of these high-end bearing applications, bearing cages, is a reality in other transportation markets and could be a first platform for locomotive testing.

What are the environmental concerns with plastics? Let's end with a look at some of the environmental questions surrounding the plasic products we use; recycling: are we doing it... and are we doing it right? Do we know which plastics are recyclable and which are not? What recycling options are available to the locomotive industry? Material identification: are all the vendors in compliance? Cradle to grave, whose responsibility is it?

First, the combined weight of the total amount of plastic parts we use on locomotives is less than 1% of the total weight of the entire locomotive. And of those parts and pieces that are currently plastic, none fall into the normal recycling material classifications described by state or federal agencies. So unless the plastic component you are using is covered with or contains a documented hazardous material, most are safely and legally discarded into privately managed land fills.

Of the products we are using, most of the thermoSET resins have chemistries which make them un-reprocessible. They can be ground up, but they cannot be remelted and reformed. Consequently, plastic recycling companies have little or no use for them. These need to be identified by the vendor and documented. Most of the thermoPLASTIC products we currently use can be ground up, re-melted, and reprocessed into new products by plastic recyclers. But none should be utilized as true substitutions for the virgin resins they once were. Their best use can be as resin fillers in low concentrations due to their reduced physical property values. As an example, a plastic pipe elbow fitting that delivered diesel fuel for 20 years should not be ground up and reprocessed into new diesel fuel fittings. Rather, the now lesser quality recycled material should be used for far less demanding second generation applications.

In the future, as more and more material classifications become documented via the government, it should be incumbent on the plastic parts suppliers to document proper material identification and classification number. Finally, any new plasic product submitted to the locomotive industries containing recycled plastic content should be thoroughly evaluated and not be assumed to be equal to products containing 100% virgin resin.

I Thank you....and thank you for continuing to think PLASTICS.

V. CAST IRON, COMPOSITION BRAKE SHOE ARRANGEMENTS VS. TYPE-J RELAY

by Rick P. Gates
BNSF Railroad

For several years, the railroads have been converting their locomotive fleets from cast iron to composition type brake shoes. The composition is rapidly becoming the industry standard. However, within this transition came confusion concerning brake rigging, air components, piping arrangements and settings.

Currently, three brake shoe arrangements exist on the older EMD, General Purpose Locomotive. Each system is unique and stands alone concerning piping layout, components used and amount of braking realized. Our purpose is to answer the following concerns.

- What type J Relay required by condition.
- Difference between brake cylinder pressure and independent brake valve setting.
- How much brake cylinder pressure provided - based on Type J Relay.
- Difference between J16 and J1.6-16 relay valve.
- Correct piping schematic.

The following conditions, linked with underlying arrangements of components, are necessary for proper brake application. Clearly, if any segment is not correct, the locomotive will not have sufficient braking or it will slide the wheels.

Type J Relay Required By Condition

Type Brake Rigging	Type Brake Shoe	Type J Relay
Single shoe/wheel	Composition	J1.6-16
Clasp 2 shoes/wheel	Composition	J16
Clasp 2 shoes/wheel	Cast Iron	J1

Note: All Independent Brake Valve are regulated to provide 45-lb. of line pressure full application. Do not confuse this setting with Brake Cylinder pressure observed at Gage on Control stand.

Brake Cylinder Pressure provided - Based on Type J Relay

Type Relay	Full Ind. App.	Auto Full Serv.
J1.6-16	72	45
J 16	45	27
J1	45	45

J 16 Vs J1.6-16 Relay Valves

Note: The J1.6-16 and J16 Relay Valves do not work in the same way. When application requires brake cylinder pressure of greater than 100%, **you cannot simply use J16 and plumb up both the exhaust and 16 pipe.** That is because there is a little plunger that exists between the 60% chamber and 100% chamber on J1.6-16 relay. That little plunger creates the multiplier effect allowing more than 100%. There is no little plunger in the J16 relay, so consequently the chamber having the higher pressure will dominate. If there is air in the 100% chamber, it will override the 60% chamber.

The J16 relay valve designed for double clasp composition type brake shoe, allows you to have adequate Independent braking (45-lbs. full application) without sliding the wheels. Whereas the J1.6-16 relay provides 160 percent Independent braking (72-lbs. full application) required having sufficient braking with the composition single shoe arrangement.

Inspection

The inspection involves checking a wheel for type and quality of brake shoes per wheel. Once this has occurred, make an Independent brake application by moving handle to Full Application. Observe brake cylinder pressure at gage to determine correct arrangement, as previously mentioned. If this reading does not comply with the number of, or type shoes, it will be necessary to change some components on the locomotive. For example, you have inspected a locomotive having two composition shoes per wheel, with 72-lbs. brake cylinder pressure. This indicates one of the following conditions exists on this particular locomotive:

1. Locomotive equipped with wrong truck design. Need to remove and apply trucks with composition single shoe per wheel construction.

2. Locomotive equipped with a J1.6-16 relay valve, should be the J16 type. When found in this condition it will be necessary to inspect piping arrangement. This unit may have been piped wrong in relation to truck application. When ascertained, extensive work will be required to bring locomotive back into compliance.

J-1.6-16 Relay Valve Independent Brake Application (45-lb. Application)

When the independent brake valve handle is moved to the right into the application zone, signal air enters the independent application and release line through the independent brake valve by increasing amounts.

Signal air is also directed to the J-relay valve via two-way check valve.

The J1.6-16 relay valve is separated into two chambers. The top chamber allows main reservoir air equalizing 100% of the signal to flow to the brake cylinder. At the same time, the second chamber allows main reservoir air equalizing 60% of the signal to flow to the brake cylinder. This multiplier effect allows 160% of signal air to enter the brake cylinder.

The top chamber directs main reservoir air to the brake cylinders on a 1 to 1 ratio. Therefore, a 45-lbs. signal would result in 45-lbs. of brake cylinder pressure from top chamber. Occurring simultaneously, 45-lbs. of signal air is directed to the 60% lower chamber of the J1.6-16 relay valve. This 45-Lb. signal equates to

(45 x .6=27) 27-lbs. of main reservoir air to follow into the brake cylinder.

The result is (45 + 27=72) 72 lbs. of brake cylinder pressure.

Automatic Brake Application (Full Service Set 24 Lb. Reduction)

Moving the automatic brake valve handle to the full application position reduces air pressure in the equalizing reservoir by 24 lbs. Brake pipe always follows equalizing reservoir by design.

The automatic brake valve now exhausts brake pipe pressure down to the same level as the equalizing reservoir pressures and maintains that brake pipe pressure against leakage.

The control valve senses the reduction in brake pipe pressure, causing the control valve to direct auxiliary reservoir pressure to the J-relay valve via the two way check valve to the top chamber.

The auxiliary air signal sent to the J-relay valve is approximately 2-1/2 times the brake pipe reduction.

The top chamber allows main reservoir air equalizing 100% of the signal to flow to the brake cylinder.

Thus (24 x 2.5 = 60) the current 24-lbs. brake pipe reduction will produce a 60-lbs. auxiliary air signal.

The result is 60-lbs. of brake cylinder pressure.

Note: Brake cylinder pressures may vary according to the brake service limit settings in the 26-F service portion.

J-16 Relay Valve Independent Brake Application (45Lb. Application)

When the independent brake valve handle is moved to the right into the application zone, signal air enters the independent application and release line through the independent brake valve by increasing amounts.

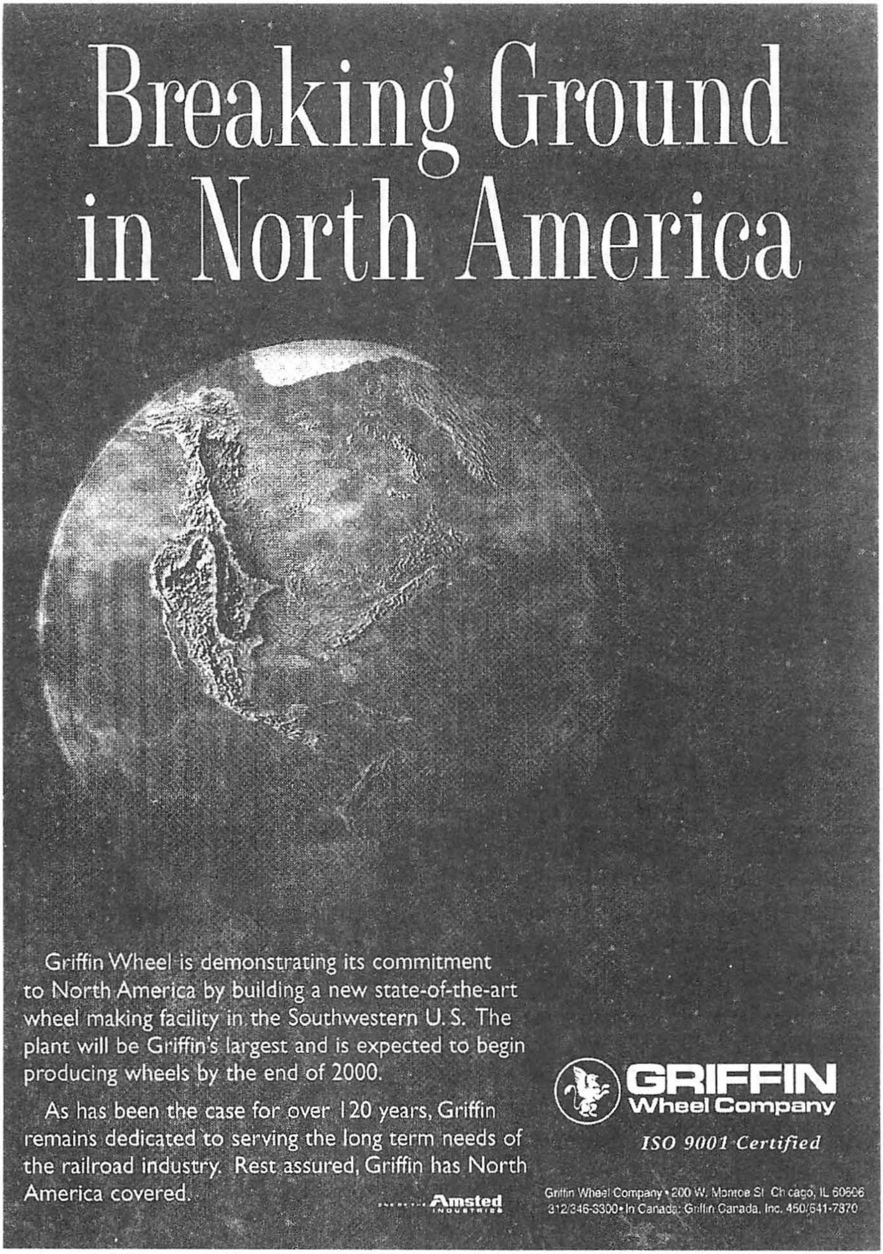
The J16 relay valve also has two chambers; however, when independent application occurs only the top chamber is utilized. Signal air is directed via Line 20 from the MU2A valve to the exhaust port, to top chamber of the J-relay. The top chamber allows main reservoir air equalizing 100% of the signal to flow to the brake cylinder.

The top chamber directs main reservoir air to the brake cylinders on a 1 to 1 ratio. The result is 45-lbs. of brake cylinder pressure.

Automatic Brake Application (Full Service Set 24 Lb. Reduction)

Moving the automatic brake valve handle to the full application position reduces air pressure in the equalizing reservoir by 24 lbs. Brake pipe always follows equalizing reservoir by design.

The automatic brake valve now exhausts brake pipe pressure down to the same level as the equalizing reservoir pressure and maintains that brake pipe pressure against leakage.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The control valve senses the reduction in brake pipe pressure, causing the control valve to direct auxiliary reservoir pressure to lower chamber of the J-relay valve. The lower chamber allows main reservoir air equalizing 60% of the signal to flow to the brake cylinder. The auxiliary air signal sent to the J-relay valve is approximately 2-1/2 times the brake pipe reduction.

Thus (24 x 2.5 =60) the current 24-lbs. brake pipe reductions will produce a 60-lbs. auxiliary air signal. However the lower chamber equalizes at 60% (60 x .6 =36) of the signal to flow to the brake cylinder.

The result is 36-lbs. of brake cylinder pressure.

J-1 Relay Valve
Independent Brake Application (45 Lb. Application)

When the independent brake valve handle is moved to the right into the application zone, signal air enters the independent application and release line through the independent brake valve by increasing amounts.

Signal air is also directed to the J-relay valve via two-way check valve.

The J-1 relay only has one chamber that directs number two main reservoir air pressure into the brake cylinder.

This chamber directs main reservoir air to the brake cylinders on a 1 to 1 ratio.

The result is 45-lbs. of brake cylinder pressure.

Automatic Brake Application
(Full Service Set 24 Lb.Reduction)

Moving the automatic brake valve handle to the full application position reduces air pressure in the equalizing reservoir by 24 lbs. Brake pipe always follows equalizing reservoir by design.

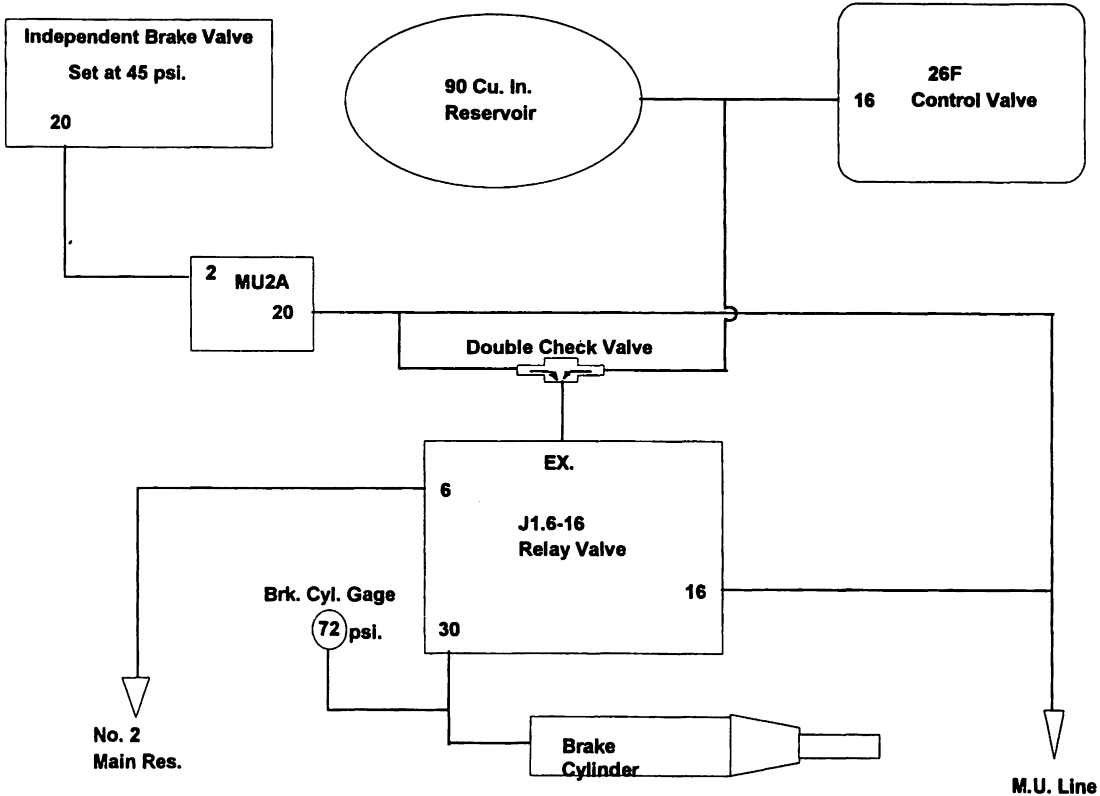
The automatic brake valve now exhausts brake pipe pressure down to the same level as the equalizing reservoir pressure and maintains that brake pipe pressure against leakage.

The control valve senses the reduction in brake pipe pressure, causing the control valve to direct auxiliary reservoir pressure to the J-relay valve via the two way check valve.

The auxiliary air signal sent to the J-relay valve is approximately 2-1/2 times the brake pipe reduction.

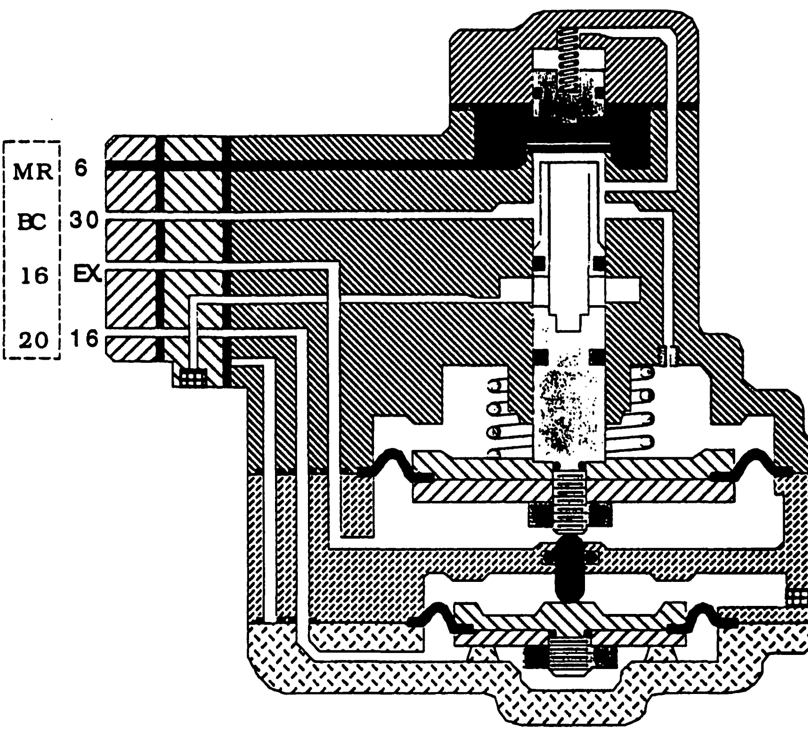
Thus (24 x 2.5 = 60) the current 24-lb. brake pipe reductions will produce a 60-lbs. auxiliary air signal.

The result is 60-lbs. of brake cylinder pressure.

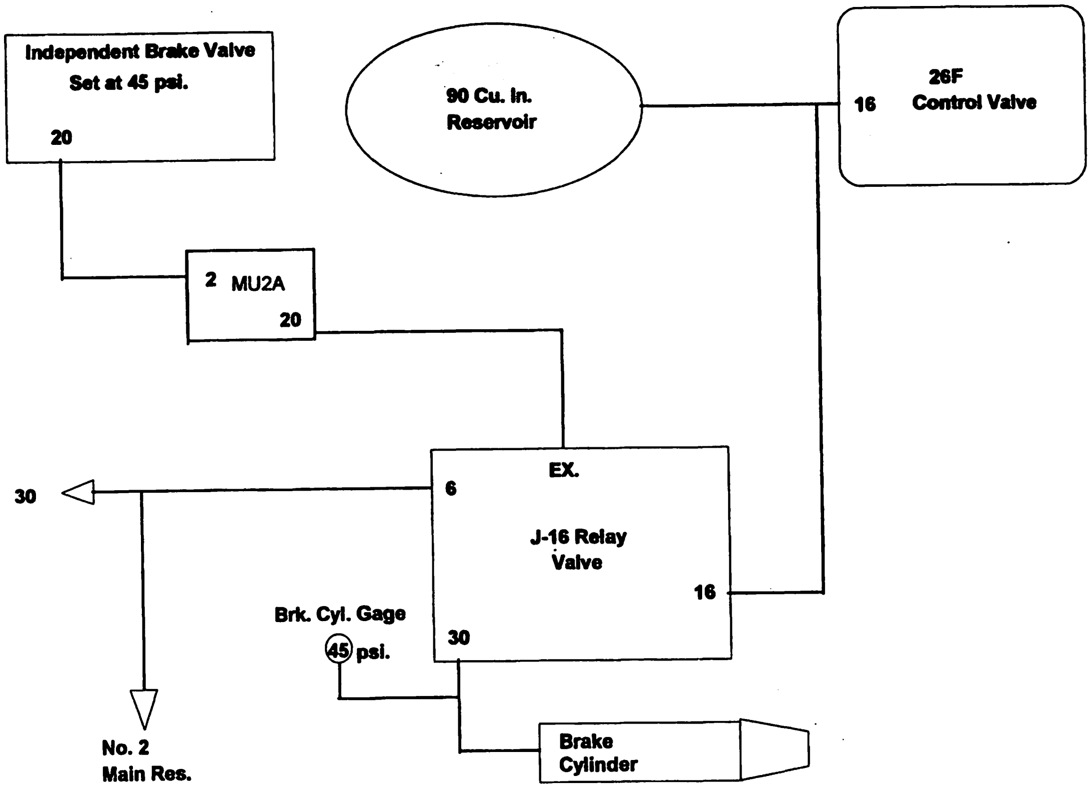


Single Composition Shoe Per Wheel

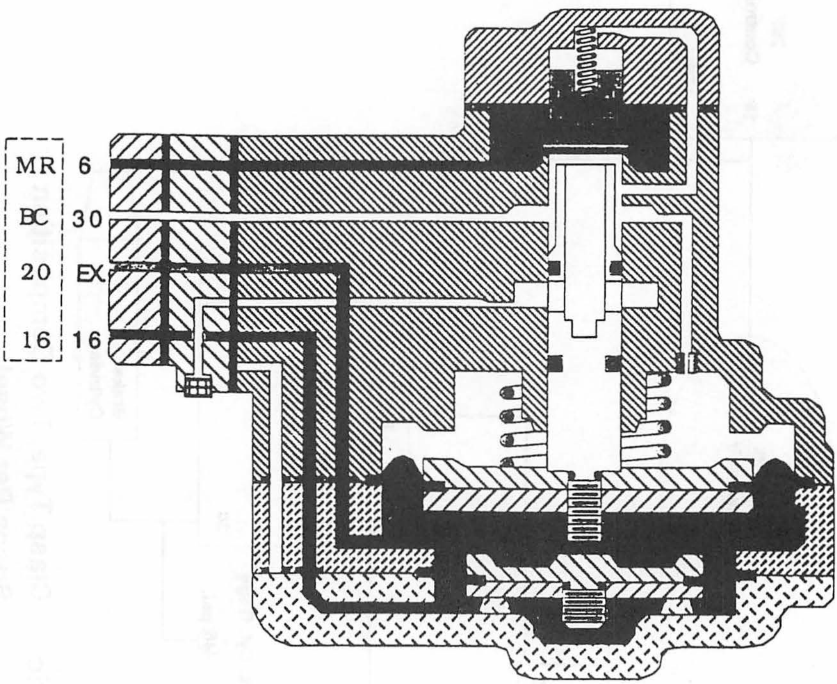
RELEASE POSITION



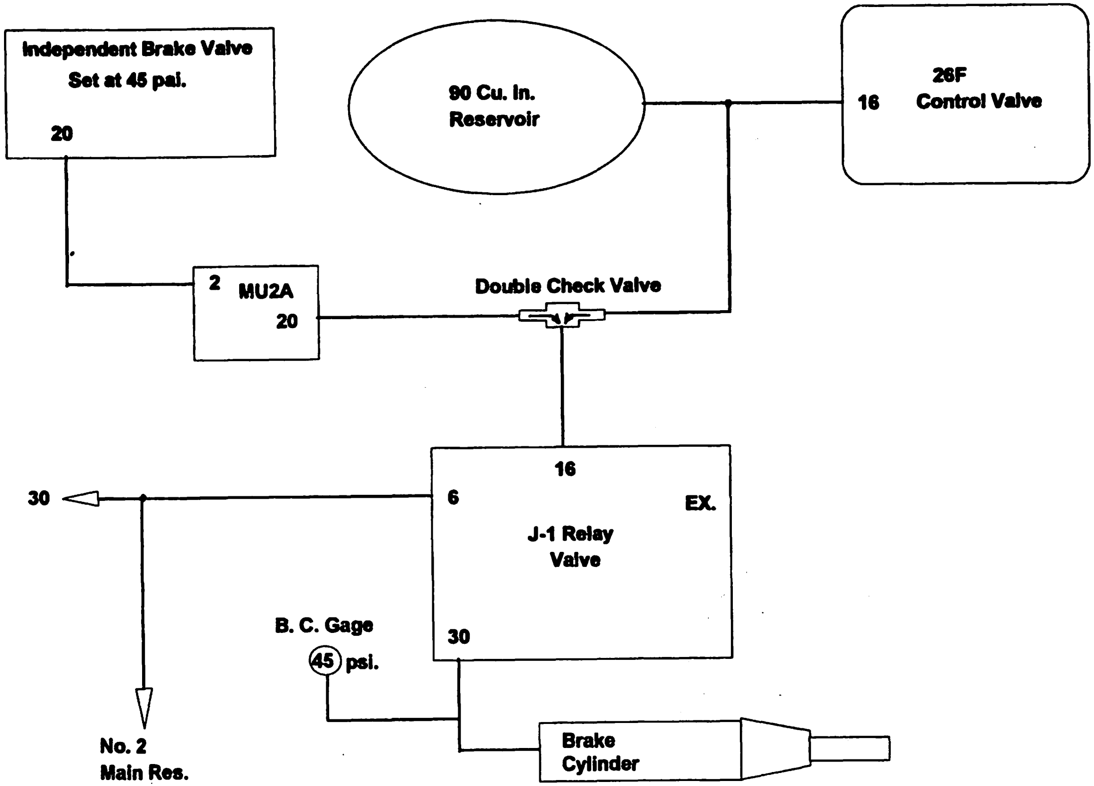
J1.6-16 RELAY VALVE



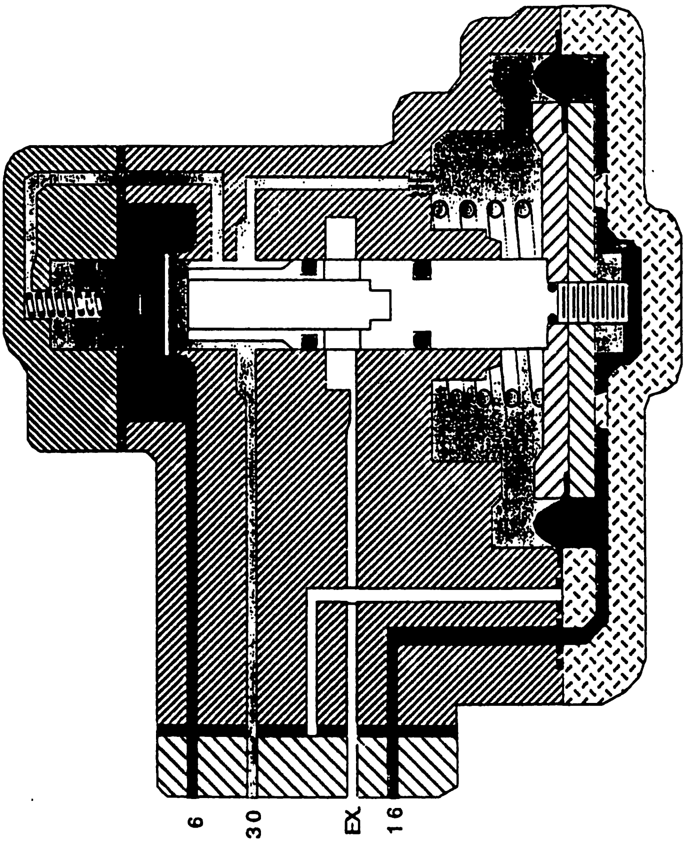
Piping Schemetic: **Clasp Type, Two Composition Shoes Per Wheel**



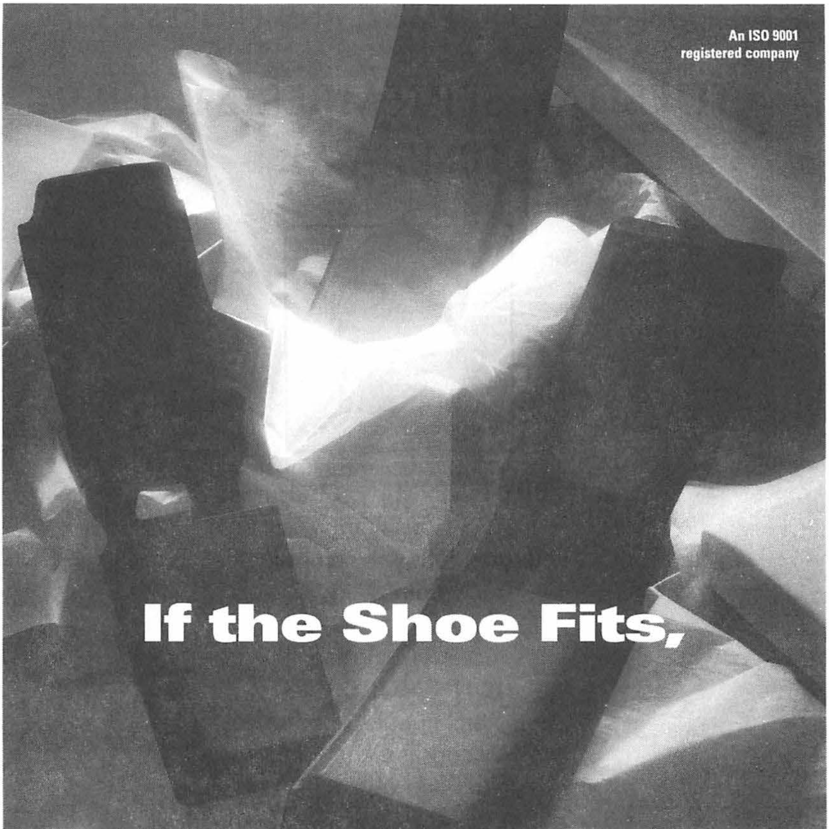
J16 RELAY VALVE



Piping Schemetic: **Clasp Type, Two Cast Iron Shoes Per Wheel**



J-1 RELAY VALVE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REPORT OF THE COMMITTEE ON SHOP EQUIPMENT AND PROCESSES

TUESDAY, SEPTEMBER 21, 1999
10:45 A.M.

BILL PETERMAN, Chairman
Consultant
Peterman Railway Technologies
Montreal, PQ

Vice Chairman
JOHN MORGANO
Asst. Mech. Supt.-Locomotives
Wisconsin Central Ltd
No. Fond du Lac, WI

COMMITTEE MEMBERS

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J. Cutright	Senior General Foreman	Norfolk Southern	Roanoke, VA
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P. Gagne	District Manger	St. Lawrence & Hudson (CP)	Scarborough, ON
J. Hunt	Project Coordinator	Illinois Central	Homewood, IL
J. Muench	Shop Layout Specialist	CSX Transp.	Jacksonville, FL
T. Stefanski	Manager-Loco. Maint.	Electro Motive Div.	LaGrange, IL
R. Yartin	Managing Dir-Loco. Assets	CSX Transp.	Selkirk, NY

Note: Mike Scaringe, Amtrak, was recently appointed Regional Executive for the Shop Equipment and Processes Committee.

I. INCREASING DIESEL SHOP CAPACITY

Presented by
P.J. Gagne
St. Lawrence & Hudson Railway
(Canadian Pacific Rail)

The current existing situation was as follows...

- Locomotive maintenance performed in two locations 300 miles apart.
- Shop A - large and under utilized.
- Shop B - smaller but optimally sited.
- Shop B over its rated capacity.
- Decision to consolidate at Shop B.
- Changes required at Shop B to accommodate transfer of workload.

The project process involved...

- Assessment of current operation,
- Benchmarking process,
- Quantifying workload transfer,
- Reviewing capacity impacts before and after,
- Developing implementation plans,
- Assisting with implementation,
- Following up and tracking implementation.

The current operation assessment involved...

- Analysis of locomotive cycling, traffic patterns, volumes and congestion levels,
- "Brown paper" process documentation for:
  - servicing
  - scheduled repairs
  - unscheduled repairs
  - production control
- Process workshop to evaluate processes
  - identify problems and issues
  - highlight bottlenecks and constraints.
- Utilization Survey

Process workshops identified numerous problems including...

- 80% of units only required servicing, and these units were mixed in with units requiring repairs,
- Too many units were coming to the shop,
- Servicing was done on departure,
- Inspections on repairs were left until too far down the process, limiting work segregation,
- Servicing was done after repair, causing backtracking and extra moves,
- and many others too numerous to list.

Workshops identified the main reasons for non productive time:

- Congestion,
- Overstaffing on days in fast track,
- Basic shop floor control and disciplines,
- Time lost on shift changeovers,
- A number of basic methods issues, causing the men to leave the line for such items as:
  - finding tools,
  - kits for datals,
  - searching for parts/materials stored off the line.

In a following series of workshops...

- Numerous process improvements were developed and documented,
- Key bottlenecks/constraints were highlighted,
- Detailed implementation plans were developed to improve labor utilization, and address issues,
- Capacity was measured, modelled and evaluated,
- A capacity management strategy was developed and agreed on,
- Impact of workload transfer was determined.

The following actions were taken...

- Additional area freed up for servicing locomotives, and infrastructure developed and installed,
- Numerous process changes made:
  - service *everything* on arrival,
  - increased use of mobile servicing,
  - service yard power on weekends,
  - etc...,
- Shop methods improved,
- Shop disciplines tightened.

A project plan was developed...

- External resources were engaged,
- Shop supervisor seconded to project team,
  - credibility of findings
  - skills and knowlege transfer into shop,
  - exposure to new ideas/approaches etc...,
  - provide continuity.
- Facilitated workshop approach used to identify problems / issues, and develop solutions,
- Union involved throughout,
- Follow up and tracking results with KPI's.

Follow up results showed...

- New service area is servicing


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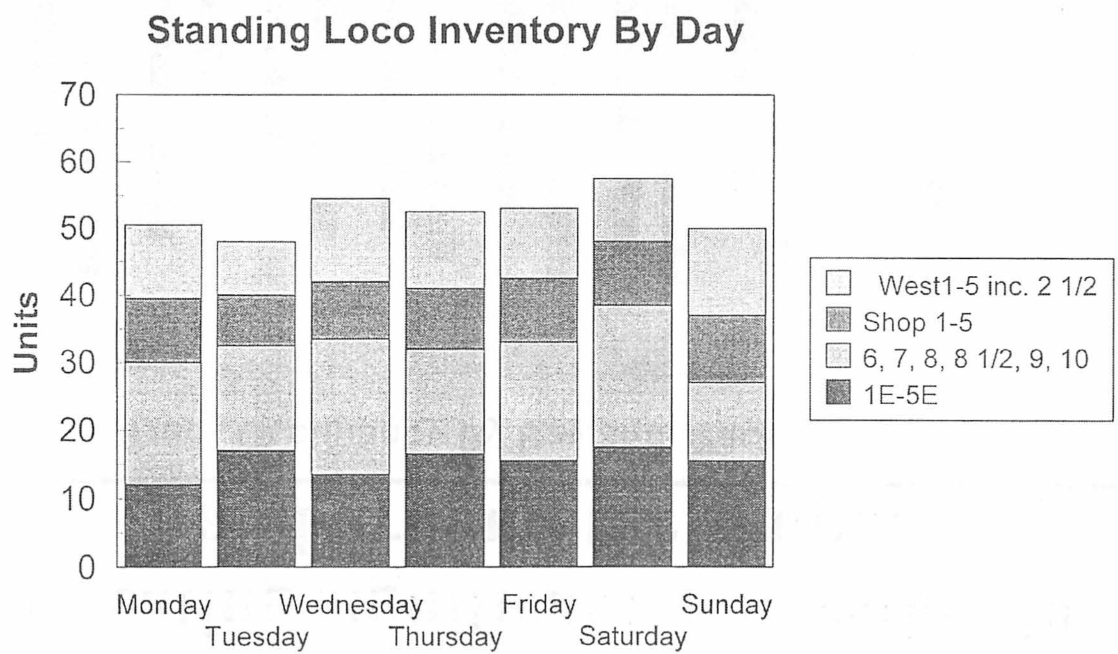
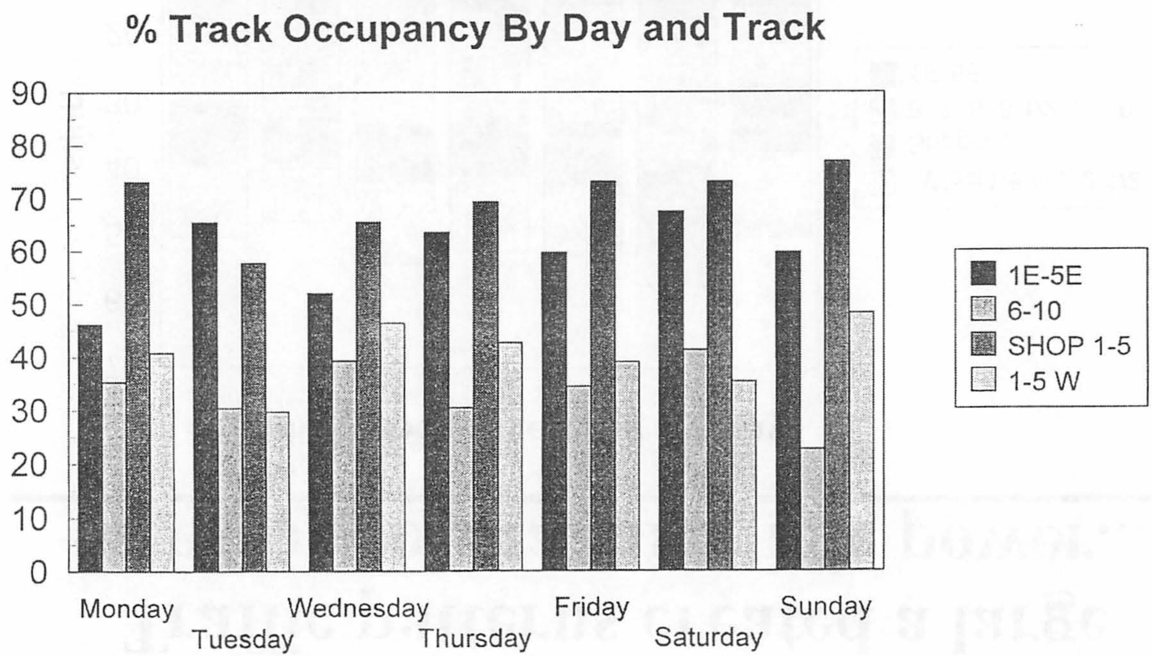
10-15 units per day, relieving significant congestion,

- Labor utilization on days (main problem area), increased from 30% to 44%,
- Workload transfer successfully absorbed,
- Numerous additional units transferred to Toronto, over and above original...,
- Availabilities, MTBF, maintained or improved.

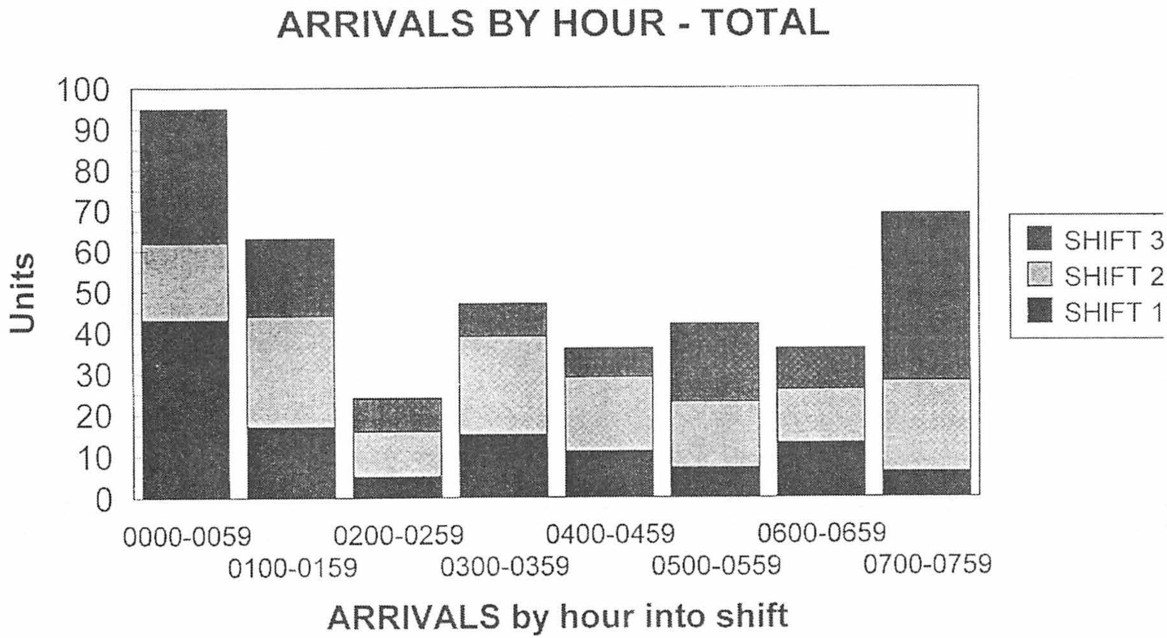
Traffic patterns created a large inventory of standing idle power....



Creating significant congestion in and around the shop...



Especially around shift starts and ends.....



II. CONRAIL: COLD ASPHALT PROCESSING OF ENVIRONMENTAL WASTE SAND AND SLUDGE

by Ron Yartin,
Conrail/CSX

Historically, Conrail has used landfill disposal as well as thermo-absorption to dispose of their oily contaminated traction sand and the sludge generated from wastewater treatment plants. A new technique for incorporating diesel fuel contaminated soil into cold asphalt mixture for use on Conrail's roads and parking areas was identified to be an economical solution regarding contaminated sand and sludge removal cost.

Project Goals

- Refurbishment of Dewatering Beds with Virgin Aggregate,
- Improvement of Site to Facilitate Vehicle Traffic,
- Waste Minimization via Recycle and Reuse of 300 tons of Dewatering Bed Aggregate Contaminated with Petroleum Hydrocarbons.

Land fill usage exposed the Company to continued liability while asphalt recycling eliminated offsite material liability as well as created favorable public and regulatory relations.

Project Stages:

Regulatory Approval - An exemption for the legitimate use of a "segregated waste stream" by Indiana Administrative Code 329-10-3 (15) was secured. Materials demonstrated minimal environmental impact based on laboratory analysis.

Pre-mixing - Virgin 73D stone at a ratio of 1 to 1 was required for size distribution and homogenization. All mixing was completed within storage structure to avoid potential stormwater runoff.

Site Preparation - Consisted of grading and rolling.

On Site Asphalt Formulation - Portable plug mill was loaded with homogenized aggregate with a track hoe. The portable plug mill was used to blend the aggregate and asphalt emulsion. A screened hopper on the plug mill rejected large aggregate and any miscellaneous debris. The blended asphalt was then moved from the plug mill area and stockpiled on site. Asphalt emulsion was provided by a tanker truck connected to the plug mill asphalt feed pump. Asphalt content was metered into mill at 4%.

Dewatering Bed Refurbishment - Material is hand leveled and raked to produce uniform surface.

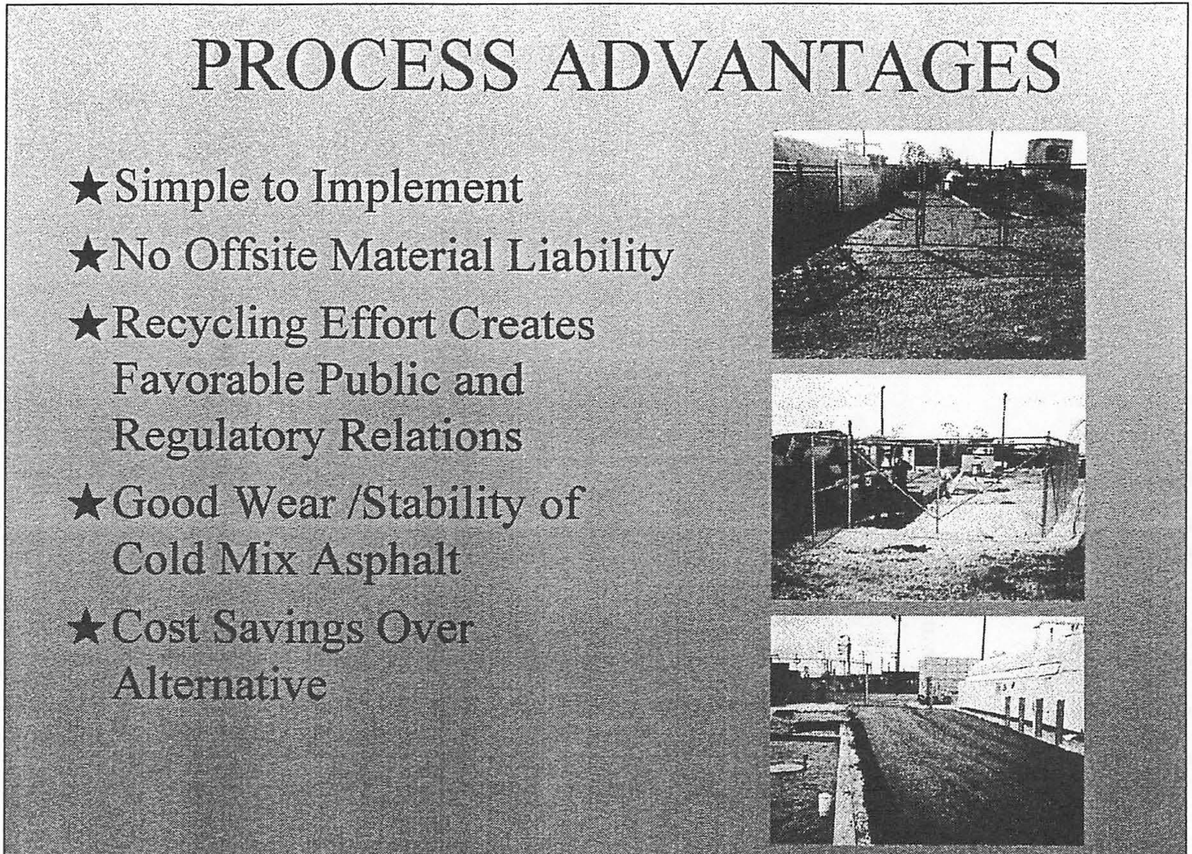
Asphalt Application - Asphalt was applied to the site with a dump truck fed. paver. Depth of asphalt controlled at depth of 4". The paving machine was able to apply the asphalt in irregular shapes. A roller was used to compress the asphalt and increase its load bearing properties. A tamper was used to smooth out minor imperfections.

Wear Coat Application - Virgin aggregate is spread over the paved area and worked and rolled into the top few inches of asphalt to decrease cold mix asphalt cure time, increase resistance to scarring and increase the load bearing capacity and wear properties.

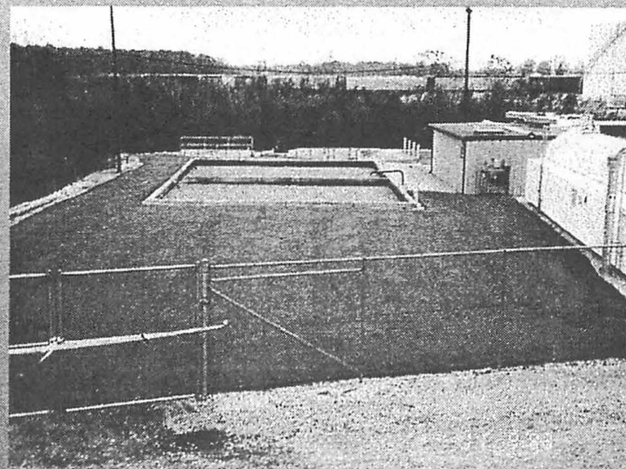
Process Advantages:

- Simple to Implement
- No Offsite Material Liability
- Recycling Effort Creates Favorable Public and Regulatory Relations
- Good Wear/Stability of Cold Mix Asphalt
- Cost Savings over Alternative

Cold Asphalt Process in a cost comparison with the disposal of 300 tons of contaminated sand/sludge provided the following savings over the referenced methods: Over Landfill disposal - $30,400.00, over Thermo-Absorption - $12,400.00 and over conventional black-topping - $17,400.00.

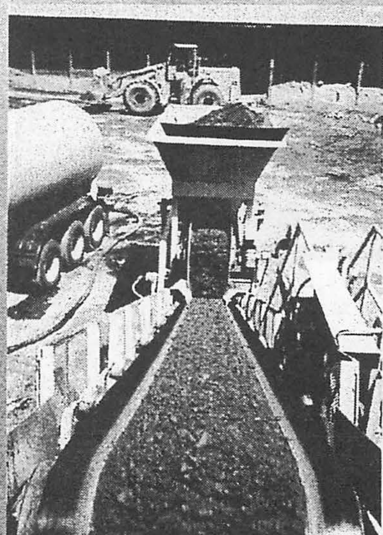

PROCESS ADVANTAGES
★Simple to Implement
★No Offsite Material Liability
★Recycling Effort Creates Favorable Public and Regulatory Relations
★Good Wear /Stability of Cold Mix Asphalt
★Cost Savings Over Alternative

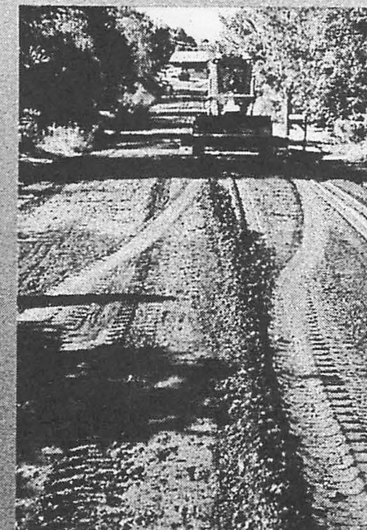
Cold Mix Asphalt Formulated with Petroleum Contaminated Aggregate

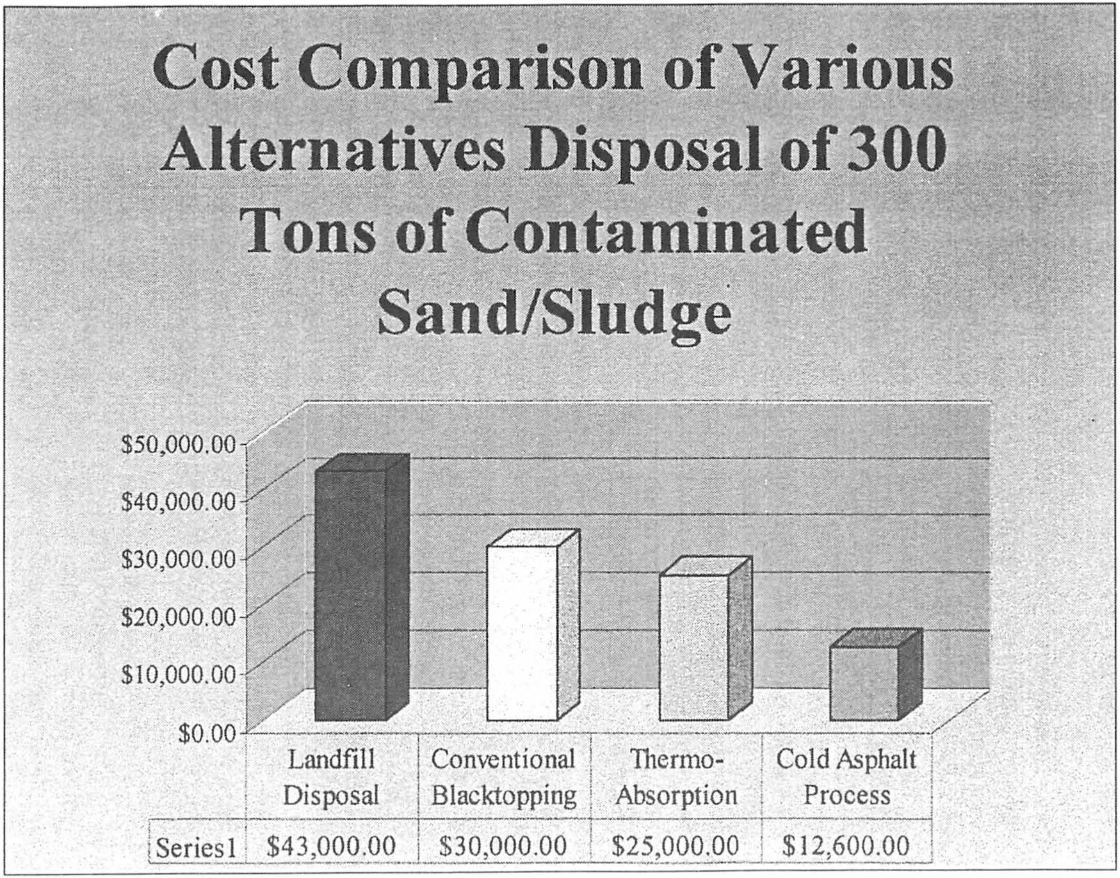


AVON YARD PAF SITE- B
1998

A new technique for incorporating diesel fuel contaminated soil into cold asphalt mixture for use on Conrail's roads and parking areas was identified to be an economical solution regarding contaminated sand and sludge removal costs.






Cost Comparison of Various Alternatives Disposal of 300 Tons of Contaminated Sand/Sludge
$50,000.00
$40,000.00
$30,000.00
$20,000.00
$10,000.00
$0.00
Landfill Disposal
Conventional Blacktopping
Thermo-Absorption
Cold Asphalt Process
Series1
$43,000.00
$30,000.00
$25,000.00
$12,600.00

III. DRY ICE CLEANING OF GE INTAKE PORTS

by Mike Dombrowski, GE and Joe Muench, CSX

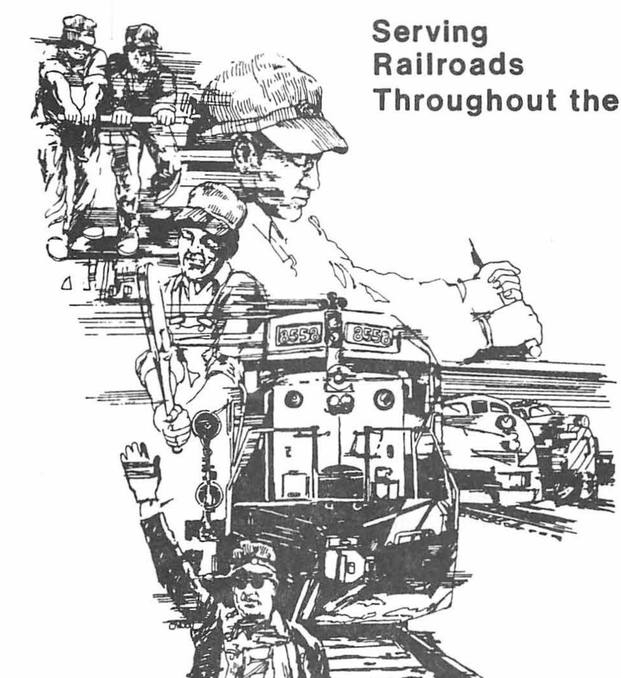
This document serves to complement and expand upon the presentation of the Diesel Mechanical Committee's report - the "Innovative Technique for Addressing GE7FDL Engine Cylinder Intake Port Fouling". The Mechanical Committee has related the reasons for carbon and oil deposits in GE cylinder intake ports and its effect on engine performance and component failures. This report will focus on the cleaning process, tooling and safety equipment needed to remove these deposits using a dry ice blast.

Several techniques have been used in the past to clean GE intake ports. They include steam, hot water blast, walnut or pecan shells and other abrasive blasts. Although these techniques have been employed with some success, they have been found to be somewhat labor intensive with an inherent loss of locomotive availability.

CSX Transportation is striving to reduce the time needed to clean GE intake ports so that these locomotives run more efficiently, are more readily available for train service and the work flow in the locomotive shop remains fluid. The time needed to clean these ports has consumed 16 man-hours or more using other cleaning techniques. The Dry Ice Cleaning System used in conjunction with modified intake manifolds has been used at CSX to reduce overall cleaning time to less than two hours.

Dry Ice (CO_2) is solidified carbon dioxide. At -109.3 degrees Fahrenheit, it is extremely cold in its solid state. It will not burn, support combustion and will not support life. Carbon dioxide can exist in any one or all states of matter - solid, liquid or vapor depending on temperature and pressure. Dry ice at a temperature of -109.3 degrees Fahrenheit transforms directly from a solid into a vapor without formation of a liquid. Although this material must be treated with respect, it is not harmful unless mis-used or mis-applied. Protective gloves must be used when handling dry ice pellets as severe cold burns will occur within seconds of direct contact with skin. The cleaning system must be used in a well-ventilated area because carbon dioxide, an asphyxiant, tends to settle in low areas. It is an odorless gas and must be treated as a material with poor warning properties.

This innovative cleaning process is normally used with the locomotive engine running at idle speed. As in other blasting operations, the dry ice pellets are directed at the engine deposits breaking the carbon loose. The abrasive and explosive energy of dry ice pellets directed to impact upon the intake surfaces will quickly and effectively remove most surface contamination



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without adverse effects. The dry ice is tranformed into carbon dioxide gas and dissipates requiring little clean up. Most of the dislodged carbon from the intake port is blown out but some is drawn into, then burned in the cylinder combustion chamber. The work site without the water, abrasive and carbon debris associated with other cleaning media, is easier to maintain and safer to use.

The normal consumption of dry ice is about 50 pounds per engine and the current price is about 35 cents per pound for approximately $17.50 of product per engine. A full hopper, which is about 50 pounds, will last about 25 minutes at 100% trigger time. The cost of dry ice blast machines runs from under $16,000 to $32,000 depending on the manufacturer. The cost to modify a 16-cylinder engine intake manifold is approximately $1,500.

The primary components of the system are:

- Dry ice pellets with a maximum size of 1/8 inch diameter provided in an insulated shipping container
- Dry ice blast machine with loading hopper
- Air supply (minimum 1" diameter supply hose)
- Blasting wands equipped with nozzles of varied angles.

No one should be allowed within 20 feet of the operation without ear protection and eye protection because of hazards associated with airborne projectiles. Personal protective equipment must be inspected and properly donned before using the system.

They include:

- Eye and breathing protection - Approved Self Contained Air Ventilation System with independent air supply
- Ear Protection - Ear plugs or muffs
- Skin Protection - Long Sleeve Shirt, Coveralls with hood
- Hand Protection - Protective gloves

Some operational tips:

- Poor quality dry ice reduces effectiveness, therefore special precautions and handling techniques must be implemented to assure product performance. For example, dry ice, which is supplied in insulated shipping containers, should be maintained in the shade and out of the wind to prevent premature evaporation. Properly managed, the CO_2 pellets will last in storage over one week.
- Supply air should be cooled, filtered and dried as water; oil, rust or other contaminants will clog the internal filters of the blast unit.
- The blaster should not sit idle for periods greater than 1/2 hour with dry ice in the

hopper as this could result in plugging hopper ports.

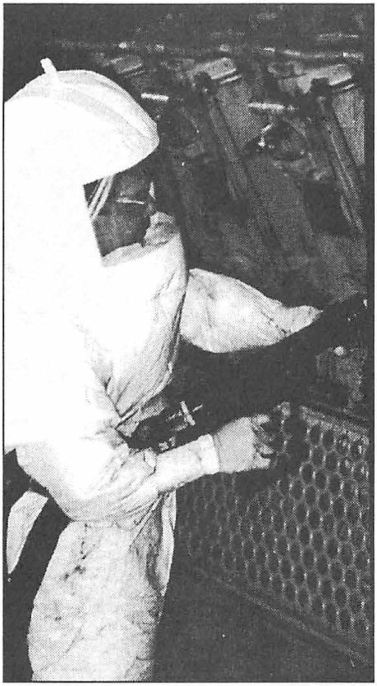
- Since an important part of maintaining a carbon dioxide dry ice blaster is understanding properties of CO_2, a qualified carbon dioxide equipment technician should perform service, maintenance and training.

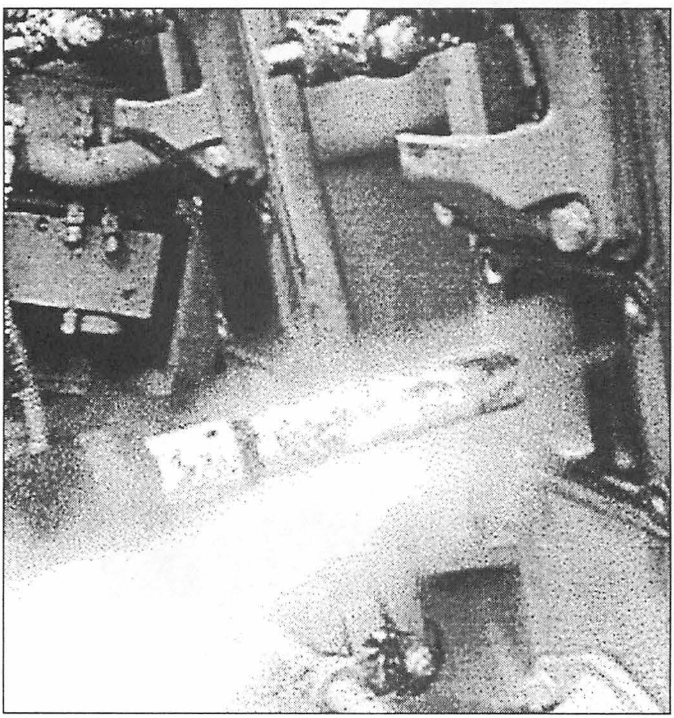
Other locomotive features that are candidates for CO_2 cleaning include electrical components including diode panels.

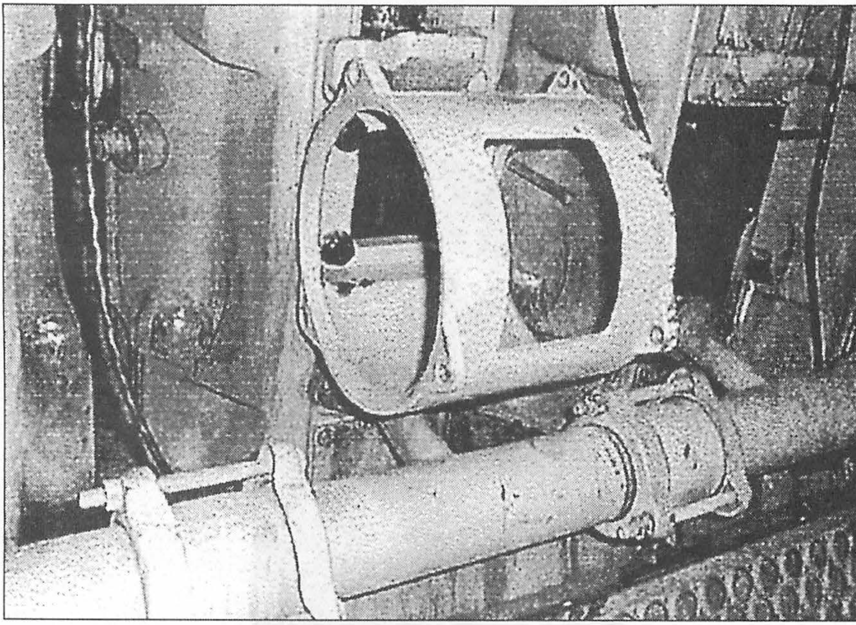
Dry ice blasting and intake air manifold modifications can make cleaning GE diesel engine air intake ports, a necessary maintenance practice, much more convenient in terms of time and clean up. Maintenance forces, using this technology, can make GE locomotive fleets more fuel-efficient and perform better, while reducing in-shop locomotive detention time. Isn't this what our customers want?

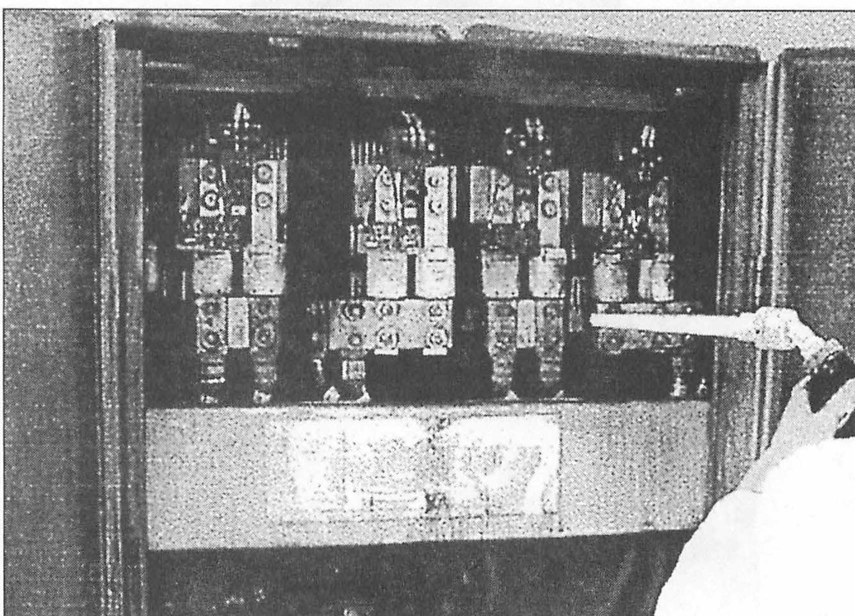

TOM
EAR PROTECTION REQUIRED
EYE PROTECTION REQUIRED


15
14









IV. AAR-LFIS NO SPILL FUELING SYSTEM

By Robert Koeninger - CARCON Locomotive Fueling Group

Locomotive fueling technology is undergoing changes that will greatly improve efficiency, safety and environmental protection. These changes are motivated primarily by the costs, legal consequences and environmental concerns associated with spills during locomotive refueling.

Railroads, locomotives and fueling

For regulatory purposes, the nation's railroads are classified into four general categories. They are:

- Class I
- Short Line
- Metro or regional passenger and
- Museum

This article will focus on the fueling of Class I railroads, which are defined by the total ton/miles of freight hauled in a given year – typically 100 billion tons or more per year. Typical Class I railroads are familiar companies like Union Pacific, Norfolk Southern, Illinois Central and Burlington Northern Santa Fe. Through recent mergers there are now eight Class I railroads in North America. The main-line railroads used by passenger and freight trains are, for the most part, Class I railroads.

The diesel electric locomotives that pull (or push) these trains typically use a #2 diesel with alcohol additive during the winter months. Typically, a locomotive has a fuel capacity of 4,000 gallons of fuel, and will be fueled twice per week.

Railroads own and manage their own fueling facilities. Fuel is delivered by truck and is suction-pumped from the cargo tank into a fixed above ground storage tank. DTL (Direct Truck to Locomotive) fueling is performed by a mix of railroad employees and contracted fuel jobbers. Fixed fueling facilities are located in every major switching yard with more than 2,000 fueling locations in North America.

A single Class I railroad fueling facility will consume 500,000 to 1.2 million gallons of fuel per month. Fuel management is key to controlling cost of fuel inventory. These fuel management systems provide full SCADA (Supervisory Control and Distribution Automation) and provide a method for railroads to charge fueling costs back to foreign locomotives that pass through for fueling.

A typical fueling system uses a pressurized manifold design in which the manifold is held at a constant pressure while the locomotive is fueled. A vacuum- or hydraulic-type shut-off nozzle acts as the primary control valve in the fuel delivery system. Here's how it works: The locomotive is fitted with a fuel adapter threaded into the fill pipe. This adapter has a vent tube, in the case of a vacuum-type shut-off or a hydraulic tube, in the case of a hydraulic type shut-off.

Current spill prevention efforts focus on continuous operator training and equipment maintenance. The railroads continually stress the importance of fuel awareness with their operators. All facility fueling is done over collection pits where the spilled fuel is collected and stored for recycling. DTL fueling does not have this advantage; however, a growing trend is to use DTL because of its convenience. Although this can be done at various locations, they are unequipped with fixed fueling systems and spill prevention and containment. While convenient, DTL fueling can pose greater risks of uncontained spills.

Class I railroads consume about 3.5 billion gallons of diesel fuel each year - which puts the railroads second only to the US military in diesel fuel consumption. And the 3.5 billion figure does not even include fuel consumed by short-line or regional railroads. The figure does, however, include fuel that was lost, either to theft, delivery discrepancies or spills.

The cost of diesel fuel varies depending on location and contracted delivery volumes. The average cost in 1998 was $.65 per gallon. As shown in *Figure 1*, fuel costs account for about 11 percent of a railroad's operating expenses.

Cost of Non-Conformance

By far, the number one problem for locomotive fueling operations is preventing, containing and cleaning up fuel spills. A significant part of the prevention and containment is focused on locomotive fueling. Although fuel spills occur during fuel delivery, this is far less of an issue than spills during locomotive fueling. This is because fuel transfer from the truck to storage tank is done by suction pumping, which limits fuel loss at the truck cargo tank.

According to railroad estimates, fuel spills alone account for about one-half of one percent of the 3.5 billion gallons of diesel fuel consumed annually. While a small amount *percentage-wise*, this figure actually amounts to about 17.5 million gallons. At $.65 per gallon, this comes to $11.4 million - and the cost doesn't stop there.

The cost of spill containment and collection equipment can reach roughly around $1 million per facility. Additionally, reclaiming fuel from containment areas - which involves separating, treating, transporting and disposing of water - can increase the cost of spilled fuel by more than $4.00 per gallon. For spills that occur where there are no containment devices, the cost of reclamation or remediation (including controlling the spill, removing and treating soil and disposing of waste) can reach $100 per gallon. And, if a spill occurs on a mainline section of track - requiring a disruption of service - the cost can be many times more than these remediation costs!

Given both the environmental and monetary costs incurred, the railroad industry is taking positive steps to improve the effectiveness of its prevention and containment of spills during locomotive refueling. Railroad companies are committed to protecting the environment and controlling expenditures for fueling operations, including losses, reclamation and cleanup. Under federal law CFR 40, Volume 19, Parts 300-399, the US Environmental Protection Agency (EPA) can take action to penalize groundwater polluters and force them to clean up contaminated soil water.

Answering the challenge

About three years ago, AAR established the Locomotive Fueling Systems Task Force (LFSTF), with the following objectives:

- analyzing locomotive fueling methods and equipment to identify causes of spills;
- researching hazardous liquid-handling methods and equipment in other industries; and
- developing and testing a new locomotive fueling standard.

The LFSTF was made up of management representatives from the Class I railroads, AAR project managers, fuel systems suppliers and consulting engineers from ARINC Engineering of Annapolis Maryland. In its analysis of locomotive fueling systems, the LFSTF identified the following as the main causes of spills during the locomotive fueling cycle as:

- Nozzles' tendency to "fail premissive." This means that the nozzles tend to allow fuel to flow after sensing the locomotive's fuel tank is full. This malady was found to be related to the passive vacuum or hydraulic shut-off circuits used in most locomotive fueling nozzles. The functions of the shut-off circuit are to detect the fuel level in the tank and cause the nozzle lever to trip, thus stopping the flow of fuel before the tank is over-filled. Any malfunction, such as a failure in a diaphragm or leak in the sensing tube, would cause the system to fail permissive.

- Restrictions in fuel tank vents, causing the tank to pressurize and (1) blow fuel out the fuel inlet when the nozzle is removed or (2) force fuel to leak out of the fuel inlet on the opposite side of the locomotive. Locomotive fuel tanks have inlets on both sides. The tanks and vents are under the locomotive. During winter months the under carriage can become packed with ice and snow that blocks the vent pipe. Since the inlet tubes extend to the bottom of the tank, any tank pressure will force fuel out both fuel inlets.

- Fueling locomotives while they are sitting on a track that has side-to-side grade. In this situation, the fuel inlet on the low side can overflow before the nozzle senses the fuel level on the high side. See *Figure 2.*
- Defeating or by-passing the nozzle shut-off. Failed or unreliable nozzles are frequently "bypassed" by the nozzle operator. Bypassing forces the nozzle valve to stay open with no automatic shut-off protection. This usually results in a fuel spill through the locomotive tank's vent piping. Operators defeat the nozzle shut-off feature by tying off the nozzle control lever, often as a way of "force-fueling" with nozzles that tend to shut off prematurely or to "top-off" a fuel tank. This practice is easily done using a shop rag or rope and usually results in a fuel spill. I have seen one fuel operator use a rope with a slip knot that he tugged quickly to stop the fuel flow.
- Using adapters in connection with incompatible fueling system components, which defeat the automatic shut-off feature.
- Poor visibility of sight-gauges. All locomotive fuel tanks have some type of fuel level sight glass or gauge. Any sight glass that has been in use for two years or more is coated with a dark varnish, which makes the fuel level nearly impossible to see. For manual nozzles or nozzles with shut-off by-passes, inability to see the fuel level means that a spill is the first indication that the tank is full.
- Spillage of fuel retained in nozzle spout during disconnect from the locomotive fuel tank inlet.
- Direct Truck to Locomotive fueling where no automatic shut-off system is used. DTL fueling is used where a locomotive needs fueling in a remote area or in a switching yard not equipped with a fixed fueling system. DTL fueling costs are higher, but permit the locomotive to be fueled on the mainline or remote area without removing the locomotive from the train. DTL is a valuable option for any railroad trying to improve locomotive utilization. The problems are that DTL fueling typically does not use spill containment of a sufficient capacity and, also, that it relies on the operator to remain observant and prevent any fuel spills.

Cleaning up a significant fuel spill from DTL fueling on a mainline can mean lost revenue, in addition to the normal cleanup costs. Railroads attempt to deter fuel spills by transferring the cost of remediation to the DTL servicing company, by way of language in the fuel supply contract. In reality, the inadequacies in fuel nozzle technology have prevented the most well-intentioned operator from avoiding spills.

Development of an Open Standard

In December 1996 the AAR prepared a conference open to all suppliers and railroad officials. The purpose of the meeting was to distribute and answer questions on a "Statement of Need" memorandum that outlined the fundamental system requirements.

AAR-LFIS Locomotive Fueling Interface Standard, July 27, 1998, 8th Draft is currently under testing by the Union Pacific, BNSF and Illinois Central. It is expected the standard will be released by the end of 1999. The standard is known as the AAR-LFIS (as any equipment built to this standard must be labeled "AAR-LFIS") and must have passed a qualification testing spelled out in the standard. Testing of components designed to meet the standard are ongoing so that systems and components will be available when the specification is released.

AAR-LFIS is a recommended practice, and railroad implementation is voluntary. The benefits of the system are clear, "Not one fuel spill has been reported to date." The standard addresses the problems identified by the task force. AAR-LFIS is based principally on the established standards used in aviation fueling and the bottom loading of petroleum cargo tanks, both of which use dry disconnect nozzles and electronic fluid level or pressure control.

AAR, and the railroad industry in general, views the American Petroleum Institute's APIRP-1004 *Bottom Loading and Vapor Recovery of Tank Motor Vehicles*, September 1983, for cargo tanks as the standard most adaptable to locomotive fueling. Other advantages of the API 1004 system are its familiarity to DTL fueling operators; 20 years of reliability data; higher speed fueling; and availability from competitive suppliers.

APIRP-1004 defines the mechanical and electrical interface of liquid and electronic components. As mentioned above, the API method of bottom loading has demonstrated 20 years of "spill free" and reliable operation. AAR Task Force tours of petroleum and aviation terminals found clean and safe operations.

The AAR-LFIS standard incorporates two proven API 1004 technologies. A spill-free system is achieved through the combination of a dry disconnect nozzle and a fail-safe automatic shut off electronic optic sensing system. The AAR-LFIS system contains six key compontents:

- Dry disconnect nozzle
- Dry disconnect fuel adapter
- Liquid level sensor

- Communication plug and socket
- Fueling control monitor
- Solenoid control valve

The *dry disconnect nozzle-* An AAR-LFIS nozzle is a three-inch dry disconnect nozzle. The nozzle must have a maximum flow of 600 gpm with a maximum pressure drop of 10 psi. An interlocking feature prevents nozzle disconnection while the internal dry disconnect poppet assembly is open. A dry disconnect fuel adapter is fitted to the fuel inlet pipe on the locomotive.

The AAR-LFIS standard requires the combination to have a maximum leakage of five milliliters throughout the fueling cycle. This equates to .005 liters, compared to pints or gallons with existing nozzles. The dry disconnect feature addresses fuel spills resulting from any leakage or blow back from the fuel adapter.

Ergonomics were considered in the specification requiring a push-on, pull-of coupling feature and a maximum weight of 10 pounds. This is less than half the weight of some nozzles in use today.

Automatic shut-off system - The automatic shut off system consists of four parts: a liquid level sensor mounted in the locomotive fuel tank, a communications plug-and-socket connection, a fueling control monitor and a solenoid control valve. The liquid level sensor is designed to resist fuel agitation, frosting and the tar buildup typically found on fuel tank sight-glasses. An optical transducer detects the level of fuel with a repeatability of one-sixteenth of an inch.

Two sensors are mounted on the locomotive fuel tank. Sensors are positioned so that one is towards the front and the second is towards the rear of the locomotive. Sensor depth is set to two inches, or 200 gallons, of outage space. This is done to ensure thermal expansion does not cause fuel to spill out the venting system. The sensor communicates to the mounted fueling control monitor through an electrical plug-and-socket connection. Sensor communications uses a defined digital pulsed signal sent to the sensor from the control monitor. When dry and operational, the sensor receives the signal, modifies the signal and echoes the modified pulsed signal back to the control monitor.

Sensor communications are documented in the standard to ensure compatibility between manufacturers. Mounting of the socket is typically on the locomotive fuel tank near the fuel adapter inlet. Design of the plug-and-socket connection conforms to mechanical and electrical requirements defined in the AAR-LFIS specification. The plug and socket uses a push-and-twist motion to make the electrical connection.

Communication between the sensor and control monitor uses a unique "fail-safe, handshaking" signal format. Any failure in the sensor, wiring, plug and socket connection, or in the fueling monitor will result in a loss of this handshaking signal - thus causing the system to stop fueling.

The fail-safe nature of this system is the primary defense against fuel spills. The electronic components are small and easily installed in almost any style fuel tank. System operation is similar to overfill prevention equipment found at API petroleum bottom loading terminals, and is very familiar to any DTL operator. Equipped with start, stop and status controls, the fueling control monitor is available for fixed fueling sites and DTL mobile fueling.

DTL Fueling

An important factor in the development of the AAR-LFIS specification has been to address the concerns around DTL fueling in the many cases in which spill containment is unavailable. Typical DTL suppliers use standard petroleum DOT-406 cargo tanks or fuel delivery tank wagons. These tanks perform a variety of fuel delivery services and typically do not permit modification, thus limiting their use to single customers. Here is where the flexibility of the AAR-LFIS standard shows its ability to be applied in *any* fueling application.

Smaller nozzles and mobile fuel control monitors are available to permit a tank wagon to provide fueling service compatible with AAR-LFIS, yet permit transfer of equipment between tanks. An electric over-air PTO solenoid valve is installed on any truck providing DTL service and the nozzle; the hand-held control monitor may then be moved to any tractor equipped with the PTO valve. A mobile system limits the cost of DTL conversion and maintains flexible management of the tank fleet.

The most measurable value to the DTL fuel supplier comes in the form of liability management. Investment in an AAR-LFIS system will greatly reduce exposure to significant clean-up costs and possible loss of a key customer.

Several Class I railroads are testing the AAR-LFIS technology to evaluate equipment performance and build real-life experience on their installations and operations. Change over of a railroad's fueling system is no small project and much needs to be learned through the testing process.

Testing is under way at Burlington Northern Santa Fe, Union Pacific and the Alaska Railroad. Initial prototype systems were tested at AAR's Transportation Technical Center in Pueblo Colorado. Testing to date has been very successful - with not a single fuel spill recorded since the test began!

Short lines railroads and DTL servicing companies have already taken advantage of the AAR-LFIS system. The Class I railroads are testing and developing conversion plans for the coming years. Tests are underway for DTL and fixed fueling facilities. Early testing has proven to solve fuel spill problems. This early data was sufficient for some railroads to make the commitment and install AAR-LFIS equipment in areas where spills have been a historical problem. Fueling contracts now specify the use of an AAR-LFIS system for DTL fueling.

What should a DTL operator do if the railroad has not converted to AAR-LFIS? One possiblility is to use an AAR-LFIS compatible DTL fueling system designed for use on non-AAR-LFIS locomotives; Carcon, for instance, has developed a system that consists of a module control/alarm module and temporary mounted fuel level sensor.

Fueling is done through the existing nozzle. A sensor is mounted in a special fuel inlet adapter to detect when the tank is full then automatically stopping the flow of fuel. Equipment is transferable between tanks, and no modification of the locomotive fuel tanks is needed. The integrated sensor plug-and-socket connection is compatible with the AAR-LFIS standard so the system will not become obsolete.

Final Thoughts

Fuel Management is a big expense, environmental remediation is a bigger expense. A small percentage saving on $2.5 billion dollars in fuel costs transfers a lot of money to a railroad's bottom line.

Any railroad official responsible for managing the cost of fuel or environmental policy should become well informed on the benefits of the AAR-LFIS fueling specification. Environmental law will drive its implementation and railroad CEO's will demand the cost savings. In today's environmentally aware world, key executives can find themselves criminally liable for law. AAR-LFIS is a fueling standard whose time has come.

Figure 1: Industry operating expenses (in millions of dollars)

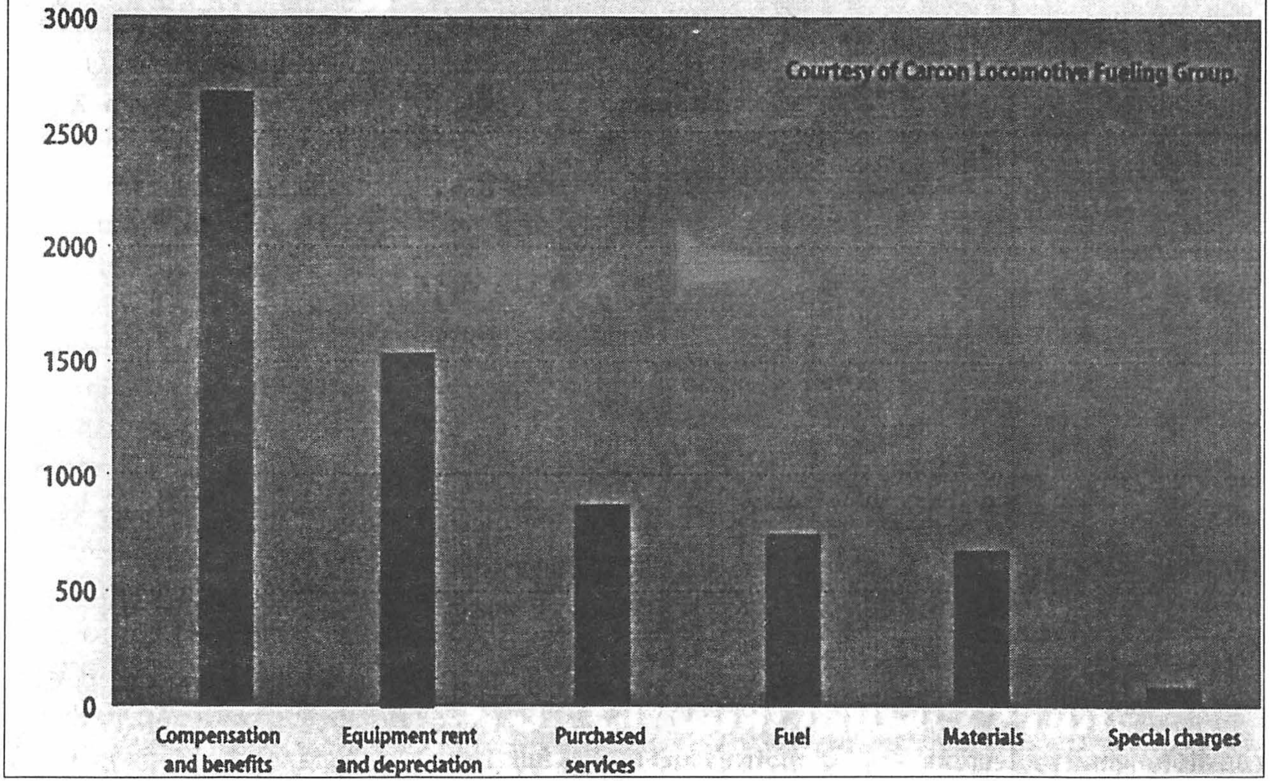
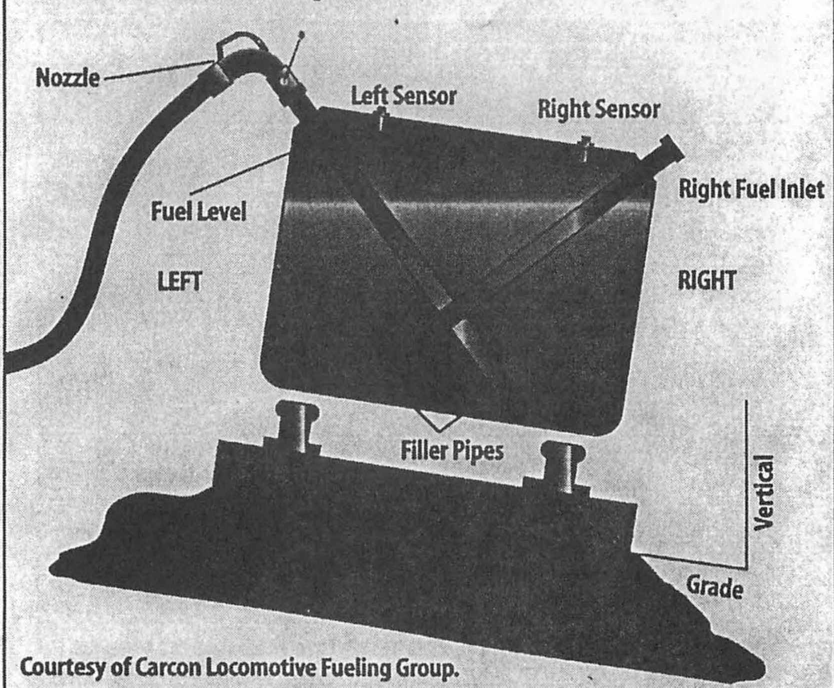


Figure 2: Fuel level tank on grade



Courtesy of Carcon Locomotive Fueling Group.

REPORT OF THE COMMITTEE ON FUEL, LUBE AND ENVIRONMENTAL

TUESDAY, SEPTEMBER 21, 1999 2:00 P.M.

GLENN BOWEN, Chairman
Director-Lab Services
BNSF Railway
Topeka, KS

Vice Chairman
KEVIN COTE
Territory Manager
Exxon Company
Linden, NJ

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D. Tuttle	Supvr. RR & Marine	Valvoline Oil	Marietta, GA

PERSONAL HISTORY

Glenn W. Bowen

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

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

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

I. LUBE OIL ANALYSIS - ACHIEVING QUALITY RESULTS

by Leighton Haley
Norfolk Southern Corp.

The rail industry uses oil analysis as a means of utilizing oils for as long as possible and as an aid in monitoring the mechanical condition of the equipment. Railroad oils are generally comprised of two or more components, a base oil or oils, a multi component additive package, and possibly a viscosity index improver (VII). During use, any and all of these components can degrade or be consumed. To obtain the longest life from the oil without putting the equipment in danger, the physical and chemical condition of the oil requires monitoring. Extending use of the oil past its useful life can create conditions that are detrimental to the internal components of the equipment. These conditions can include the following:

- Formation of acids in the oil - loss of pH or total base number (TBN) or high total acid number (TAN),
- Increase viscosity due to oxidation of the oil,
- Loss of viscosity due to fuel dilution or shearing of the VII,
- High solids content.

These conditions all increase the rate of wear of internal components, and over time, can significantly shorten the rebuild cycle or cause early replacement of the equipment.

Monitoring the physical and chemical make-up of the oil also helps in identifying equipment related problems such as:

- Fuel leaks,
- Coolant leaks,
- Improper air filtration,
- High temperature conditions,
- Alignment or clearance problems.

Historically, the larger railroads have used their own laboratories for oil analysis. These laboratories have tended to be located in locomotive shop facilities. This has been so they can have quick sample turn-around times and be able to react to the lab recommendations before the locomotive leaves the shop. However, as competition from other sectors of the transportation industry has increased, many railroads have re-evaluated the benefit of performing their own routine laboratory work. In many instances, it has been determined to be more cost effective to use outside contractors for oil analysis. Although the trend is now for oil analysis to be performed by outside contractors, railroads have not wanted to lose the benefits of on-site analysis. Therefore, most have contracted with outside labs to perform the work at the railroad's facilities.

The function of the oil lab is to supply the railroad with accurate, timely results along with recommended actions based on current and historical data.

Obtaining quality data and interpretations are not functions that will happen automatically. Typically a large railroad will utilize multiple labs, and the measurements from each need to be compared and correlated in the decision process for recommending actions. If a good correlation between labs or between analysis in a single lab is not present, situations such as that shown below are possible:

Sample Date	Result	Reporting Lab
10/01/98	32	A
10/12/98	9	B
10/16/98	7	B
10/22/98	25	A
10/31/98	14	B
11/09/98	12	A

Interpretation of these data is very difficult since one doesn't know if the variations are due to lab or personnel differences, from problems with the equipment, or from sampling issues. Sampling is an issue that can greatly affect the results from the lab but generally is not a function of the lab.

The railroad normally has the responsibility of collecting the sample and transporting it to the lab. Samples need to be representative of the oil in the lube oil system and free from outside contamination. Before the sample is taken, the equipment should be running and at operating temperature. Any sampling device, such as a built-in sampling valve or suction gun, should be clean and thoroughly flushed with the oil before the actual sample is collected. The sample should be placed in a clean, dry container, capped, and clearly labeled with the equipment ID, sample date, type or source of the sample, and the person who collected the sample. Once collected, the sample should be forwarded to the lab in the most expeditious manner.

Once the lab receives the sample, several factors are necessary to ensure the data and recommendations supplied are what is needed by the railroad. These factors include:

- Laboratory personnel,
- Equipment,
- Laboratory and measurement practices,
- Standard operating procedures,
- Documentation,
- Training - safety and procedural.

Personnel:

The expertise and competence of the laboratory staff are the first requirements that should be examined when evaluating potential contractors. Many contract labs have minimal standards for their personnel hired to perform the routine analyses and tests and generally, the pay scales are low and the turnover rates high. In many instances these employees have no real understanding or interest in the quality of the results as long as their daily workloads are met. Even so, there are certain characteristics one should look for

in the technician ranks. These include the following:

- They should have an interest in the physical sciences,
- Have good number sense,
- Be able to follow written and oral instructions,
- Be observant of details,
- Be cooperative,
- Have the ability to work well with their hands.

The lab should also have a manager or supervisor with ultimate responsibility for the operation of the laboratory (ies) and the quality of the information supplied. This person should have the following traits:

- A sound educational background,
- The ability to work cooperatively with all levels of personnel,
- Be resourceful,
- Be adaptable,
- Be inquisitive and critical of detail,
- Be effective in communication, both orally and written,
- Have laboratory experience,
- Be computer literate.

Railroads utilizing laboratories employing personnel that do not meet these traits run the risk of having high employee turnover rates and of receiving low quality data and recommendations. For example, if little attention is given to detail, the equipment identification may be mislabeled, samples may be run in the wrong order, the results may not be thoroughly reviewed before recommendations are made, or procedures may not be followed precisely. In other words, the results supplied to the railroad may have little or no meaning and the value of the oil analysis is wasted.

The laboratory's upper management also needs to be committed to providing quality output. This requires regular communication between the contract lab's upper management, the staff at the local lab, and the railroad's contact. Without this commitment, it is up to the local lab supervision or in the worst case, the technician to ensure the information provided meets the railroad's purposes. Upper management should, at a minimum, visit each site semi-annually to reaffirm its commitment and to review safety and quality procedures with the local employees.

Equipment:

Oil analysis requires specialized facilities and equipment. The success or failure of a laboratory can often be traced to the adequacy and utilization of the facility and equipment. To ensure the quality of work, both the facility and equipment need to be adequately maintained. This can be accomplished by establishing maintenance schedules, calibration intervals, and the use of good housekeeping practices.

The equipment and facilities being used in railroad contract laboratories has generally been supplied by the railroad. Where the work has been contracted out, railroads have typically transferred their oil analysis equipment to the contract lab but continue to maintain the facilities. In many cases the equipment is old and possibly even outdated. Although the use of old or outdated equipment is not neccessarily a problem by itself, if it is not kept in good operating condition the numbers generated by that equipment can have no value. If the instrumentation frequently breaks down, the results and recommendations are delayed in getting to the shop forces, possibly increasing the railroad's cost of corrective action.

Mechanisms need to be in place to ensure that the equipment is adequately maintained and calibrations are up to date. Requiring service contracts on the major instrumentation with the original equipment manufacturer throughout the life of the contract is one step that can be taken to minimize downtime. The lab should also maintain calibration and repair logbooks that are always available for railroad review. Repair or trouble logs can reduce downtime by allowing the lab personnel to quickly review previous troubles and what steps were taken to resolve it.

However, of most importance, the equipment must be kept in calibration. The purpose of calibration is to minimize or eliminate any bias in the measurement process. Calibration refers to measuring the response of an instrument and relating the response to the concentration of the analyte being evaluated and eliminating, by adjustment, any variation in the accuracy of the item being measured. Calibrations should be performed on a regular basis using appropriate and accurate standards. The standards used should ideally be as identical as possible to the samples being tested. In addition, they should be stable and have an expiration date assigned showing the stable life expectancy. Standards should not be used past this date.

When equipment is down for extended times, the contract lab should have a back-up lab that can perform the work using equivalent procedures and equipment. Equivalent equipment and procedures are necessary to ensure compatibility between labs.

Good Laboratory and Measurement Practices:

Good laboratory and measurement practices refers to the general practices and techniques that relate to the quality of the data supplied by a laboratory. Laboratory practices should address such items as facility maintenance, record keeping, sample handling, and cleaning of laboratory glassware while measurement practices address specific measurements techniques. Both laboratory and measurement practices must be written and implemented if good measurements are to be expected. Although many procedures are thought to be common knowledge and do not require a formal writeup, the critical operations should be identified and formalized. The critical operations are any that can be identified as a cause of significant variation or bias.

Standard Operating Procedures:

Standard operating procedures (SOPs) provide detailed written descriptions of the way specific operations and methods are performed. In the laboratory these include sample preparation, instrument operation and use, calibration of instrumentation and chemicals, measurement procedures, and any other operation done repetitively. These procedures do not need to be written by a formal standards writing organization like the American Society For Testing And Materials (ASTM). However, when appropriate standards are available from such organizations they should be considered since they do represent peer judgement and review. Procedures written in-house should be reviewed by colleagues in the laboratory to ensure understandability. The use of a standard form will simplify the writing and provide a screening mechanism for possible description omissions. A well-written procedure, either published or in-house, will contain explicit instructions for performing the operation along with the tolerances for all critical parameters necessary to obtain results of a specified accuracy.

Documentation:

An essential part of any measurement program is the documentation. The data must be sound and defensible. Inadequate documentation creates doubt about the validity of the data and limits one's ability to defend it. Without the ability to defend the data, their value is diminished. The documentation needs to cover all aspects of the measurement process - the methods used, calibration or standardization, any manipulation of the data, and the final recommendation. Details of the documentation procedure should be included in the good laboratory practices write-up.

Training:

Before accurate, reliable measurements can be obtained from a laboratory, the personnel must have adequate training in safety and the proper techniques for the measurments to be performed. Laboratory management should establish written procedures describing training steps for new hires and the methods for demonstrating proficiency in the procedures that affect the quality of information supplied.

Summary:

Obtaining quality results from an oil laboratory requires several factors to be considered and addressed.

- Personnel,

- Equipment and facilities,
- Laboratory and measurement practices,
- Standard operating procedures,
- Documentation,
- Training.

All are important and no one is more important than the others. If one area is overemphasized another may be overlooked and the end result is a low quality output that does not meet the needs of the railroad. As the end user of the laboratory's information, the railroads must demand and be willing to pay the price to obtain the desired level of defensible quality. Anything less than defensible quality can actually increase costs through incorrect recommendations and by missed identification of developing equipment problems.

When contracting out the work, the railroad should review and discuss each of the above items. They must be in full agreement with the steps the contractor will take to ensure the data and recommendations supplied are at the desired level. Otherwise, the railroad may not get the quality of service it expects or needs and the value of the oil analysis program is lessened.

II. EFFECTS OF ENGINE LUBRICANTS ON OIL FILTRATION

by A. J. Murphy and
Wes Middleton
Chevron Chemical Co.

In today's operational environment, oil performance can have a significant impact on engine performance. In the case of oil filter plugging, EMD lube oil systems will go into partial by-pass and GE engines will de-rate. This can minimize available power, cause significant delays, require expensive unscheduled maintenance and accelerate engine wear.

Background

Lower oil consumption, high soot loading and increased combustion temperatures and pressures have all added up to significantly increased stress on engine oils. This was highlighted in the 1996 LMOA paper authored by Glenn Bowen, titled "A Look at Generation 5 Oil Performance and Future Oil Needs." Mr. Bowen stated that in the time since LMOA Generation 5 oils had been in use (1989 - 1996), "oil stress has increased by 135%." In addition, improved insoluble control was the number one response in that paper's survey of "What railroads would like to see in a new engine oil." Mr. Bowen also made reference to "oil filter plugging problems." All of these issues must be considered, especially when looking at engine lubrication from the total system viewpoint.

In addition, there are industry changes and issues on the near horizon that will have an impact on lubrication. The introduction of the GE 6,000 horsepower engine has occurred. Computer controlled fuel injection systems are considered commonplace. EMD is producing its first line of 4-stroke engines and tighter emission requirements will go into effect in 2002 and 2005. Engine oils will be depended upon to do more and more work as we tackle these issues. In other words, "oil stress" or, the amount of work we expect from the same gallon of oil, will continue to rise.

Documenting Field Performance

In developing new lubricating oil technology in 1995 and 1996, major improvements were found in locomotive testing at a Class I railroad over existing LMOA Generation 5 products. By improving the insoluble handling performance of the oil, a significant reduction in the amount of material being trapped in the oil filter elements was found. Although a majority of the insoluble material produced related to engine combustion, design, operation and fuel used, the oils themselves do produce oxidation by-products over time. These can be detected by routine laboratory analysis. Advancements in additive and base oil technology over the last 15 years, have greatly reduced the amount of lubricant derived insolubles in used oils.

During the first year of operation, oil filter sections were removed and examined from the existing Generation 5 fleet oil and the new test oil. Figure 1 shows the relative performance of the test oil versus the fleet oil based on oil flow performance through the used oil filter sections. Duplicate test runs were made to confirm results. Figure 2 compares additional oil filter performance from the fleet and test oil versus a new filter. To help demonstrate the ability of the new test oil to handle the higher levels of stress, the oil drain intervals and the oil filter change interval were both doubled to 180 days for an additional year. The fleet oil remained at 92 days for oil drain interval and filter change out. After one year, no increase in engine wear resulted from extending oil drain and filter intervals. Key power assembly components were measured versus their new tolerances. During inspection and tear down of the test oil and fleet oil engines, we were fortunate to have representatives of three Class I railroads and one OEM attend. The filter elements from the fleet oil and the test oil were cut away and the results can be seen in FIgure 3. The test oil filter which shows reduced filter deposits was visually cleaner and did not display the traditional signs of filter "slicking", a tacky physical buildup of material. This phenomenon was also explored by Dave Hutchinson and Chuck Kunkel in their paper *"Modeling of Filter Blinding in Mixtures of Medium Speed Diesel Engine Oils,"* ASME 1997-ICE-25. These filters were de-oiled, flow tested and photographed in the laboratory. Figure 4 compares the test oil filter at 180 days versus fleet oil filter at 92 days. The fleet oil filter illustrates the "blinding" effect of material that causes filter tank pressure increases. Note the significant decrease of that same material in filters operating on the test oil at 180-day intervals. In addition, the engines on the test oil were instrumented to monitor filter tank pressures daily. We found no evidence to suggest that filter plugging increased by extending oil and oil filter life. Note that filter efficency and media integrity issues are additional items that must be addressed.

Demonstration Test at Site With Filter Plugging Issues

An opportunity arose to demonstrate this performance when a mid-western railroad was experiencing difficulty on older 20 cylinder EMD's. Their filters could not make 92 days and operations required 45-day oil filter changes, which increased overall costs. In addition, the operator had increased oil filter pore size above typical OEM recommendations. Before commencing this performance evaluation, the test product noted above had received full OEM approval and was being commercially sold as a new LMOA Generation 5 technology. Baseline testing was run on fleet oil compared to the newly commercialized LMOA Generation 5 oil. Locomotives were run in identical service and oil filters were changed at 45 days for the first cycle. After evaluating the filters, a recommendation was made to double the filter interval of the newly commercialized LMOA Generation 5 oil. Figure 5 summarizes the oil filter tank pressures on the new oil at the 92-day intervals. This additional information was used as back-up data to the filter analysis. It is interesting to note that only one filter tank showed 37-psi at notch 8. Partial by-pass would occur at 40-psi. Looking to the oil analysis for help, we reviewed the LMOA pentane insolubles results. Pentane insolubles were 2.53 and 4.80 weight % on that engine during two separate sample dates. This engine truly stood out as a "soot generator". This performance evaluation ran successfully for more than 6 months, and after review with the railroad technical staff, the fleet was switched over to the new product.

Eastern Railroad Field Experience

After almost two years of service on the new LMOA Generation 5 oil at a Class I eastern railroad, a fleet review was undertaken in 1998 to examine filter conditions. Older GE locomotive series B23-7 to the latest Dash 8-40C's and EMD GP38-2 to SD70's were included. A total of 46 oil filters; all taken at 92-day service intervals were examined. Again, filters were de-oiled, flow tested and photographed. As a reference, a new EMD 12μ filter gave a filter flow time of 4.3 seconds. Since actual fleet filters evaluated were Clark C-24, EMD replacement filters sized at 18μ, we would expect the smaller reference filter to be more severe. A completely plugged filter would show a flow time of 400 seconds. As shown in Figure 6, only 2 out of 24 units showed significant filter plugging. Figures 7 and 8 respectively show photographs of the best and worst filter performance. Although the filter with the highest flow time was not completely plugged, when reviewing oil analysis records, this unit showed 225-ppm of sodium. General conclusions would be water content in the oil causing filter swelling and increased filter plugging. This is a relatively common field problem, especially with filters using cotton fibers.

For the GE filters, it is most important to note the larger filter pore size of 28μ. In a simplistic sense, the size or amount of particular matter has to be much larger to cause plugging of these filters. Insolubles generation on traditional four stroke engines is relatively high, and oils and filters can become overloaded with soot, requiring change out. In general, this is due to the lubricant consumption on the four stroke engines being traditionally lower than the two stroke. In Figure 9, the new technology Generation 5 oil shows very good filter performance except for one unit.

Figures 10 and 11, are photos of the filters with the best and worst flow times. In the worst case, the pentane insolubles from oil analysis was almost 6.4 weight %. This would explain the extremely high soot loading of the oil and account for the deposition in the filter media.

Summary

As a result of these laboratory and field efforts, there are some interesting lessons learned and future actions to consider. Currently available products have shown and documented the ability to handle insolubles better than ever before. The plugged units shown have been the exception, rather than the norm. Further investigation into those units pointed to other operational problems that would impact oil and filter operation. These programs have identified lubrication system benefits that can directly impact operational costs. Filter life extension programs can be undertaken with excellent chances of success and performing baseline analysis offers the ability to analyze fleet performance before implementing fleet wide decisions. Extending oil filter life can reduce landfill disposal and incineration costs.

Future work lies ahead for developing a system that can anticipate filter plugging, either through oil analysis or on-board filter pressure differential electronics. This will give operators the ability to detect problem locomotives and also issue corrective action. An example in today's operations would be to ask the question, "Why do we change oil filters every 92 days?" If the answer is, "Because 100% of the fleet won't make it to 180 days", we may want to look at specific reasons or provide a different information feedback loop. In modified form, maintenance actions could be generated from the combination of lube oil analysis and pressure data. Fleet operators could predict those few locomotives that would not make the scheduled 180-day oil filter interval and direct them for servicing at 92 days. Filter plugging or exceeding lubricating oil parameters could be the result of improper injection timing, water contamination or piston ring blow-by. These are a few of the typical situations occurring today. Handling the few locomotives that require early filter changes would reduce maintenance and waste generation. Those units could also be inspected for other "out of normal" operational parameters. Correcting the source problem would immediately put those locomotives back on the fleet wide objective of 180-day oil filter life.

The work outlined here is only the beginning of demonstrating oil filter performance benefits in existing fleet and new technology locomotives. New chemistry, hardware design, oil analysis and field test work can bring operator the tangible benefits and cost reductions they desire.

Oil Filter Flow Study

(GE B30-7A Filters at 92 Days)

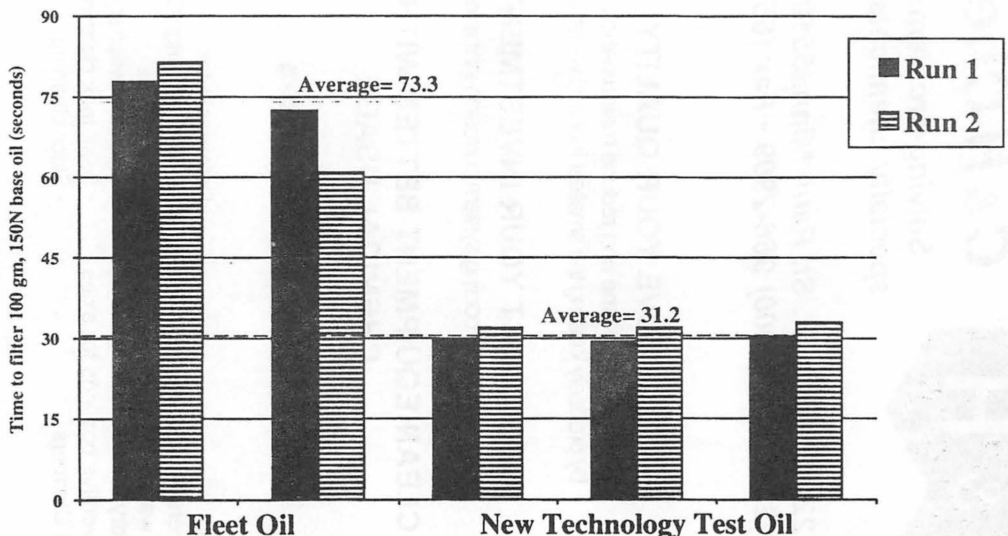


Figure 1

Flow Testing 92 Day Filters

(GE B30-7A)

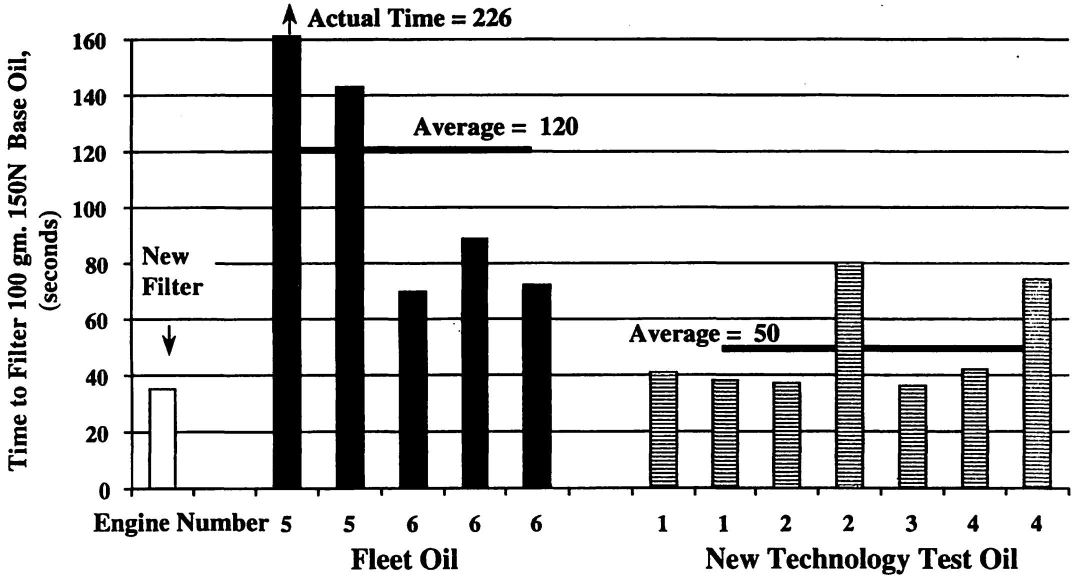
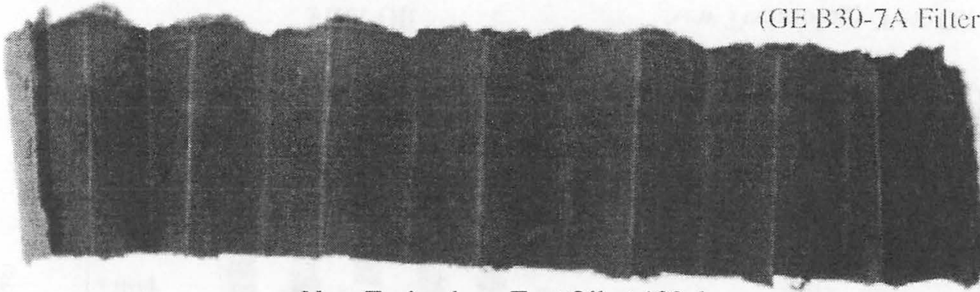


Figure 2

New Technology Test Oil vs. Fleet Oil

(GE B30-7A Filter Strips)



New Technology Test Oil at 180 days

Fleet Oil at 92 days

Figure 3

New Technology Test Oil vs. Fleet Oil

(GE B30-7A Filters)

Fleet Oil at 92 days | New Technology Test Oil at 180 days

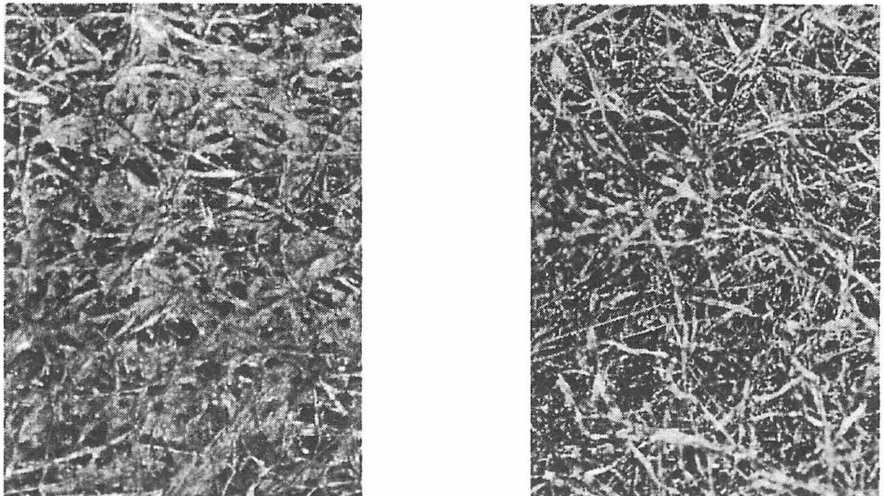


Figure 4

Tank Pressures

46 Days on Filter

Unit #	Date	8 Notch PSI Pre-Load
1	06/19/96	20
1	08/11/96	11
1	11/25/96	10
2	06/25/96	10
3	07/16/96	10
3	09/01/96	7.4
4	07/10/96	8.4
4	08/24/96	9
5	07/11/96	11
6	08/05/96	15
7	08/12/96	8

92 Days on Filter

Unit #	Date	8 Notch PSI Pre-Load
3	11/24/96	12
4	11/29/96	10
5	11/25/96	37

Figure 5

Oil Filter Plugging Evaluation

EMD Engines

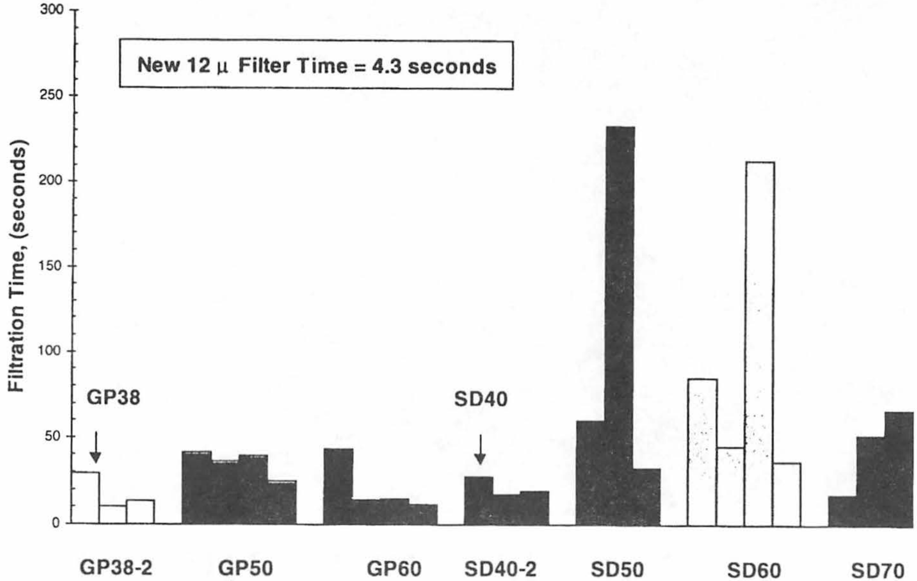


Figure 6

EMD Filter Performance

Filtration Time 17.6 Seconds
Mag 3.2X

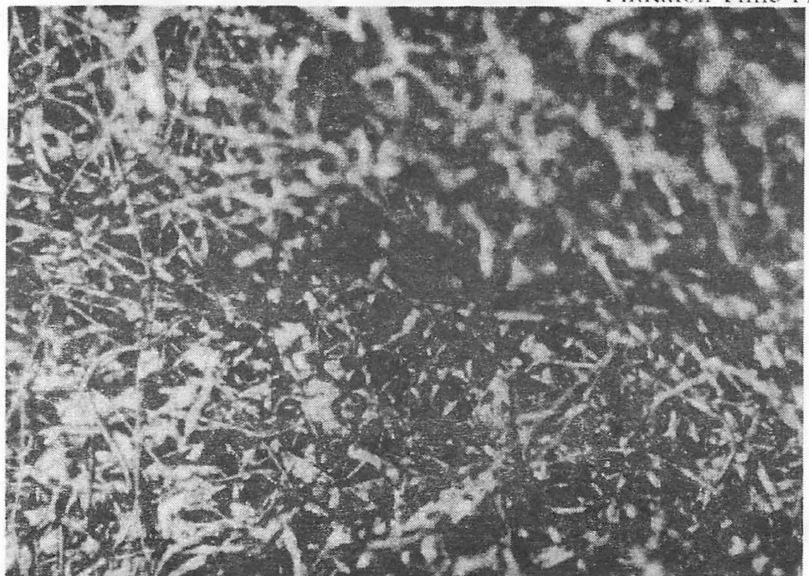


Figure 7

EMD Filter Performance

Filtration Time 233.2 Seconds

Mag 3.2X

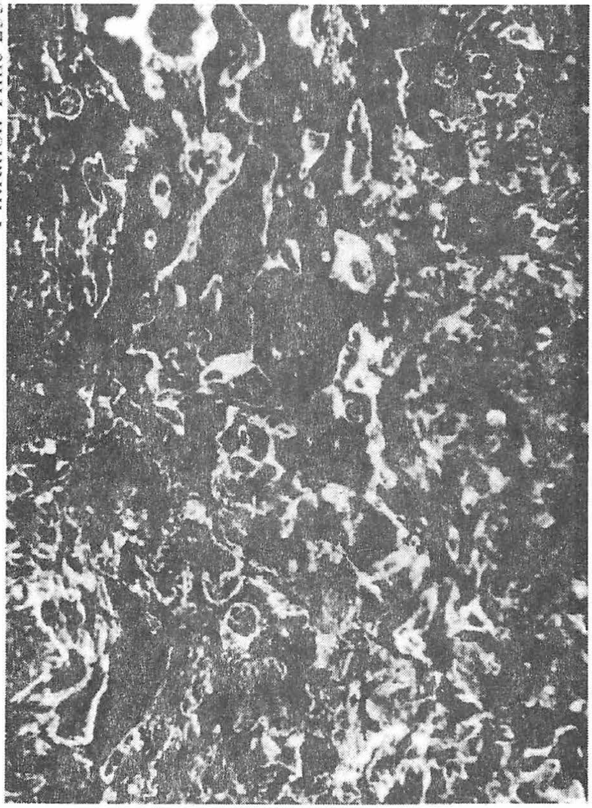


Figure 8

Oil Filter Plugging Evaluation

Class I GE Engines

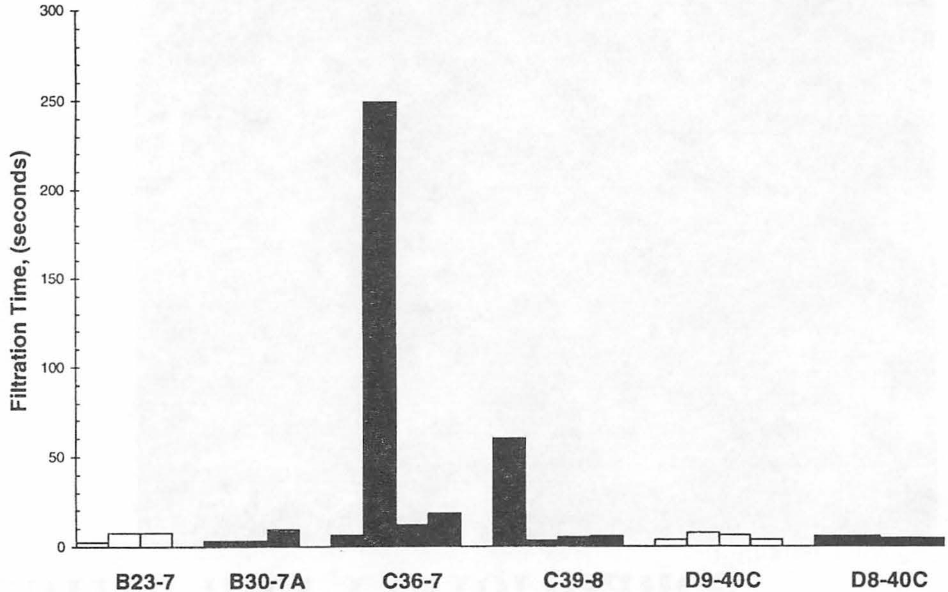


Figure 9

GE Filter Performance

Filtration Time 3.0 Seconds

Mag 3.2X

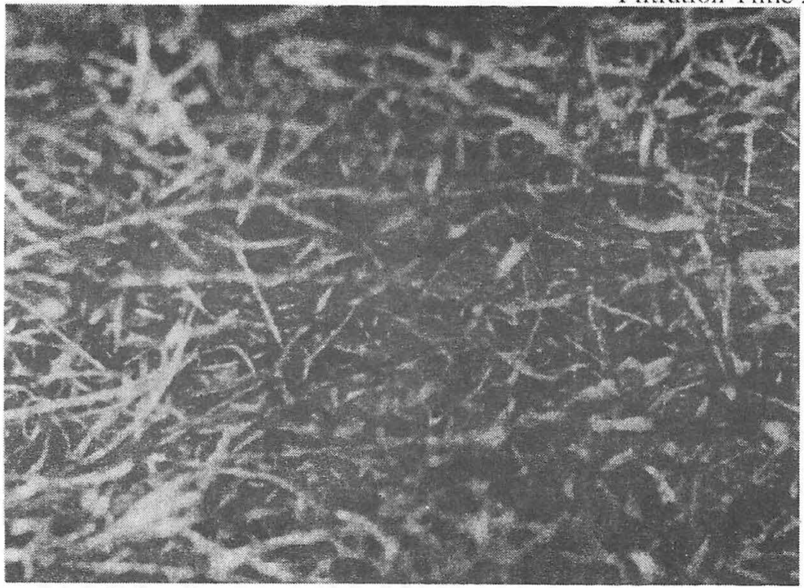


Figure 10


GE Filter Performance
Filtration Time 249.3 Seconds
Mag 3.2X
Figure 11

III. RECYCLING AND RE-REFINING OF USED LUBRICATING OILS

by Cline A. Tincher
Lyondell Lubricants

With increasing emphasis on the environment, the proper disposal of waste products is essential. Today, people of all ages and occupations are getting involved in the proper disposal of cans, glass, paper, and even industrial waste streams. (Figure 1)

The Environmental Protection Agency (EPA) along with state and local agencies is increasingly changing its requirements for the disposal of waste materials by making them more restrictive. Laws requiring waste generators to account for their waste and its proper disposal already exists. In addition, the generator of any waste is responsible for knowing if it contains any hazardous material such as polynuclear aromatics, heavy metals, chlorinated organics, flammable solvents, or corrosive materials. Railroads, along with other industries, are being more vigilant in the disposal of their waste oils and chemicals.

When it comes to the disposal of used lubricating oils, a waste generator has roughly six options, which are as follows:

- indiscriminate dumping,
- road oiling and foliage control,
- land filling,
- burning for energy recovery,
- reclaiming, or
- re-refining.

The first two options - indiscriminate dumping along with road oiling and foliage control - are not viable for industrial waste oil generators. Federal and state regulations have become so strict in the tracking, accountability, and disposal of waste oil that dumping it into the environment has been eliminated for waste oil generators. Only household wastes are generally exempted from government regulations. A waste oil generator is responsible and accountable for its waste oil from the time it is generated until the oil is properly disposed of. This is what is called "cradle to grave responsibility." Illegal disposal by industrial generators can lead to large fines and even criminal prosecution.

One only has to recall incidents such as Times Beach, Mo., and Love Canal, NY, (Figure 2) to see what problems improper disposal of waste products can cause to a community and the surrounding environment. A waste generator is responsible for the proper disposal of its waste oils. It is liable for any penalties, clean up costs, and possible criminal prosecution, for failing to monitor the disposal of its waste products. Criminal charges can be assessed at all levels from the executives to the dockworkers, whether or not they were aware of any illegal activities. Therefore, it is imperative that a waste generator knows what is happening at its selected treatment, storage, and disposal facility.

This leaves as the only possible options for used oil disposal as: landfills, burning for energy recovery, reclaiming, and re-refining.

Landfilling

Disposal of waste products in landfills is primarily restricted to solid material. Disposal of waste oil in landfills is currently restricted by Federal Regulation 40 CFR 268 as well as by limitations on the placement of liquids in landfills. Landfills that accept liquids have to meet stringent requirements, such as liners (Figure 3) and monitoring wells (Figure 4), to prevent liquid wastes from leaking into the environment. Space in these facilities is limited, so only small quantities of hazardous liquids are placed in these landfills. Clearly, with the large quantity of used engine oil the railroads generate, disposal of the oil in a landfill is out of the question.

This leaves three possible options for railroads to dispose of their spent crankcase oil: burning for energy recovery, reclaiming, and re-refining.

Burning for Energy Recovery

Energy recovery is the most common form of used oil disposal. Over two-thirds of all the oil collected is used for fuel. There are many advantages and some controversies to this form of "recylcing." According to Federal Regulation (40 CFR Part 279 Subpart E), all collectors of used oil for purpose of resale must document whether or not the used oil meet the Used Oil Fuel Specification listed below.

Used Oil Fuel Specification

Property	Specification
As	<5 ppm
Cd	<2
Cr	<10
Pb	<100
Halogens	<4000*
Flash Point (Min.)	100 °F

*Total Halogen levels > 1000 are presumed to to contain listed hazardous wastes unless analysis indicates otherwise.

Used oils meeting these criteria are referred to as "on specification" and can be handled as any fuel oil.

Oils that are too severely contaminated to recover by other methods are frequently disposed of in cement kilns or incinerators (Figure 5). Based on current regulatory standards, using kilns or incinerators offers lowest risk for waste burners because the technology they use provides complete destruction of the used oil. Burning as a form of disposal only allows the oil two lives - the initial use as a lubricant and final energy recovery. Therefore, energy recovery does not qualify as recycling under some regulations.

The major problem with the burning of used oil is that many collectors, marketers and processors of used oil are small. These used oil haulers usually operate within a two hundred-mile radius of their facility to keep costs low so they can compete in the local fuel market. The EPA requires that testing and/or other records for each load be kept from receipt to final disposition. However, many collectors do not maintain a quality control laboratory with the necessary analytical equipment. This creates the potential for hazardous waste being mixed with non-hazardous waste, yielding a new hazardous waste where all generators involved are ultimately responsible for disposal.

Many collection facilities are expected by their customers to treat the waste in some form such as decanting, drying, or distillation, to remove contaminates that may be in the waste before sale. This can be expensive. Therefore, the used oil generated and picked up at your facility may go directly to a burner with no testing or treatment. Again the generator is responsible for knowing not only how the used oil is being handled, but also how other wastes sent to this treatment, storage, and disposal facility are handled. The generator is ultimately responsible for the operating practices that are used to process his used oil and other material blended with these oils.

The best solution would be that all fuels sold are "on specification" as defined within Federal Regulation 40 CFR 279 Subpart E. A further restriction applies if the fuel contains between 2 and 50 ppm PCBs, again requiring notification by the end user, as described in 40 CFR 761.20.

Reclaiming

The use of used/waste lubricants for alternative less strenuous lubricant applications is a common practice. Some used oils have minimal contamination and can be cleaned up with simple process steps. This type of recycling is referred to as reclaiming. For example, heating used oils to evaporate moisture and running dry oil through simple filtration equipment remains a common practice for hydraulic fluids that are relatively clean.

Small compounder blenders, who mix additives with the partially spent used oil before marketing it as cutting oil or API/SA motor oil, generally perform commercial reclamation. These uses do not require adherence to the highest standards of performance from the lubricant.

A waste locomotive engine oil reclamation process, which has been used on a limited number of railroads, involves dehydration, coagulant addition, and filtration or decanting prior to reuse in locomotive engines. If kept as a very small percentage of engine oil charge, operators believe cost savings have occurred with no documented adverse effect to the engine function. The major locomotive manufacturers do not recommend this practice. Acid neutralizers (measured as total base number) remaining in the used oil are often times not completely depleted and remain effective. However, any fuel dilution and cracked hydrocarbon molecules from combustion offer limited (if not detrimental) lubricating factors. Also, acid and metal contamination from combustion and wear - if not completely removed - may act as catalysts and may further degrade or limit the life of new, fully compounded lubricants.

From an environmental point of view, reclaiming does reduce the volume of oil requiring disposal. However, when evaluating this option for in-house installations, one must consider the additional cost and long term liability of the water, fuels, sludges, and residues generated by the drying and filtering process. These wastes may need to be treated further, either in-house or by one's separator system in the case of water and fuel, or landfillled or incinerated in the case of sludges and filter media. As discussed earlier, the use of landfilling is not a preferred method of disposal. It is important to stress the need to review all applicable federal, state, and local regulations before undertaking any treatment of used oils.

Re-refining

Of all the forms of recycling, re-refining is usually the most expensive. However, it offers solutions to the environmental requirements applied to disposal - eliminating long-term liability, meeting the requirements of the Resource Conservation and Recovery Act, and providing re-refined lubricants and other petroleum products equivalent to those manufactured from crude oil. Several types of recycling/re-refining process employed are:

- introduction of used oil into crude oil refining streams,
- acid clay process,
- thin film evaporation/clay contact finishing,
- thin film evaporation/ hydrotreating finishing.

Introduction of Waste Oil Into Crude Oil Refining Streams

This type of recycling involves injecting used oil into a process feed stream during the refining process of crude oil. This approach reduces "the cradle to grave" liability of a used oil generator. The used oil stream is usually introduced in small amounts into the existing crude oil stream to minimize process change requirements.

When added to the front end of a crude oil feed stream, the process distills the used oil as it does virgin crude oil into fuels, lubricant base stocks, and asphaltic bottoms. Contaminants found in used oil have found their way into fuels and have poisoned refinery catalysts and overhead liquid products. These problems along with regulatory reasons have caused some refiners to return to processing only virgin crude oil. Other refiners inject used oil at other points in the refining process to avoid system and product contamination. For example, one refiner is injecting used oil directly into a thermal cracking unit called a delayed coker (Figures 6 and 7). Essentially all components of the used oil are thermally cracked to yield coker gas oils. All coker overhead products are subsequently hydrogenated to remove sulfur, nitrogen, unsaturated hydrocarbons and any non-hazardous halides. The process also produces a small amount of petroleum coke, a solid material similar to coal. The hydrotreated heavy gas oil is then sent to a catalytic cracking unit to produce conventional fuels such as gasoline, diesel fuel, and petrochemical feed stocks, with about 98% recovery of overhead products.

Acid/Clay Process

The acid/clay process for re-refining has been employed for many years but is not used very much today due to environmental concerns and to newer technology. This process introduces concentrated sulfuric acid into the dehydrated oil. This creates an acid sludge, which is a characteristic hazardous waste due to its low pH. It contains spent additives, combustion by-products (soot), and wear metals. The acid sludge is removed and disposed of, usually in a landfill. The remaining oil is heated, treated with activated clay, and filtered. The filtered clay must also be disposed of, usually in a landfill.

The oil after filtering is essentially clean, although it still has some odor. Lubricants prepared after compounding with new additives are of lower quality when compared to those prepared from virgin base oils or re-refined base oils produced with newer technology. Typically oil prepared by the acid/clay process is used in applications with reduced severity. Because of "cradle to grave" liability and EPA regulations concerning by-products of processing, most facilities which have employed this process have changed to newer technology or gone out of business.

Thin Film Evaporation with Clay Contact or Hydrotreat Finishing

Clay Contact

An alternative to acid treatment is vaccum distillation, which separates the useful hydrocarbons from the high molecular weight contaminants. The process begins with dehydration and stripping process to remove water, solvents, and light fuel fractions from the waste stream. The water is sent to a treatment facility and the light hydrocarbons are burned in the process for heat recovery. Excess recovered fuels may be sold as "on" or "off" specification fuel, depending on the properties.

The dry, stripped oil stream is fed through a thin film evaporator which distills and recovers the selected hydrocarbon fractions under vacuum and leaves the residual asphalt cut for sale as an asphalt extender, or to be used as fuel in a cement kiln, steel mill, or

other industrial applications.

The base oil cut is removed and further treated by the addition of clay which removes some combustion acids, color bodies, and some odor. The oil slurry runs through a filter press and the base oil product is tested and evaluated for sale.

The EPA considers the base oil and asphalt products to be chemically changed finished products. Therefore, the waste has been treated and the "cradle to grave" liability has been terminated. The generator must still be concerned about the by-products and that they are handled in accordance with the law. A further concern is the disposal of the oily clay, which is similar to the material generated by the acid-clay process.

Although not the state of the art, this re-refining process eliminates much of the liability and produces a less odorous, higher quality re-refined base oil, which can be blended and compounded to meet most manufacturers' specifications. After passing quality control testing, the base oils and finished lubricants produced from this process are often an economical source of lubricants as well as an environmentally safe disposal method.

Hydrotreat Finishing

This disposal-manufacturing process is the next generation beyond the thin film-clay contacting form of re-refining. The larger re-refiners use this form of processing. Not all-waste oil streams available are selected to be processed in the re-refining operation (Figure 8).

The better feedstocks include automotive and railroad crankcase oils, hydraulic and transmission fluids, and other high quality hydrocarbon based waste oil streams. Pontential feedstocks with high water, excessive contamination, or animal fats and or some synthetics are processed as fuel. The feedstocks remaining are of sufficiently high quality that they will not affect the efficiency of the plant operation. Initial quality control analysis of the feed, yields a higher quality product exiting the process.

Streams selected for process are mixed in a large holding tank to produce a consistent feed. This eliminates any chance of the system seeing any truck-to-truck variations. The feed is sent on a continuous basis to a dehydration unit to remove water, solvents, and light fuel fractions. Any water collected is processed until it meets municipal disposal permit standards and is discharged to the sanitary system. The solvents and light fuel fractions are recovered and burned within the facility to supplement the energy required by the boilers for operation.

The dehydrated oil is sent through a second defueling distillation column at high temperature and a moderate vaccum to remove heavier cuts of fuel. This produces a high quality industrial fuel and a topped oil feed stock. The oil feed is then sent through a series of thin film evaporators, which are held at different temperatures to produce multiple fractions or viscosities of hydrocarbon base oil (Figures 9 and 10). The unfinished oil is tested against manufacturing specifications and sent for the final finishing step.

Hydrotreating, or catalytic hydrogeneration, is the final finishing step. This is simular to the process used on "virgin crude oils" to remove most sulfur, oxygen, and nitrogen from the base oil while saturating some of the aromatics. The hydrogenation step eliminates most of the compounds causing color, odor and/or auto-oxidation. The finished product is tested against manufacturing specifications and sold to industry as base oils or blended with additives and sold as fully compounded lubricants.

Conclusion

Railroads have three possible options for disposing of their spent crankcase oil: burning for energy recovery, reclaiming, and re-refining. Which method the railroads choose usually depends on cost and disposer reliability. Currently, it is estimated that 83% of used railroad crankcase oil is burned for energy recovery, approximately 15% is re-refined, and the remaining 1 or 2% is processed by in-house reclaiming systems and is blended with new locomotive engine oil before use. These are changing, and the trend toward re-refining is gaining.

When selecting a facility to remove and process waste such as used oil, it is important for a generator to consider more than current costs. With "cradle to grave" responsibilty for one's wastes, it may be less expensive in the long run to select a facility which is financially stable, meets environmental regulations, and is operationally clean.

FIGURE 1

FIGURE 2

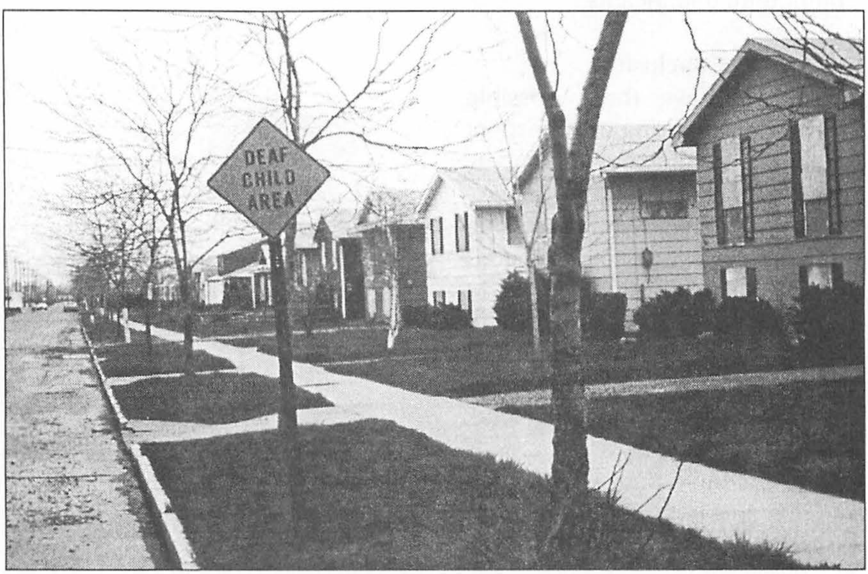


FIGURE 3

FIGURE 4

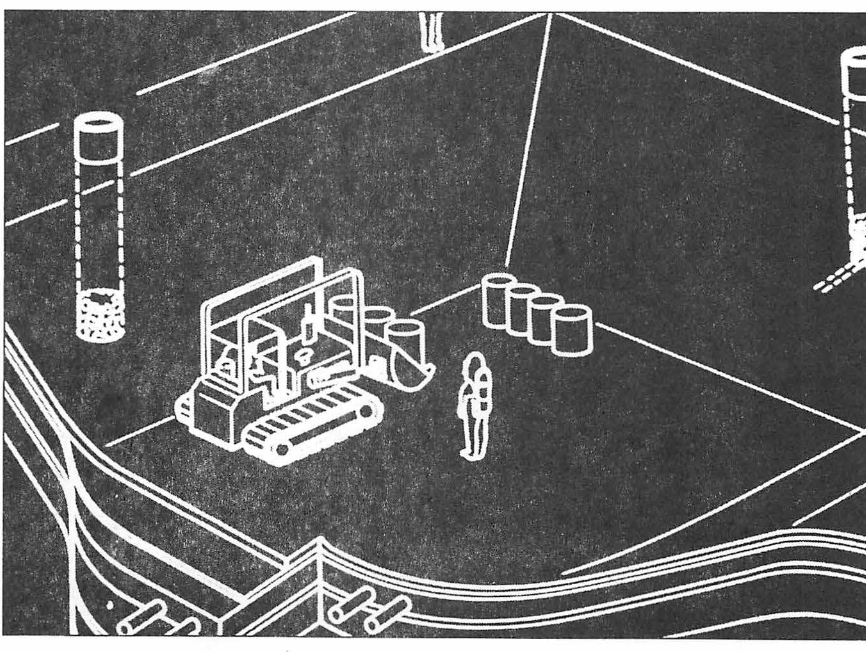


FIGURE 5

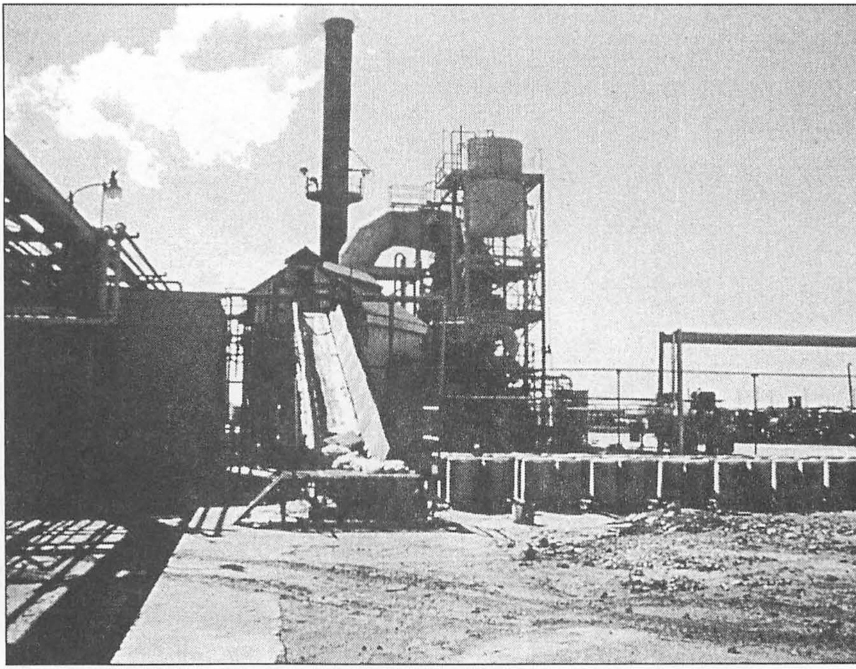


FIGURE 6

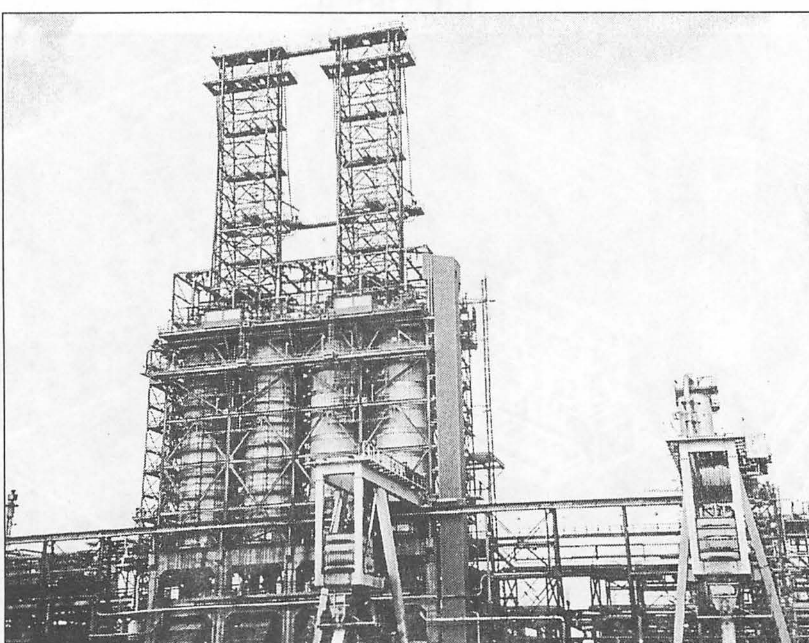


FIGURE 7

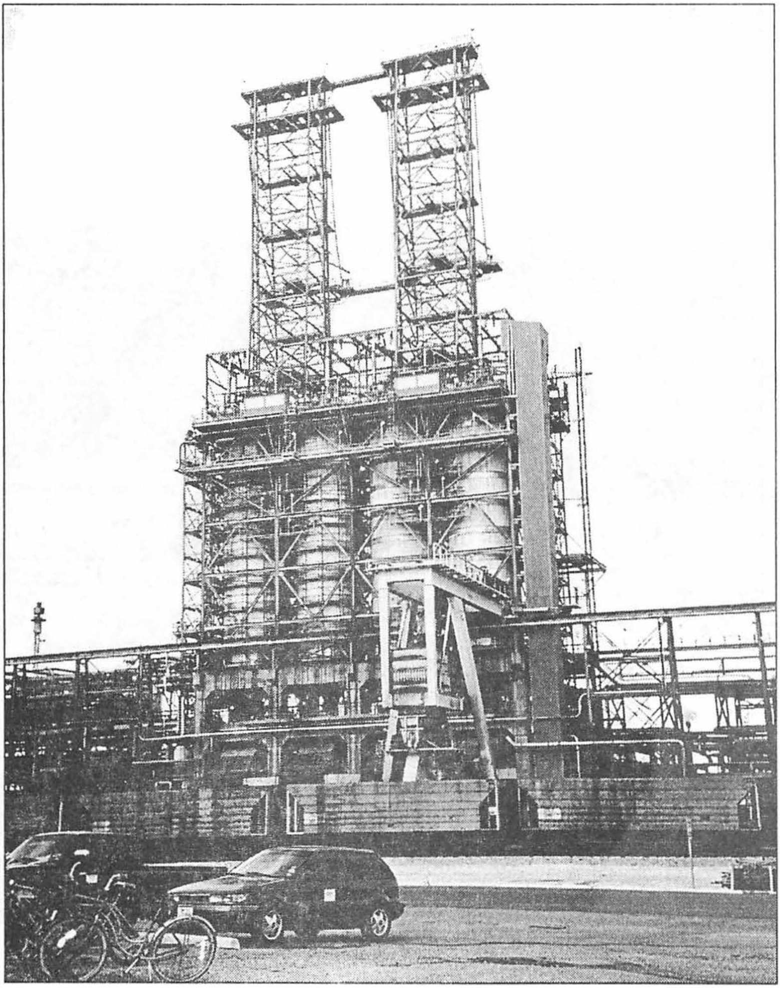


FIGURE 8

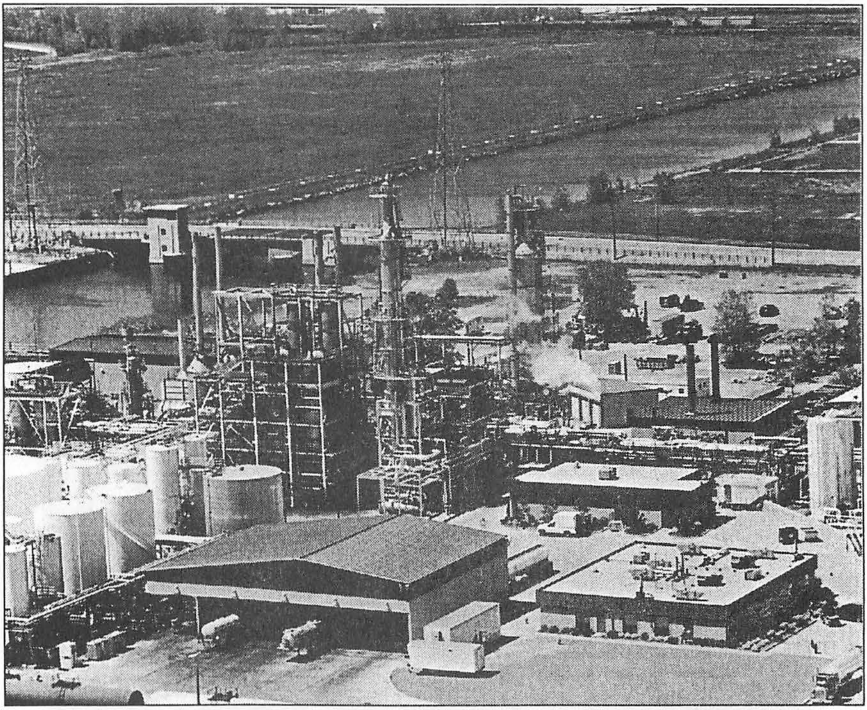


FIGURE 9

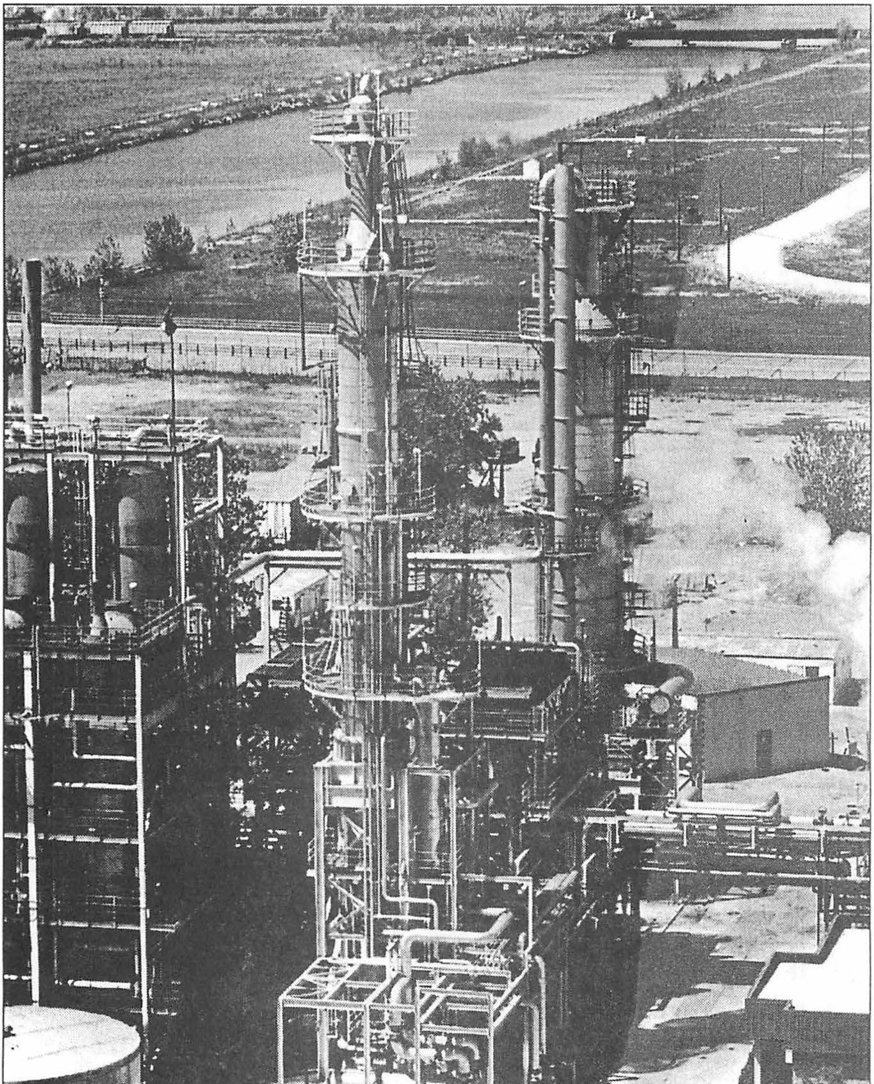
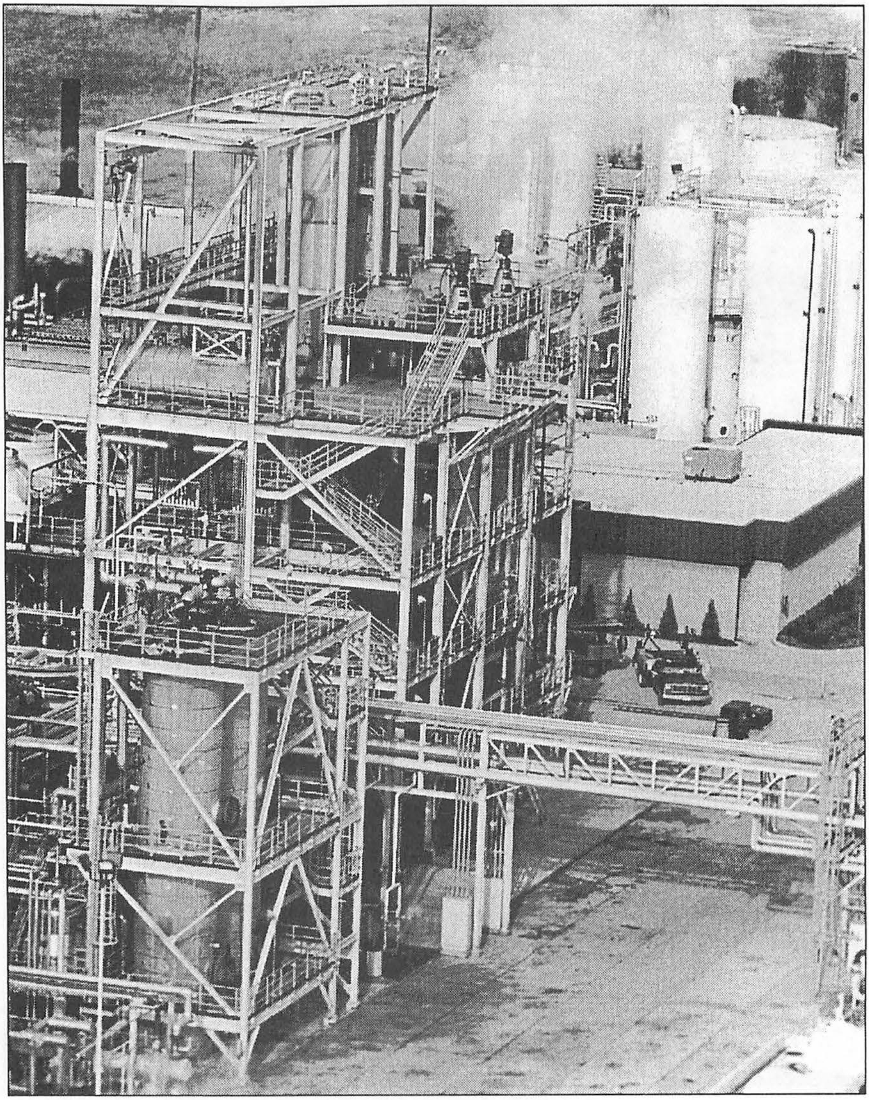


FIGURE 10



CONSTITUTION AND BY-LAWS LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

Article I - Title:

The name of this Association shall be the Locomotive Maintenance Officers Association (LMOA).

Article II - Purpose of the Association

The purpose of the Association, a non-profit organization, shall be to improve the interests of its members through education, to supply locomotive maintenance information to their employers, to exchange knowledge and information with members of the Association, to make constructive recommendations on locomotive maintenance procedures through the technical committee reports for the benefit of the railroad industry.

Article III - Membership

Section 1 - Active Railroad Membership shall be composed of persons employed by a railroad company and interested in locomotive maintenance. Membership is subject to approval by the Board of Directors.

Section 2 - Associate Membership shall be comprised of persons employed by a manufacturer of equipment or devices used in connection with the maintenance and repair of motive power, subject to approval of the Board of Directors.

Associate members shall have equal rights with active members in discussing all questions properly brought before the association at the Annual Meeting, but shall not have privilege of voting or holding elective office.

Section 3 - Honorary Membership: Honorary Membership may be issued at the discretion of the President, subject to the approval of the Board of Directors. Honorary Members may not vote or hold elective office; all Honorary Membership shall expire at the end of the current membership year.

Section 4 - Life membership shall be conferred on all Past Presidents. Honorary life memberships shall be conferred on others for meritorious service to the Association, subject to approval by the General Executive Committee.

Section 5 - Dues and fees: Membership dues for individual active and associate membership shall be set by the Board of Directors and shall be payable on or before September 30th of each year. The membership year will begin on October 1 and end September 30. Life and honorary life members will not be required to pay dues. Members whose dues are not paid on or before the opening date of the annual convention shall not be permitted to attend the annual meeting, shall not be eligible to vote and/or shall not be entitled to receive a copy of the published Pre-Convention Report or the Annual Proceedings of the annual meeting. Failure to comply will result in loss of membership at the end of the current year. A registration fee will be set by the Board of Directors for those attending the annual meeting. Life, life honorary, and honorary members will be entitled to receive a copy of the Pre-Convention Report and Annual Proceedings.

Article IV - Officers

Section 1 - Elective Officers of the Association shall be President, First Vice President, Second Vice President and Third Vice President. There will be one Regional Executive for each technical committee. Each officer will hold office for one year or until successors are elected. In the event an officer leaves active railroad service, he may continue to serve until the end of his term, and, if they choose, continue to serve as an executive officer and be allowed to elevate through the ranks as naturally occurs, to include the office of President.

Section 2 - Board of Directors: There shall be a Board of Directors composed of the President, Vice Presidents, and all Past Presidents in active official railroad service. In the event a member of the Board of Directors becomes inactive, he may continue to serve until the end of his term of office.

Section 3 - General Executive Committee: There shall be a General Executive Committee, composed of the Board of Directors, the Regional Executives, and the Technical Committee Chairpersons.

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

Section 5 - Advisory Board - There shall be an Advisory Board composed of at least nine members, who are Senior Mechanical Officers, Assistant Vice Presidents or Vice Presidents. They will be invited by the Board of Directors and serve as ex-officio members of the General Executive Committee without vote.

Article V - Officer, Nomination and Election of

Section 1 - Elective officers shall be chosen from the active membership. The nominating committee, composed of the Board of Directors, shall submit the slate of candidates for each elective office at the annual convention.

Section 2 - Election of officers shall be determined by a voice vote, or if challenged, it shall require show of hands.

Section 3 - Vacant offices. Vacancies in any elective office may be filled by presidential appointment, subject to approval of the Board of Directors.

Article VI - Officers - Duties of

Section 1 - The President shall exercise general direction and approve expenditures of all affairs of the Association.

Section 2 - The First Vice President, shall in the absence of the President, assume the duties of the President, he shall countersign all expenditures of the Association and be responsible for preparing and submitting the program for the Annual Meeting.

The Second Vice President shall be responsible for selecting advertising. He will coordinate with the Secretary-Treasurer and contact advertisers required to underwrite the cost of the **Annual Proceedings.**

The Third Vice President will be responsible for maintaining a strong membership in the Association. He will ensure that membership applications are properly prepared and distributed, monitoring membership levels and reporting same at appropriate time to the General Executive Committee.

Section 3 - The Secretary-Treasurer shall:

A. Keep all the records of the Association.

B. Be responsible for the finances and accounting thereof under the direction of the Board of Directors.

C. Perform the duties of the Secretary of the Board of Directors, Nominating Committee, and General Executive Committee, without vote.

D. Furnish surety bond in amount of $5000 on behalf of his/her assistants directly handling Association funds. Association will bear the expense of such bond.

Section 4 - The Board of Directors shall be responsible for the following duties:

A. Assist and advise the President in long-range Association planning.

B. Contract for the services and compensation of a Secretary-Treasurer.

C. Serve as the Nominating Committee.

D. Serve as the Auditing and Finance Committee.

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

F. Exercise general supervision over all Association activities.

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

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

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

Section 5 - There will be one Regional Executive officer assigned to each technical committee. Their duties will consist of:

A. Participate in the General Executive Committee meetings.

B. Monitor material to be presented by the technical committees to ensure reports are accurate and pertinent to the goals of the Association.

C. Represent LMOA in their respective regions.

D. Promote Association activities, especially those held within their assigned region and monitor membership activities on those railroads so assigned.

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

Section 6 - Duties of General Executive Committee:

A. Monitoring technical papers for material considered unworthy or inaccurate for publication.

B. Approve topics for the **Annual Proceedings** and Annual Meeting program.

C. Approve the schedule for the Annual program.

D. Administer all Association activities not specifically assigned to the Board of Directors.

Section 7 - The Advisory Board shall act in a consulting capacity. Past Presidents still in official active railroad service shall automatically become members of the Advisory Board.

Section 8 - The Board of Directors are entrusted with all public relation decisions within LMOA and coordinated associations with confidentiality.

Article VII - Technical Committees

The technical committees will consist of:

Section 1 - A chairperson, appointed by the President and approved by the Board of Directors.

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

Section 3 - Committee members will be made up of:

A. Representatives of operating railroads and regional transit authorities submitted by their Senior Mechanical and Materials Officers and approved by the President of LMOA.

B. Representatives of locomotive builders designing and manufacturing locomotives in North America.

C. The Fuel and Lube Committee will include members from major oil companies or their subsidiaries as approved by the General Executive Committee.

D. At the discretion of the General Executive Committee, non-railroad personnel may be allowed to participate in committee activities, subject to annual review.

E. All individuals who are on technical committees must be LMOA members in good standing. (See dues and fees, Article 3, Section 5).

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

Article VIII - Proceedings

The Locomotive Maintenance Officers Association encourages the free interchange of ideas and discussion by all attendees for mutual benefits to the railroad industry. It is understood that the expression of opinion, or statements by attendees in the meeting, and the recording of papers containing the same, shall not be construed as representations or statements ratified by the Association.

Article IX - Rules of Order

The proceedings and business transactions of this Association shall be governed by Roberts Rules of Order, except as otherwise herein provided.

Article X - Amendments

The Constitution may be amended by a two-thirds vote of the active members present at the Annual Meeting.

DIESEL MECHANICAL MAINTENANCE COMMITTEE
EIGHTEEN YEAR INDEX

1998

1. LMOA Best Practices Series: GM Engine Crankcase Pressure Troubleshooting
2. Union Pacific's New EMD Diesel Engine Rebuild Line At Downing B. Jenks Locomotive Facility-No. Little Rock, Arkansas
3. GE Turbo Rebuild Procedures
4. Mechanical Impact of Locomotive Emissions Regulations
5. Locomotive Engine Bearing Developments

1997

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

1996

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

1995

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

1994

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

1993

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

1992

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

1991

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

5. Personnel training on New Technology.

1990

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

1989

1. Wheel Axle Gear Wear/Impact on Traction Motor Life.
2. 710 Engine - Operational and Overhaul Update.
3. GE Power Assembly Improvements on Welded Head-to-Liner
4. Assembly Rework Procedures.
5. EMD Engine Oil Leaks. Secondary Air Filtration - Barrier vs. Impingement.

1988

1. Low-idle Operating Costs vs. Fuel Savings.
2. Rebuilding GE's EB Liner.
3. The Extended Maintenance Truck
4. Flange Lubricator Update.
5. Permaspray II - Cylinder Liner.

1987

1. EMD Water Pump Rebuilding.
2. On Board Flange Lubricators.
3. Gear Case, Bull Gear and Pinion Gear Longevity in the 1980's - Gear Cases - Canadian National Experience.
4. Maintenance of Locomotive Fueling Systems for a Spill Free Operation.

1986

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

1985

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

1984

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

1983

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

1982

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

1981

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

DIESEL MATERIAL CONTROL COMMITTEE
EIGHTEEN YEAR INDEX

1998
1. Tighter is Not Better
2. Are Vending Machines the New Wave for Safety Items?

1997
1. Raising Our Standards for Safety
2. The Rail Industry's Electronic Parts Catalog Exchange Standard (EPCES) - A Better Way

1996
1. Technology Transfer-The Hot Process of the 90's-Condition Based Maintenance
2. Warehouse Automation

1995
1. Warranty and Reliability Management
2. Railroad Industry Group (RIG) Exchange Standard for Parts Catalog Information

1994
1. Material Consignment.
2. The Next Step in Electronic Information Management - Interactive Technical Manuals.
3. Electronic Catalog Alternatives.

1993
1. Technology Transfer
2. Electronic Cataloging from a Material Perspective
3. Computerized Reordering from the Mechanical Employee's Point of View
4. Electronic Catalogues: OEM /Supplier Point of View

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

1991
1. The World of Recycling.
2. Problems with Solutions.
3. Problems with Opportunities.

1990
1. Waste Minimization.
2. Hazardous Materials End Cost
3. The Role of the Suppliers.

1989
1. Packaging and Containerization for Today's Railroad.
2. Innovations in Material Distribution Resulting from Shop Consolidations.
3. Outsourcing! Does Anyone Really Understand the Difference Between UTEX and Repair and Return and the Affect on the Budget?
4. "Stuff" Happens! - A Skit About the Necessity of Feedback from Suppliers - Suppliers to the end User.

1988
1. Communication - The Vital Link in Materials Acquisition.
2. Quality Assurance Through Communications and Feedback.
3. Paperless Requisitions.
4. A Practical Application of Bar Coding in the Railroad Industry.

1987

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

1986

1. The In-House Electronic Requisition System.
2. Electronic Data Interchange.
3. RAILING and Electronic Purchasing.
4. Quality Evaluation of Material Sourcing Decisions.

1985

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

1984

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

1983

1. Improved Locomotive Productivity Through Computerized Data.
2. Inbound Material Inspection.
3. Minimize Maintenance Cost Through Material Management Systems.
4. New Ideas In Material Storage Containers.

1982

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

1981

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

SHOP EQUIPMENT COMMITTEE
EIGHTEEN YEAR INDEX

1998

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

1997

1. Wheel Truing as Preventive Maintenance
2. Conrail-Selkirk Diesel Terminal Wastewater Treatment Facility Recent Evnironmental Improvements

1996

1. Locomotive Painting
2. Drop Table Tooling for New EMD and GE Locomotives

1995

1. Pre-Maintenance Inspection
2. Railroad Turntable Modification
3. Mobile Locomotive Service Vehicle

1994

1. Electronic Fuel/Unit Injection Tooling.
2. Locomotive Roller Support Bearing Tooling.
3. Fall Protection and Man Lifts.
4. Locomotive Washing Systems.

1993

1. Dynamic Balancing for GE Dash 8 Model Locomotives
2. Air Compressor Automated Station
3. Ergonomics in the Work Place
4. Hydraulic Traction Motor Shimming Table

1992

1. Automated Test and Production Equipment
2. Safety Corrective Action Team
3. Automated Locomotive Wheel Shop
4. Cleaning and Surface Preparation with Sodium Bicarbonate Based Abrasive Blasting
5. Trainline Continuity Tester
6. BN - Railroad Power Assembly Shop of the 1990's.

1991

1. Economic Separation of Emulsified Oil from Waste Water Using Ultra Filtration Membranes.
2. EMD Cylinder Head Valve Seat Machining.
3. Automated Barring Over Machine for EMD Diesel Engines.
4. New Equipment for Testing EMD Engine Protectors.
5. Compressed Air for Railroad Facilities Issues and Solutions to Achieve Clean, Dry, Oil Free Air.

1990

1. EMD Valve Bridge Machine
2. GE Traction Motor Roller Suspension Bearing Replacement Equipment and Procedure.
3. Locomotive Component Replacement Forklift Attachment.
4. Locomotive Sanding, Fueling and Drop Tables.
5. Hazardous Waste Disposal.

1989

1. Automated Locomotive Wheel Shop.
2. Laser Guided Material Handling Vehicles.

3. Bulk Rail Lubrication Storage & Fill System.
4. Pilot Plate Straightening Equipment.

1988

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

1987

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

1986

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

1985

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

1984

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

1983

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

1982

1. Tools.
2. Rebuild line for EMD turbochargers.
3. Air brake equipment line.
4. Industrial robots.
5. Automated machines.
6. Safety related items and equipment.

1981

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

DIESEL ELECTRICAL MAINTENANCE COMMITTEE EIGHTEEN YEAR INDEX

1998

1. Locomotive Troubleshooting Assistant
2. Locomotive Electronic Brake Maintenance
3. SD70MAC Capacitor Discharge Procedure
4. Power Savings for Electrical Locomotives
5. Auto Stop/Start and Layover Systems

1997

1. Review of Battery Maintenance and Available Options
2. Battery Charger/Booster
3. Locomotive System Integration
4. Electronic Governors

1996

1. EMD SD80MAC High Voltage Safety
2. GE AC Locomotive Electrical Safety Features
3. Electromagnetic Interference (EMI on AC Locomotives)
4. QTRAC 1000 Adhesion Control System
5. Locomotive Health Monitoring-The Key to Improved Maintenance

1995

1. Canadian National Battery Water Usage
2. Remote Diagnostics-Radio Download
3. Programmed Preventive Maintenance
4. Commutation Monitoring in Locomotive DC Traction Motors
5. The EMD Diesel Engine Control (EMDEC) System

1994

1. Safety First - Video on Electrical Safety.
2. Locomotive Health Monitoring Systems.
3. Event Recorder Update.
4. SD60 Dynamic Brake Improvements

1993

1. Automatic Engine Shutdown and Restart System
2. Layover Systems/Standby Power Systems
3. CN North America - Electronic Temperature Control
4. Speed Sensing Devices
5. Adhesion Alternative
6. Modern Tooling Update

1992

1. Nickel-Cadmium Batteries as an Alternative
2. Overview of Locomotive Microprocessor Based Controls
3. Locomotive Air Conditioning
4. Testing Traction Alternator Fields on EMD Locomotives
5. Flange Lubricators

1991

1. Locomotive Rebuilding - Something Old - Something New. Standardization of Electrical Equipment.
2. Locomotive Batteries
   a. Storage Handling Procedures.
   b. Recommended Maintenance Procedures.
   c. Recommended Repair Procedures.
3. Amtrak's AC Traction Locomotives.
4. Modern Tooling for Electricians

1990

1. Modern Tooling of Electrical Troubleshooting.
2. Maintaining Solid State Event

Recorders.
3. Why Can't We Have One Central Computer?
4. EPA and Regulation Driven Cleaning.

1989

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

1988

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

1987

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

1986

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

1985

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

1984

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

1983

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

1982

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

1981

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

NEW DEVELOPMENTS COMMITTEE
SIXTEEN YEAR INDEX

1998

1. Expert Systems
2. EMD SD90MAC 6000 HP Locomotive - Where Are We Today? GE AC6000CW Locomotive - Where Are We Today?

1997

1. An Overview of the Electro-pneumatic Train Brake
2. Locomotive 6724, Where Are You? GPS, Mobile Telemetry and GIS Technologies in a Railroad Environment
3. Runout Measurement Using Non-Contact Sensor Technology
4. Common Rail Fuel Injection

1996

1. Activities Toward New Safety Standards for Passenger Equipment
2. SP-3 Thin Sensor Technology for Variable Force Measurement
3. Top-Of-Rail Lubrication
4. Traction Motor Vibration and its Effects

1995

1. Beltpack Locomotive Control System
2. The MK1200G Switching Locomotive
3. Advanced Traction Motor Testing

1994

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

1993

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

1992

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

1991

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

1990

1. Motor Driven Air Compressors for Diesel-Electric Locomotives
2. Locomotive Cab (HVAC) Heating, Ventilation and Air Conditioning Systems.
3. Effect of Technology on Standardization of Cab Control

Equipment.
4. Locomotive Durability, Reliability and Availability - Understanding Your Abilities.

1989

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

1988

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

1987

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

1986

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

1985

1. The Sprague Clutch for E.M.D. Turbocharged Engines.
2. A.C. Traction Locomotives Update.
3. Natural Gas Locomotive Update.
4. Ceramic Coated Engine Components.
4. Locomotive Cab Developments.

1984

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

1983

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

FUEL, LUBRICANTS AND ENVIRONMENTAL COMMITTEE EIGHTEEN YEAR INDEX

1998

1. Safety and Chemical Cleaners
2. Development of a Low Emissions, Dual Fuel Locomotive
3. Fuel Oil Stability Update
4. Ten Questions on EPA's Locomotive Exhaust & Emission Regulations

1997

1. Ferrography-Used Oil Analysis Program
2. 2000 - A New Millennium for Locomotive Maintenance: EPA Exhaust Emissions Regulatory Impacts
3. Standardized Test Procedures - Current Developments
4. Industry Updates and New Developments

1996

1. Standardized Test Procedures-The Annual Subcommittee Update
2. Diesel Fuel Standards and their Applications to Railroad Fuel Quality Issues
3. A Look at Generation 5 Oil Performance and Future Oil Needs
4. LNG as a Railroad Fuel

1995

1. MSDS'S - What do they tell us?
2. Applying Satellite Communications Technology to On-Line Oil Analysis of Crankcase Diesel Engine Lubricants
3. Standardized Test Procedures - Past, Present & Future Developments
4. Locomotive Exhaust Emissions Regulations

1994

1. TBN-A Review of Currently Accepted Methods.
2. GE Multigrade Lubricating Oil Testing and Specification.
3. The Economic Impact of Low-Sulfur Diesel Requirements.

1993

1. Used Oil Analysis of Multigrade Oils and Condemning Limits.
2. Insoluble Determination with the Advent of Multigrade Diesel Engine Oils
3. Bioremediation.

1992

1. Environmental Issues Relating to Multigrade Railway Issues.
2. Readily Biodegradable and Low Toxicity Railroad Track Lubricants
3. Support Bearing Oils.
4. Recycling and Re-refining Locomotive Oils.

1991

1. Infrared Spectroscopy as an Analytical Tool.
2. Diesel Exhaust: Health Effects Research and Regulations.
3. Traction Motor Gear Case Seals and Lube Containment (Oil Lubricant)
4. Partnership in Development.

1990

1. The Responsibility of Railroads and Facility Managers in the Handling and Disposal of Hazardous Materials.
2. Update on Diesel Fuel Regulations.
3. Diesel Exhaust and Worker Exposure.
4. Field Experiences with Multigrade Railroad Locomotive Oils.
5. Conrail Wheel/Rail Lubrication Update.

1989

1. Field Test Data Follow-Up and Description of "Generation 5" Locomotive Crankcase Oil.
2. Diesel Emissions: Regulations and Fuel Quality.
3. Petroleum Storage Tank Regulations - Guest Speaker - George Kitchen, International Lube & Fuel Consultants.

1988

1. Used Oil Analysis and Condemning Limits.
2. Review of A.A.R. Procedure RP - 503, "Locomotive Diesel Fuel Additive Evaluation Procedure."
3. Update on Improved Oils - Multigrade.
4. Wheel Flange Lubrication Update - Lubricants Being Used.
5. Survey of Disposable Practices or Locomotive Engine Lube Oil and Lube Oil Filters.
6. Speaker on Overview of Environmental Requirements for The Use of Petroleum Products in The Railroad Industry - Peter Conlon - AAR.

1987

1. Common Fuel Additives and their Effectiveness.
2. History of LMOA Lubricating Oil Classification System.
3. Performance Requirements Needed by the Railroads for a New Generation Lube Oil.
4. How do we Provide the Performance Needed for a New Generation Oil.

1986

1. Extended Performance Lubricants Through Better Chemistry.
2. Fuels and Lubricants Handling Hygiene.
3. Fuels Availability and Price Outlook.
4. Selection of Lubricants for Wheel Flange and Rail Lubricators.

1985

1. Disposal of Lube Oil Drainings.
2. Non-ASTM No. 2 - D Fuel.
3. Oxidation Analysis.
4. Wheel Flange and Rail Lubrication.

1984

1. Locomotive Filters
2. Traction Motor Gear Lube Field Test.

1983

1. Field Test Update of Multigrade Oils.
2. Update of Alternate Fuel Testing.
3. A Review of Locomotive Fuels.

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