

LMOA

Locomotive Maintenance Officers Association

**Proceedings of the
60th Annual Meeting
September 21-23, 1998**

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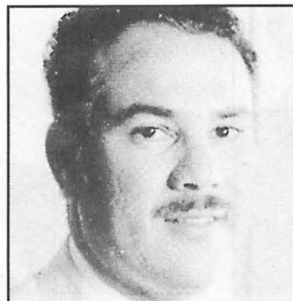


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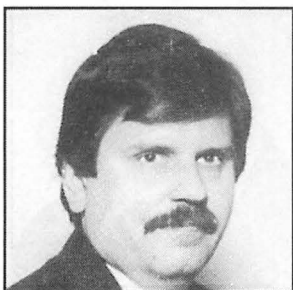


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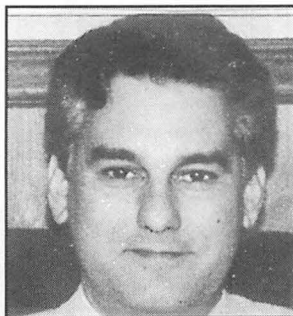
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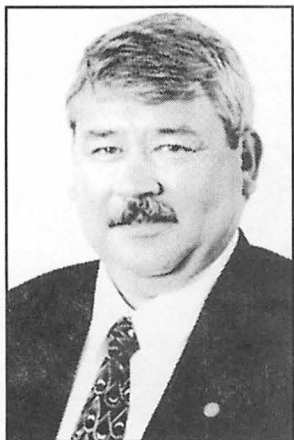


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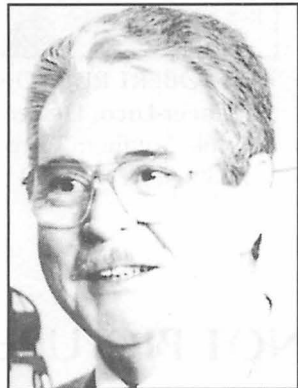
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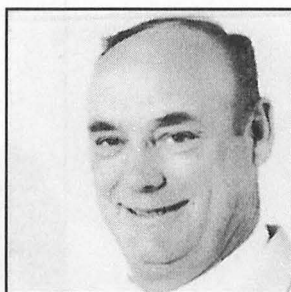


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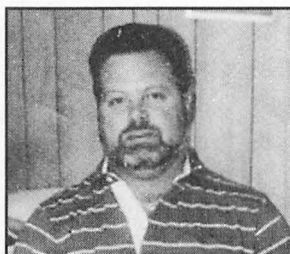
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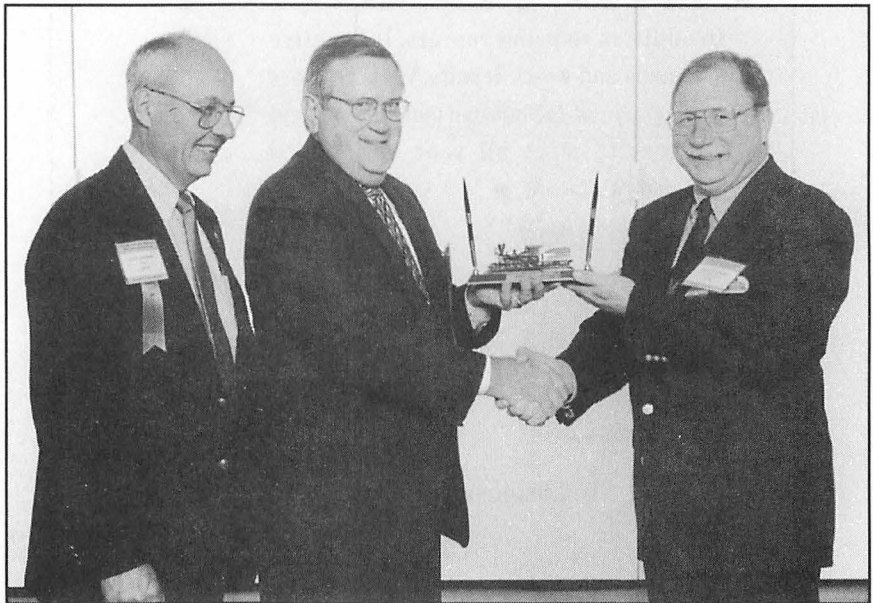
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Outgoing President David Wetmore, center, Amtrak, presents gavel to newly elected President, Harry (Mike) Pennell, Ellcon National, while 1st VP Jake Vasquez, CMC Railroad Inc., looks on



Past President Dale Propp, center, New York Air Brake, presents General Desk Set to outgoing President, David Wetmore, Amtrak. Past President David Goehring, retired Amtrak, witnessed the ceremony.



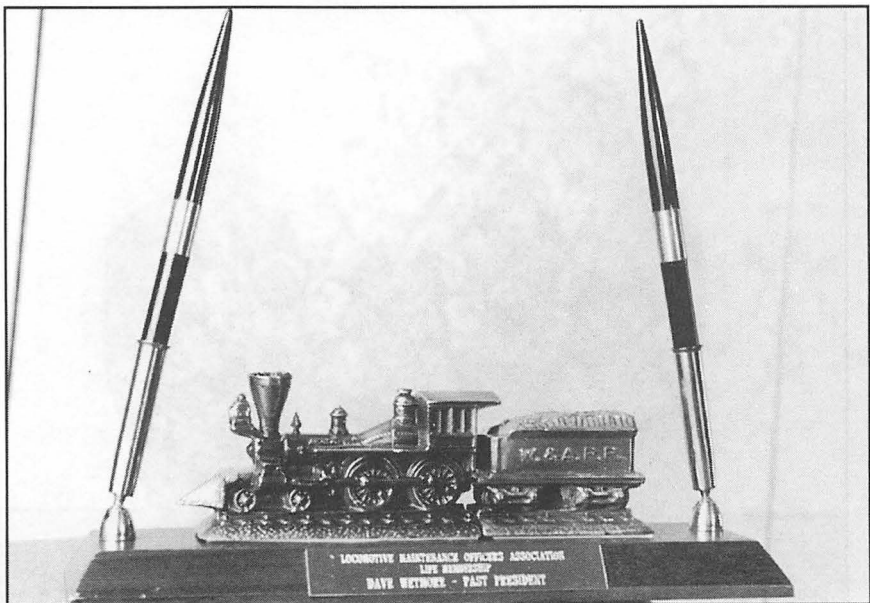
Doug Corbin, right, Norfolk Southern, assists newly elected 3rd Vice President, Ron Lodowski, Conrail, with his LMOA blazer. Past President Bill Brown, Montana Rail Link, was in attendance.



Past President Gil Bruno, cnefer, Amtrak presents Past Presidents Pin to outgoing President, David Wetmore, Amtrak, while Past President David Goehring, retired-Amtrak, looks on.



Outgoing President, David Wetmore, Amtrak, presents General Desk Set to 1997 Keynote Speaker Don Graab, Norfolk Southern. Don was also bestowed a lifetime honorary membership in LMOA.



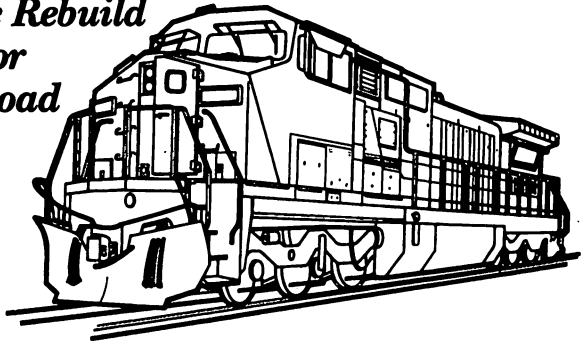
General Desk Set which is given to each LMOA executive who has honorably served a term as President of LMOA and to those who receive a lifetime honorary membership in LMOA



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KEYNOTE ADDRESS**Joint Session of the Coordinated
Mechanical Associations and
Railway Supply Association,
September 15, 1997**

*by Donald D. Graab, Assistant
Director Locomotive Maintenance
Norfolk Southern*

*Introduction by David Wetmore,
President, LMOA:*

With a great deal of pleasure and honor, I have the task of introducing our keynote speaker. Mr Graab is the assistant director, locomotive maintenance, Norfolk Southern railroad.

Don Graab was born and raised in suburban Cleveland, Ohio. After graduating from high school, Mr. Graab attended Purdue University, majoring in mechanical engineering. He was an active member and officer of Triangle Fraternity, a fraternity of engineering, science and architects.

After graduating with honors in 1975, Mr. Graab joined Illinois Central Railroad in a job that led to a supervisory assignment in Carbondale, Illinois and in Markham Yard here in Chicago.

In 1978, Don joined Norfolk and Western Railroad in Roanoke, Virginia as a training instructor for shop craft employees. In 1980, he was transferred to a foreman's job at Shaffers Crossing. Two years later, changes came on many fronts. In 1982, Don received a

Master's of Administration degree from Lynchburg College. In June of that same year, he was transferred to the Roanoke Shop and promoted to general foreman of the machine shop.

In March of 1986, Don was transferred back to Shaffers Crossing and worked in a locomotive facility as a general foreman on the second shift. In 1987, he became general foreman of the day shift, a position which he held for four years.

In 1991, Don was appointed manager of the Assembly Shop, Norfolk Southern's EMD overhaul facility in Chattanooga, Tennessee. During 1994 and 1995, Don was a Master Mechanic for Norfolk territory with responsibility of the 38th Street car shop and maintenance of the Pier 6 coal transloading facilities at Member's Point, Norfolk. In January of 1996, Mr. Graab was named assistant director of locomotive maintenance and assumed responsibility for maintenance of the Norfolk Southern locomotive fleet.

Don lives in Roanoke, Virginia with his wife of 20 years, Peggy, and their two daughters, Alison and Lindsey. Don has attended the Coordinated Associations meetings and the RSA convention since 1976. He has been an active member in the Locomotive Maintenance Officer's Association, and he is past chairman of the shop equipment committee.

Good morning. It's always good to be in the Chicagoland area on a warm September morning in this glorious hotel. And as a long time Methodist, it's always a pleasure to hear Dr. Winkler's invocation. Although it has been seven months since I accepted the invitation from David Wetmore to speak, he continues to flatter me til the last minute.

This morning is the beginning of an exciting three days of learning, discussion, and dialogue. I sense your enthusiasm and hope the relationships forged here prove to be profitable and enduring.

In the months I've had to anticipate this address, a series of thoughts have flashed through my mind as I recall my railroad experiences. In the midst of those thoughts I saw a theme I want to reflect in this morning's comments. A theme that touches on our status and looks toward the future with optimism.

So I titled my remarks, somewhat light heartedly, The Great Train Robbery and Opportunities to Come.

At first blush we think of holdups of the express car when the words train robbery come to mind. But I am not talking about robberies of the express car. The loss from robberies like those was easy to control. Nor am I talking about the modern day loss of assets, which people like our internal auditors guard against. The monies I am talking about were not taken by masked men but by

the ever changing forces in the market place, our market place. The marketplace of inter-city freight.

While it is probably wrong, perhaps even reckless, to suggest that any portion of commerce is rightfully ours in a free market economy. let's take a moment to look at what has been happening in our transportation market place over the last 35 years.

Did you ever ponder what seemed to be the sluggish career opportunities you face and wonder what it would have been like to work in a growth industry? Well, amazingly, you have been in a growth industry when the unit of measure is intercity ton miles. Since 1960 our business, as measured in ton miles on the nations railroads, has grown from 597 billion to 1375 billion ton miles. That is a 237% increase. More good news, as a percent of the market place, ton miles were near a 30 year high as we handled 41% of the intercity freight in 1995. That's over a 5 point increase in market share since 1986 a short ten years ago.

But the Great Train Robbery did not occur in intercity ton miles. The Great Train Robbery happened on the revenue side. When we look at the nation's freight bill for intercity freight, we see constant growth from 47 billion dollars in 1960 to a whopping 420 billion in 1994. This is a nine-fold increase and speaks to the tremendous growth in our market place. Simply put, the pie is

expanding! On the other hand, rail revenues grew from 9 billion dollars in 1960 to 33 billion dollars annually. As you can see, revenue growth for railroads has been slow in the 80's and early 90's. You probably won't be surprised to learn that intercity truckers, saw their revenue increase more than 11 fold during these same years when railroad was relatively flat.

This is my concept of the Great Train Robbery. It is not a robbery of mail or express cars. It is not the armed robbery of rail passengers, nor is it a modern day story of corporate raiders. Only part of the story is about the loss of existing business. The dominant theme of this robbery, is one of missed opportunity. The story of steady market growth in which we only sometimes participate.

One thing about it, growth in the market place for the nation's freight traffic is sure to continue. Why am I so certain? Because the number of Americans keeps growing. By the year 2005, a short 8 years from now, the population of the United States will be 286 million people. You may be interested to know much of the population growth is going to be to the South and Southwest. States in those areas will experience 16-36% growth between now and 2005. States in other areas will grow by 11-16%, and all states will grow in this time period.

The point being that our story, the story of the railroad industry, need not be one of lost opportunity. The opportunity for real growth remains.

Having set the stage, I would like to direct my remarks toward how we build great railroad organizations to compete vigorously in this market place called intercity freight. I would like to develop six points I believe crucial to building organizations that can fend off the next round of robbers, not bandits mind you, but robbers of our future.

Let's begin with safety.

"Safety First" is more than just a cry for protecting our employees. When we place safety in its rightful place as the first priority for organizational development, we lay the cornerstone for success. The railroad industry already has cause to be proud of its safety record. Bureau of Labor Statistics figures clearly reflect our leadership role. As a whole, railroad employees are safer at work than the people who work in grocery stores, hotels, department stores, manufacturing and all other transportation sections. But the rail industry has always been one where small errors can produce dramatic results. Never in the history of railroading does it seem our accidents have been subject to such review or publicity.

From the top down, everyone must know that their bosses' first concern is safety. In the safety driven company, conditions in the work place are always improving. In the early stages, conditions that present a hazard are first corrected out of concern for liability, and later handled out of genuine zeal

to create an injury free work place. In successful railroad operations, there develops a certain aversion to risk. Employees grow uncomfortable with workers who take risks and learn to speak up when they observe at-risk behavior. People come to understand, it's not so much a question whether risk takers will be injured but when and how seriously

An effective safety process builds team work and respect. When on course, employees find themselves aligned with team goals. Adversarial relationships with management melt away. Everyone's a winner with safety and that means happy CEO's, customers, employees and owners.

If safety is the foundation of a great railroad organization, then quality should form the walls of this structure. The inshot of quality received by the nation's railroads in the early 1990s is not a passing fad for the true competitor. Over the decades, independent surveys repeatedly show rail customers expect consistent service. Consistent service is the first step toward superior service, yet many loads, and even whole commodities, have gone to our competitor over service issues.

When it comes to quality, I am a fan of Deming. While W. Edwards Deming was sort of a crusty old fellow, by the time Out of Crisis was published in 1982, his fourteen points of management

had become must reading for anyone who wants to build a competitive organization. Deming can be controversial. I have always had difficulty with point number 12, abolishment of annual raises. Nonetheless, Deming's perspective on what quality is and how we achieve quality, is invaluable. The words that ring in my ears the loudest come from point number one. "Create constancy of purpose." How much heartache has the industry known that could have been side stepped with true constancy of purpose.

My final thought on quality. Too many of our efforts in quality have been dispersed over such things as answering the telephone after three rings, employee satisfaction surveys, better working conditions, and monthly newsletters. While all these things have their place, building quality service must be our focus. While much of the literature and training has been about manufacturing quality, our mission is a little different. Service quality is the core issue for railroads. The principles are largely the same, but there are differences. Building service quality into our culture as UPS and Fed EX have done, is critical to growing revenues. To quote the sometimes controversial Deming, "Create constancy of purpose toward improvement of service with the aim to be competitive, stay in business, and to provide jobs."

Bullet number three, hire great people. If we lay the foundation for our organizations on safety and construct walls built of quality service, people are surely the roof of this house called railroading. With great people, there is no ceiling on performance.

I say build the organization around people. People really are the most important asset, but be careful where you speak those words. If there is a sure turn-off for employees, it is to hear or read that sometimes hollow phrase, "Don, people are our most important asset." It takes years to drive home the point of how important people are. Mostly we communicate this in subtle ways and it is largely non-verbal. By the time it is clearly understood, the words are of only marginal value.

A personnel officer once told me, "Don, we have had many hiring freezes, but we have never stopped hiring." This is how it should be. Great organizations get more than their share of good people. They never stop hiring when there is the prospect of a new employee who bring special talent. In today's job market you can't get the best people with periodic spurts of hiring. Don't worry about having too much talent. Hardworking, motivated people find a contribution to make even if they are not visible on the playing field. Exceptional strength on the bench makes for great teams. Great organizations have the talent to focus on details their competitors overlook. Such is the strength of great people.

Research and development has been shrugged off by many as an unnecessary cost easily deferred, or better yet, absorbed by someone else. That could mean suppliers or the Association of American Railroads. It may not matter who does research and development so long as someone is probing in the right places. There's a tendency to think railroads don't need cutting edge technology and forget the R&D. But today's railroads are full of applications for technology. After all, we were one of the Big Blue's first customers for main frame computers. Just think, where would we have been if we had started development of the end-of-train device just before we got the green light to remove cabooses?

Application of new technologies still holds the promise of lowering costs and providing superior service. I view research and development as something which works a lot like the stock market. Most of the gains come over short intervals of time. You had better be invested when the bull market comes or you miss all the opportunity. A firm strategy for research and development is one like the dollar cost averaging stockbrokers talk about. You put a little money in all the time to assure you are invested and ready to ride the waves of success when they come. Our industry is too quick to discount research and development. Whole industries, like pharmaceutical and plastics, have built constant revenue growth

on the momentum of R&D. There is a place for supplier R&D, there is a place for cooperative research through the AAR, and there can still be a place for research and development on the railroad. Massive funding isn't the answer. It's bright people with ideas and adequate resources that can make a difference. Given a little bit of direction and the latitude to maneuver, good things can happen.

Point number five. Play the game for the long term. No where in the world does it seem as if pressures are as great for short term profitability as in the United States. After three fabulous years of stock market performance and at least seven years of economic expansion, expectations have never been higher. The anxiousness of investors sets up a trap. Just as it is dangerous to drive a race car forward with your eyes on the rear view mirror, too much focus on last quarter's profits brings on liability of its own.

What worries me about short term focus is, what happens when your global competitors are flogging you in the market place with initiatives they put in place years in advance. It is hard to restore momentum when you are behind the eight ball. Plenty of companies have floundered trying. While we don't have global competition among railroads, global transportation is growing. Now is the time to focus on long term tactics, not short term issues.

It is the right thing to do. Should Wall street fail to recognize that, you can count on stockholders to ultimately vote with their dollars when we turn long term tactics into success stories.

My final point on building a great organization is, go for growth. Too often our paradigm has been, take what you were given and cut costs for profitability. Cost cutting has worked wonders but over the long haul, you can't save yourself into prosperity. The good news is there is another way to increase profits. Grow the business! It doesn't always have to be smaller slices. Many times a bigger pie is just as good or better.

Understand that great operating managers should, and do have, a certain aversion to risk. Trainmasters question dispatching a freight with the threat of flash floods. A mechanical supervisor chooses to walk a hot bearing three miles to the nearest siding rather than take a chance. The district track supervisor sets a slow order on the conservative side. Shrewd operating managers are constantly assessing risk and making adjustments. Many railroads have a whole department called risk management.

But when it comes to growth, a risk aversion mind set becomes a liability, not an advantage. There is always risk inherent to any new business. You can play the "what if" game with new business until you talk yourself into zero growth. What if spent nuclear fuel rolls off

a flat car? What if citizens protest moving garbage to the landfill? What if the new customer goes on strike after we bought the freight cars? What if the return on investment falls below the hurdle rate? I ask this question. Do you think our predecessors at Norfolk Southern commissioned a review by MBA graduates before building Lambers Point Pier in 1885? Probably not. Six piers later, this icon of corporate success might not exist if the MBA's had gotten their hands on the 1882 proposal to buy 325 acres of hot, humid, marsh land along the Elizabeth River.

The point is, there is always risk in pursuing growth. One of the biggest challenges we face today, is managing two aspects of our business with different attitudes about risk. On the operations side, we need to cultivate the risk averse mind set as we seek the ultimate in railroad operations, zero injuries, zero accidents. On the sales and marketing side, we must be just as conscious risk taking is a part of business. Perhaps that is why we have these groups separated organizationally within our railroads. But the two must do more than meet in the middle if we are to grow our business the way the market for intercity transportation is growing. Operations people must know why we take risk and which types of risk they can tolerate. Such is the core challenge of management, to achieve success in the face of seemingly conflicting objectives. It

is a big challenge but everyone wins when the pie is growing. It is at least as good a way to add to profits as cutting costs, and has considerably more investor appeal.

As I prepare to finish my remarks, I am going to take a minute to make some predictions for the future. Over the weekend I looked into my crystal ball and for the four groups represented here, the Railway Operating Officers, the CDOA, the Air Brake Association and the LMOA, I make the following predictions:

For the operating officers, I predict positive train separation, PTS as we are calling it, will be a widespread reality in the next few years. The core technologies are in place. We now wait on development. With this technology come some new opportunities for safety, the first ingredient of a great railroad organization. But PTS will never be a substitute for alert, disciplined train crews cognizant of their surroundings. Nor will it be a substitute for the watchful eyes of conscientious road foremen, trainmasters and division officers.

For the car department officers here, I see changing job skills in the future of our car maintenance employees. New material will influence repair practices. Aluminum will emerge as a dominant material for many car types. I see widespread use of stainless alloys over the horizon, followed by composite materials and their special requirements. Lap top computers and micro

processors will become common place on the repair track. The car peck of old is facing culture shock.

For the Air Brake Association, I offer this. Electronically controlled pneumatic brakes or ECP is coming. I think it is not so much a question of if, but rather when. Transition to ECP braking systems won't be painless but the advantages of this technology will be so clear, pneumatic control valves await a fate similar to typewriters.

For the locomotive maintainers of this group, our greatest challenge for the future remains locomotive reliability. Superior service organizations need highly dependable motive power, not just more units on the head end. Too many times the issues of locomotive reliability are like a scrambled jig saw puzzle. We see pieces we recognize but we can't quite fit them together. Locomotive reliability is in many ways a challenge for our minds. Spending money on these problems based on gut feeling rather than data or knowledge, is often wasteful. Let this group be a catalyst for fact based decision making as we pursue more reliable motive power.

For the managers in the audience, and really we are all managers, the future has not been this bright for many moons. With as much certainty as death and taxes, we can predict the population will continue to grow. By the year 2015, the year I turn

62, there will be 310 million people in this country. With that growth in numbers comes growth in our economy. A 13-fold increase in gross national product since 1960 is enough to suggest the missed opportunity is real. While the GNP has been steadily growing, the percent of gross national product dedicated to the nation's freight bill has finally stopped declining. Construction of another interstate highway system seems unlikely. Some roads cannot be widened again. Development of any new right of way is approaching impossible due to environmental issues and the attitude of "not in my back yard" mind set.

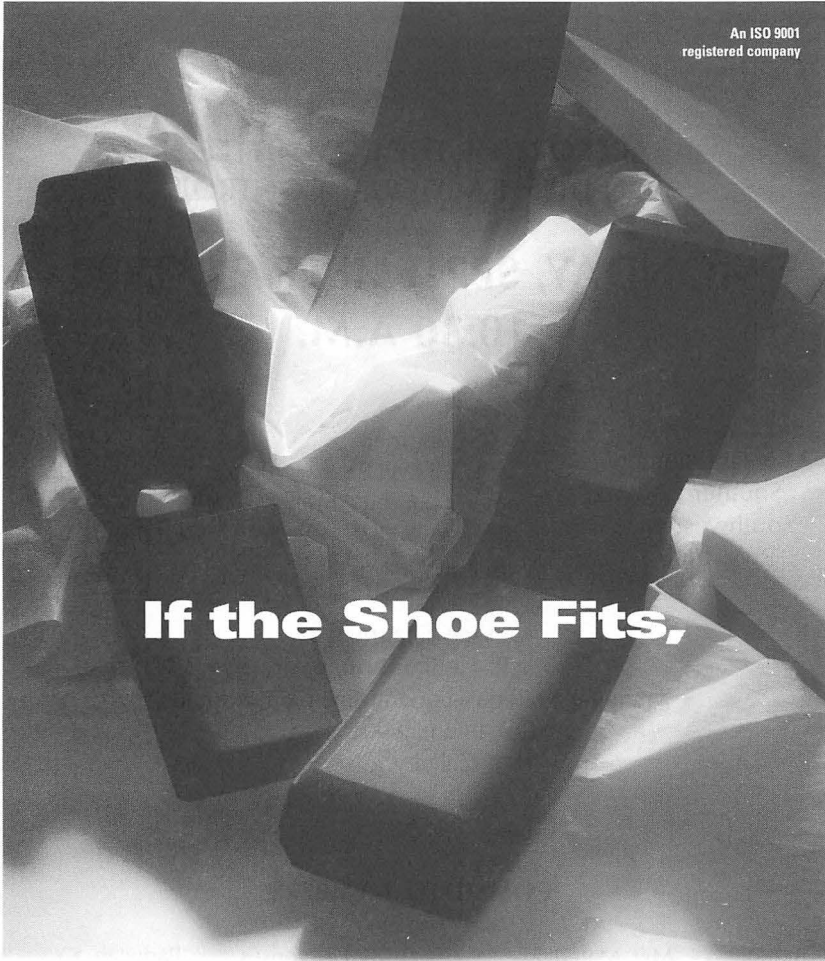
For us the challenge is clear. Leverage the competitive advantages of our steel rail network so we share in at least 10% of the revenue and 50% of the gross ton miles by the year 2005. That may seem like a lofty goal, but we all stand to benefit. Good stewards for the rail industry will do more than fend off the new robbers, they will look for ways to put more freight in the express car as we strive to participate in a growing economy. Not only will we and our companies prosper but it's in the best interest for our environment, our fellow citizens, and our employees.

In closing, groups like this remain a cornerstone for collective thinking and industry direction. I value the relationships I've formed over the years in LMOA and the

other organizations. With the prospects for just four big carriers, the pressure is on. Pressure to keep the organizations of this technical conference viable. Pressure to keep the supply community, especially our small vendors, healthy. Pressure to perform flawlessly under an ever more critical public eye.

In the midst of all this, I urge you to believe, we have more to gain by cooperating with our fellow railroaders, than if we jealously guard our secrets. Over the next three days, let us share unselfishly as we join together seeking solutions to our common problems. May I remind you, more so than our non-rail competitors, railroads are in many ways dependent on each other.

I thank you for your attention.



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**REPORT OF THE COMMITTEE
ON DIESEL MATERIAL CONTROL**

**MONDAY, SEPTEMBER 21, 1998
10:30 A.M.**

Pre-Convention
Presentation:
Southern &
Southwestern
Rwy. Club

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

July 17, 1998
Jekyll Island, GA
Villas by the Sea

Vice Chairman
R. Faulconbridge
Manager-Materials-Locomotive Commodities,
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* Recently joined committee

PERSONAL HISTORY

John Brawley

John Brawley is the Director of Materials Management at the Beech Grove, Indiana Maintenance Facility with over 21 years of experience in the rail industry. His responsibilities include Beech Grove, Chicago, Miami, Stanford 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 pas-senger 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. Two of his children attend college; Christine is a senior at Indiana Wesleyan University and Paul is currently a sophomore at Ball State University.

The Diesel Material Control Committee wishes to thank the Southern & Southwestern Rwy. Assn. for hosting their Pre-Convention Presentation in Jekyll Island, GA on July 17, 1998

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I. TIGHTER IS NOT BETTER

*by Bruce Bennett,
Stage 8 Fasteners*

Stage 8 Locking Fasteners is an innovative company dedicated to maintaining the ability of critical threaded fasteners to do their job under adverse conditions or in extreme environments. Toward this end, we have a 100% success rate.

Many of you, I'm sure, are now wondering just how this feat is being accomplished. However, before I get into exactly how the Stage 8 System works, let me first present an explanation of the age-old theory of what a threaded fastener is, how it works and why they fail.

What is a threaded fastener and how does it work?

A nut or bolt is nothing more than a circular inclined plane. The bolt or stud portion of the fastener assembly is a spring.

As the fastener is rotated the thread surfaces climb up hill against each other until they run out of room. At that point the clamping force starts to build on the mated part because the thread surfaces are wedging against each other. As more torque is applied, the wedging action of the threads against each other stretches the bolt or stud. It is this spring action which generates the clamping force on the mated part.

When specified torque has been reached, the molecular friction of the threads against each other holds the fastener in place. If

there were no friction, the spring action of the bolt would cause the fastener to back off the minute the wrench was removed.

Why Nuts and Bolts Loosen and Fail

Vibration induced shock load is the number one reason why nuts and bolts loosen and fail. When shock load is strong enough it causes loss of contact of the molecular surface engagement of the threads (loss of friction). The spring action of the fastener then causes it to literally roll down hill until all clamp load is lost (after approximately 90° rotation). At this point the fastener has failed.

Thermal cycling amplifies this effect, which is why exhaust bolts are such a problem to keep tight.

Friction drag (as on axle nuts) rounds out the list of reasons why fasteners loosen.

Conventional wisdom applied to the fastener loosening problem

I am sure everyone who reads this has employed a wide variety of methods to keep nuts and bolts tight. Wire tie, patches, epoxies, deformed or interference fit threads and tightening the bolt tighter are all commonly accepted methods to solve the problems. All of these methods have their preferred environments in which they function well; however, all have their limitations. If any and/or all worked in high stress, high vibration and thermal cycle environments, this discussion would be unnecessary. Let's briefly examine these methods:

Increasing the friction: Torque the bolt tighter so the shock load cannot cause loss of contact of the molecular surface engagement. Frequently the torque value necessary to prevent this loss of contact is more than enough to break the fastener. Now you need to use a bigger fastener, right?

But this is a fallacy. The strength of a bolt is measured by its tensile strength in PSI. The larger the bolt, the larger the number of square inches; however, the pressure per square inch is constant. A 1" G5 bolt has no more tensile strength than a 1/4" G5 bolt. Although the overall strength of the joint is increased and clamp force is greater, this force is spread over a greater thread area and the molecular friction on the threads remains the same. The next effect is that the larger fastener has no greater resistance to loosening.

Torque to yield: Sometimes torquing the bolt past yield will forestall the loosening of the fastener for a greater time period. This method is known as "torque to yield." Rule of thumb says that this method will impart the greatest resistance to loosening available. This theory only works in a theoretical world. Using this method in a hostile environment just invites failure. Why? Because tightening the fastener to this level places the level of stress outside of its working range. Shock load and thermal variation at this level can actually stretch the bolt further and only serve to weaken the joint

further. Since the fastener has lost its ability to recover, the original clamp force has been reduced.

Standard theory states that a bolt will retain all of its residual tension (clamp load) when torqued past yield. Standard theory also states that stress on a bolt is linear up to the proof load.

But when a bolt is tightened past yield it goes into its "plastic range," which is an engineering misnomer. In reality the molecular structure of the bolt has been compromised and its performance is more akin to taffy than to plastic. After the elastic limit has been reached residual tension must drop off.

Stress on a bolt cannot be linear because the graph of stress on a bolt is a hyperbolic curve (A mathematical technique called smoothing is employed in engineering calculations of this type.) If you don't believe that this statement is true tighten a bolt until it breaks. The stress starts at 0 and ends at 0. The only kind of graph which does this is a hyperbola curve.

Since a fastener tightened past yield will not return to its original configuration, its spring action has been compromised. The spring action is what allows the bolt to work. We at Stage 8 recommend that bolts be tightened to 80% of yield to allow the bolt to work within its elastic range.

Standard theory does have one correct point, that one being that a bolt torqued past yield should not be reused. This means that if the bolt requires tightening for any reason including clamp force relaxation due to compressive deformation of the mated parts.

Locking fasteners and why most don't work

There are two types of locking fasteners - passive locking systems and active locking systems. Passive locking systems include the Nylon insert or patch, and interference fit thread, anaerobic thread compound and lock washers. Active locking systems include castle nuts, cotter pin w/cap and wire tie.

In order for locking fasteners to work, the lock must be able to resist the spring action of the fastener trying to loosen itself or roll down hill. None of the above systems has the strength to absolutely resist the spring action of the fastener trying to loosen itself. I have actually seen vibration testing where a Nylon insert nut lost over 90% of its clamp load in less than 20 seconds. In testing I have also seen every other one of these systems fail. All the others took longer than 20 seconds; however they still failed. The cause, in every case, was failure to resist the spring action of the fastener.

How the Stage 8 System solves the problem

If none of the conventional methods works, what can be done

to solve the problem of loose fasteners? The answer is to find a fastener with a lock strong enough to resist this spring action, because the absolute best time to stop a fastener from loosening is before it starts!

The only fasteners capable of this feat are Stage 8 Locking Fasteners. The Stage 8 Fastening System works like having a small wrench on the fastener. If the fastener is not allowed to rotate it cannot loosen. In many cases the retainer is strong enough to torque the fastener to its specified torque setting. If a system such as this is strong enough to accomplish this feat, then it is certainly strong enough to keep it from backing off.

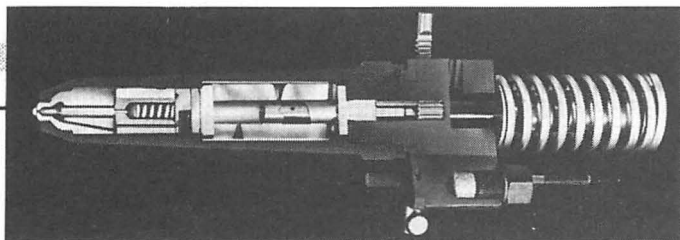
The Stage 8 advantage and available products

Since the Stage 8 System locks at the head, it does not require any thread friction or clamp load for the lock to work. In fact we recommend lubricating the threads before assembly.

The Stage 8 Locking System is the only system available able to withstand all of the forces which typically cause fasteners to loosen.

The Stage 8 System is visually inspectable. When the retainer is in place, the head of the bolt or the nut is has not rotated. If no rotation has been allowed the bold is not loosened.

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II. ARE VENDING MACHINES THE NEW WAVE FOR SAFETY ITEMS?

*by Bob Faulconbridge,
Canadian Pacific Railway*

Every day we in the Material department dispense millions of dollars worth of supplies to the shop floor. These items range from locomotive or car components, to consumables such as drill bits and paper towels, to reusable items like micrometers and small hand tools, to personal safety items like gloves and safety glasses.

Presently most of these items are distributed through stock rooms and tool rooms, which require full time attendants and are generally in one central location. These stockrooms and tool rooms may only be available to employees during normal working hours, and require the employees to leave their work stations and travel to the stock room to retrieve supplies.

Additionally, supervisors tend to control the items that appear to be the most attractive such as gloves, safety glasses, and small hand tools, to mention a few. These types of items typically end up locked in the supervisors desk drawer or cabinet in their offices.

Although well intentioned, this system is cumbersome and time consuming. Employees must track down their supervisor who personally dispenses the item to them. In today's world of doing more with less this is not the way

we want our supervisors and employees utilizing their time.

Also, this system does not provide documentation as to where our supply dollars are spent. At the end of the year we may know how much we spend in total dollars on supplies; however we don't know where it went and we have little data to make intelligent decisions on how to reduce spending on these supplies in the future.

We at Canadian Pacific Railway recognized this problem and started looking for alternative ways to dispense the consumable items, that would be more efficient and cost effective.

After reviewing several different options, we determined that the use of vending machines was the option that best suited our requirements.

We feel we are implementing a system utilizing vending machines that will:

- Reduce supply cost
- Capture real time data
- Streamline stocking process
- Improve availability
- Provide useable reports to management.

The use of vending machines has had a positive affect on all of our personal lives, from the quick trip to the cafeteria to the midnight Pepsi in the hotel or to the raid on the ATM for some quickly needed cash.

As seen during the recent winter Olympics in Japan, vending machines can be used to dispense everything from cameras to a Budweiser.

Traditionally the vending machine in the work place has been limited to dispensing food items in the cafeteria. We are looking to expand the use of vending machines to the shop floor to dispense items such as personal protective equipment, shop consumables, and tools.

These specially designed vending machines will be placed in strategic locations throughout our shops, where they can be easily accessed by our employees through the use of employee swipe cards. These swipe cards are activated by PIN numbers similar to your ATM bank card.

After the employee has swiped his card and entered his PIN number he then selects the item he requires and it is dispensed from the machine to the employee. This gives us a record of who got what and exactly when and where they got it.

It also provides the vending management firm with the real time data it requires to make decisions on the reorder and restocking process. The vending management firm is responsible for replenishing these machines on a regular basis, weekly at smaller locations or as often as daily at larger facilities, reducing the railway's inventory and improving availability. Employees now have

access to these items 24 hours per day, 7 days per week and no longer have to track down their supervisor for attractive items.

These data will also be used to generate monthly reports for CP Rail management, detailing expenditures by part number, department, location or employee. These reports will be used to make management decisions concerning budgets and recognize areas of abuse and waste. See sample reports at tables 1 and 2.

Benefits

Following is a brief summary of the benefits we expect to obtain at Canadian Pacific from the use of this technology:

- We expect to obtain an inventory expenditure reduction through closer monitoring of material usage and employee accountability. Expenditure reductions of 40% or more are being realized by our shops that have already adopted this technology.
- Our procurement for this material will be streamlined. There will be no need to issue purchase orders or requisitions to replenish stocks. This will all take place automatically as the items are consumed. We will only need to process one invoice monthly for our total requirements of this material. This greatly reduces our invoice processing costs.

- Material usage will be tracked to the employee, job or location, making it easy to identify areas of waste or abuse. Quick action can then be taken to correct this.
- Employees will now have access to critical safety and consumable items on all shifts, 24 hours per day, 7 days per week. In the past it was difficult if not impossible to obtain some of these items on off shifts.
- Our material handling costs will also be reduced as we will no longer be required to process receipts, put away, stock count or issue this material. All these functions will now be performed by the vending machine or the vending management firm. This allows the materials staff and shop supervisors to concentrate on other issues.
- Inventory control and accuracy will also improve. Each issue will now be captured as the employee swipes his card in the vending machine and enters the item code for the material he requires. These items will no longer be visible to the employee or accessible to the employee without his swipe card.
- Access to specific items can be limited to only those employees that require them.
- Different accounts or jobs can be directly charged for items consumed. This may be of use when faced with split shops, i.e. GE, GMD and your own road maintaining units in the same shop.
- The quantity of a specific item can be limited to an employee over a specific period of time.
- Specific items dispensed can be adjusted to meet seasonal demands, i.e. winter mitts or winter liners versus sun screen or rain wear.
- Control the dispensing and return of shop tools.

Through the use of vending machines CP Rail expects to reduce inventory, increase productivity, and better manage our assets. We expect to achieve a 25% to 40% reduction in supply expenditures for the items being dispensed through vending machines. In addition we also expect to achieve soft benefits, such as improved productivity through the improvement of employee time utilization and reduction in Material department and management's role in dispensing shop supplies.

Other options available to us with this technology are many. Here are just a few:

At Canadian Pacific we are in the process of implementing this technology at many of our Mechanical facilities. We feel it is the way of the future and look forward to the day when all our shops will be dispensing personal protective equipment and shop supplies this way.

TABLE 1. ITEM USAGE BY EMPLOYEE

For the Period: 7/30/97 to 8/8/97

Current date :
11-Feb-98

Employee ID and Name	Item ID and Description	Total Cost	Total Quantity
ATD Address: 1			
Dept: DIE SHOP			
5023 PAUL RIEDER	3456-44-000-0098	INSERT BCCMT 432-UR	\$104.40 10
Employee Totals:		\$104.40	10
5027 JOSEPH MAGANA	7930-44-000-0051	POLISH COMPD GRADE 3	\$527.20 20
Employee Totals:		\$527.20	20
5109 CREGG ANDERSON	7520-01-207-4288	PEN UNIBALL BLUE	\$3.39 1
Employee Totals:		\$3.39	1
5161 PATRICK NULL	3456-44-000-0098	INSERT BCCMT 432-UR	\$104.40 10
	3456-44-000-0100	INSERT GFN-4B IC835	\$71.00 10
Employee Totals:		\$175.40	20
5179 JOYCE COOPER	7520-01-207-4265	SHIM SCREW #8074444	\$3.39 1
	7520-01-207-4286	PEN UNIBALL BLUE	\$3.39 1
	7530-01-116-7889	SHIM SCREW #8764848	\$1.20 1
	8415-44-000-0019	GLOVE LATEX LARGE	\$5.95 1
	8415-44-000-0035	GLOVE LEATHER XL	\$8.86 1
Employee Totals:		\$18.77	5
DIE SHOP Department Totals:		\$829.16	56

TABLE 2. ITEM USAGE BY MACHINE

Current Date:
11-Feb-98

For the Period: 7/30/97 to 8/6/97

	Item ID	Description	Quantity	Total Cost
ATD Address:	1			
Machine Number	200			
	8415-44-000-0035	GLOVE LEATHER XL	1	\$4.84
	8415-44-000-0019	GLOVE LATEX LARGE	1	\$5.95
	7930-44-000-0051	POLISH COMPO GRADE 3	20	\$327.20
	7530-01-116-7884	SHIM SCREW 88754848	1	\$1.20
	7520-01-207-4285	PEN UNIBALL BLUE	2	\$5.76
	7520-01-207-4285	SHIM SCREW 88874444	1	\$3.39
	3455-44-000-0100	INSERT GFM-48 IC635	10	\$71.00
	3455-44-000-0098	INSERT @CCMT 432-LR	20	\$208.80
Totals for Machine Number: 200			56	\$829.16
ATD Address 1 Totals:			56	\$829.16

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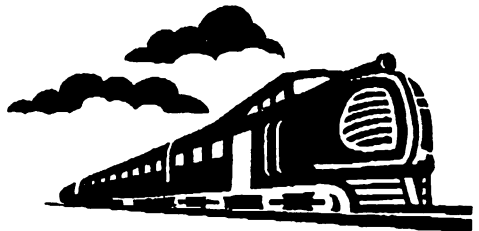
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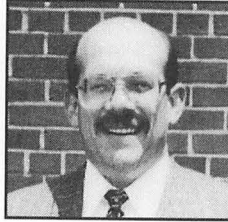
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**REPORT OF THE COMMITTEE
ON FUEL, LUBRICANTS & ENVIRONMENTAL**

MONDAY, SEPTEMBER 21, 1998

1:45 P.M.



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Manager Mech. Svcs.

EJ & E

Gary, IN

Vice Chairman

G. BOWEN

Dir. Laboratory Svcs.

BN/SF

Topeka, KS

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PERSONAL HISTORY

Bruce A. Kehe

Bruce Kehe received his B.S. degree in Mechanical Engineering from Valparaiso University. He joined the Elgin, Joliet & Eastern Railway in 1979, holding various positions in the Industrial Engineering and Mechanical Departments. In 1993, he was promoted to his present position of Manager-Mechanical Services.

In addition to his involvement with LMOA, he is active with the Chicago Railroad Mechanical

Association and SAE Technical 9 Committee for Medium Speed Diesels. He is also a member of the National Association of Railroad and Environmental Testing, serving as its Chairman in 1994.

Bruce and his wife Barb have two children, Sarah and Brian, and reside in northwest Indiana.

I. SAFETY AND CHEMICAL CLEANERS

by Chuck Kunkel, Union Pacific

Scope and Preface

This paper is about the use of blended chemical cleaners in the rail industry and the safety precautions mandated by such use. Safety and Chemical Cleaners is an extremely broad topic and would take longer than time permits to cover completely. Only some of the more important concerns will be covered in this paper.

General Safety Precautions

Your best defense is common sense. It is essential that any personnel using chemical cleaners read all instruction and other data relating to the intended and safe use of these cleaners. Any hazards described in the material safety data sheets (MSDS) for these products can be amplified when they are misused, whether through inappropriate application or when used for purposes other than intended. If you ever have any questions about a particular product, contact the manufacturer. Most manufacturers are happy to respond to your questions and concerns about their products.

Of particular concern is the use of the appropriate dilution of any product. More is NOT always better. If a product calls for 10:1 dilution, full-strength usage could produce undesired and/or detrimental consequences. Also of concern is the mixing of different

cleaners or the addition of other chemicals to a cleaner. What works well separately may produce undesired and/or disastrous consequences when mixed. Chemical manufacturers formulate their cleaners for specific applications and the cleaners are not intended for experimentation.

The wearing of contact lenses may increase the risk of eye damage when handling or using chemical products, whether concentrated or in a diluted form. Such use should be prohibited. It is strongly recommended that at a minimum, chemical-resistant safety glasses or goggles be worn when handling or using chemical products.

Due to the hazardous and/or corrosive nature of many chemical products, it is strongly recommended that all personnel involved in the handling and/or use of such products wear proper attire to minimize the risk of damage and/or injury. The MSDS will list the appropriate attire.

Manufacturing, Packaging and Transporting

Safety begins in the blending process. Blended chemical products are made from various ingredients. Some of these ingredients are blends from other manufacturers while others are pure. Safety is paramount at production facilities because personnel often work with the pure undiluted ingredients. Many ingredients in their pure state are hazardous and/or corrosive and

the risk of injury is high. Therefore, adherence to safety precautions is essential. However, by the time the railroad receives a blended product, much of the hazardous and/or corrosive nature of these ingredients has been reduced or mitigated through dilution or blending with other ingredients. For example, in commodity form sodium hydroxide (caustic soda) is generally a 50% concentrate. Through blending (generally with water), the caustic and its effects are diluted. As a result, the hazard presented by this ingredient has been reduced. It may still be harmful, but not as harmful as it would be in its pure commodity form. This brings up an important point: Dilution of a chemical does NOT dilute the need for proper safety precautions and adherence to them.

After blending, the product is placed in some variety of container. Whether that container is a tanker, a tote, a drum, or something else, the container must be thoroughly cleaned and labeled with a proper manifest according with Department of Transportation (DOT) regulations. The manifest is completed and checked for accuracy. These are frequently supplemented by a material safety data sheet (MSDS). The MSDS, although lengthy and sometimes covering obscure issues, is extremely important and should be read carefully. These documents are the start of the safety information highway.

The manifest discloses the product that is being delivered. The DOT labeling indicates the hazard category which dictates the appropriate handling. The MSDS provides essential information in the event of mishandling or accident. Together, these documents are the first line of defense for the proper handling and use of chemical cleaners. When receiving a product, examine the manifest to determine if the product being delivered is the product ordered. If there is a difference, DO NOT unload the product until the discrepancy is resolved.

This is especially important for tank truck deliveries. the unloading location is a crucial safety issue. Some of the worst chemical accidents occurred because the wrong product was transferred into the wrong storage rack. For example, if a relatively strong alkaline cleaner were unloaded into a storage tank containing an acid solution or cleaner, the heat generated by the reaction between the two solutions could rupture the storage tank. This could cause severe injury or damage to nearby personnel, equipment, or the environment.

Tankers generally pose the greatest risk due to the large volume of chemical and the necessity of transferring product from one container to another. However, smaller containers, such as totes, drums, etc. still require the same careful attention and safety

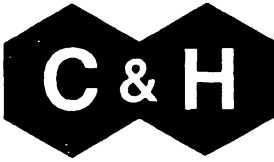
precautions. Reading labels, manifests, and MSDS is equally important. Adherence to special handling and storage instructions is essential. The old saying that "big things come in small packages" applies here to an even greater degree. It could be restated the "big disasters come in small packages" when those smaller containers are improperly handled.

In railroad facilities throughout the country, more personnel are reading the labels on drums, totes, and smaller packages. These labels are in visible locations so that the personnel using the products will read them. Much of the information relates to the safe use and handling of the product. There is additional information about what to do in the event of unintended and detrimental exposure to personnel and the environment. As a result, labels can be misleading and confusing. Chemical manufacturers use these labels to communicate the intended and appropriate use of their products. The labels can raise many questions and misgivings about the products and their use. It is said that "if a drum or tote label were printed to cover every possible contingency, it would be 55 pages long." There is no good solution to this dilemma. However, a little common sense and use of available information and resources can go a long way to resolving much of this confusion.

Alkaline Cleaners

Alkaline cleaners fall into three categories. The heavy-duty, or caustic, cleaners will generally have "free" sodium or potassium hydroxide which are also known as caustic soda or caustic potash. Medium-duty cleaners have limited amounts of these "free" caustics. Mild cleaners contain no caustic. "Free" as used in this paper does not mean that it "costs nothing." It means that the chemical exists in its natural state and has not been neutralized or converted in any manner through combination with other chemicals. Often, the total amount of caustic (when you look at the formula) in a blend is greater than the amount of "free" caustic that can be identified in the final product. This is due to the combination of the caustic with other ingredients or to its partial neutralization from combination with other ingredients.

Due to "free" caustic, heavy-duty cleaners, such as those used to soak tanks, lye vats, and alkaline paint strippers, are typically labeled corrosive and hazardous. This is a practice based on the way the DOT previously determined corrosivity. If a caustic attacked and removed more than 1/4 inch per year of 1020 SAE steel and/or caused irreversible skin damage to laboratory animals, it was considered corrosive. Testing the effects on steel was quick and easy. However, the animal tests were both costly and raised



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objections from animal rights activists. Now, DOT simply states that "any designated hazardous material that exceeds the concentration corresponding to the RQ (reportable quantity) of the material is considered to be hazardous." The following table lists the requirements based on RQ.

The higher the reportable quantity the less hazardous:

Hazard Level	Concentration by Weight		
	RQ (lbs)	percent	ppm
Less	5,000	10.000%	100,000
	1,000	2.000%	20,000
	100	0.200%	2,000
	10	0.020%	200
More	1	0.002%	20

Medium-duty alkaline cleaners are those which contain "free" caustic with concentration levels below the RQ's in the preceding table. While they frequently are not truly corrosive nor generally cause irreversible skin damage, they still deserve the same respect and must be handled with the same care and safety accorded the heavy-duty cleaners. They can cause serious eye injury, skin irritation, and much discomfort.

In many cases, a medium-duty cleaner is no different from a heavy-duty cleaner since it is merely a diluted form of the heavy-duty cleaner. Years ago, the heavy-duty cleaners were made available with the intent that they be diluted

with water at the work site. This reduced transportation costs. Why pay to transport water when you can add it at the end? This was fine except the end users frequently did not make the dilutions, reasoning that if the dilute cleaner was good, full-strength was better. This is not always true, so be sure to read the labels for dilution instructions and then...believe them!!!

Mild alkaline cleaners are those which contain NO caustic. They include such cleaners as hand soap and window cleaners. This does not mean or infer that they can be ingested or swallowed with no harm. No cleaner or chemical, regardless of type, should ever be swallowed intentionally or siphoned. The MSDS will list the proper protective equipment for handling these mild alkaline cleaners.

Acid Cleaners

Acids are regarded as something to avoid due to their generally corrosive nature and, thus, have a bad reputation. In the case of mineral acids, this reputation is well deserved because they will cause irreversible skin damage. The more hazardous mineral acids used in acid cleaner formulation include hydrochloric, sulfuric, phosphoric, and nitric acids. They may be used either singly or in combination and will be noted on the MSDS. It should be noted that the railroad industry uses this type of acid cleaner when it is the only way to accomplish the cleaning task.

Generally organic acid cleaners, often called brighteners, are not nearly as hazardous or corrosive as mineral acid cleaners, depending on formulation and concentration. However, all precautions that would be followed with mineral acid cleaners should also be followed for organic acid cleaners.

Although the pH or organic acid formulations is low, some formulations do not seem to be corrosive. They are used to clean and brighten freight and stainless steel passenger cars and are especially good at removing the tenacious brown stain from freight cars. An acid wash performed every six months is considered a wise practice by many involved with cleaning locomotives. In addition to removing the stain, the acid wash removes any soap scum build-up that may accumulate from inadequately rinsed alkaline cleaners. However, when dealing with "clear-coat paint finishes, do NOT use an acid wash. (This is a common practice on many railroads.)

Solvent Degreasers

Solvent degreasers generally fall into two classifications: halogenated and non-halogenated. All solvent degreasers will do the job, but each carries its own hazards. Adequate ventilation is essential, whether through mechanical means or other. The advent of legislatively mandated threshold limit values (TLV), permissible limit values (PLV), and time-weighted averages (TWA), as well as other data, have brought these cleaners under increased scrutiny.

For years, the only type of solvent degreasers generally available were chlorinated solvents, one of the halogenated types. They were ideal, inexpensive, non-flammable, quick drying, and great degreasers. However, questions regarding their carcinogenicity and their effects on ozone depletion became major issues. At the top of the list of major causes for ozone depletion were chlorinated solvents. The Federal government enacted a special tax on these solvents that drove the price of chlorinated solvents through the roof and forced users to find alternatives.

The search was productive because many substitutes were available. Among them are organic solvents that are available in two classes. The first is low flash point. This group is characterized by extreme flammability. They will ignite when exposed to an open flame at ambient temperatures less than 140° F. There are many examples of this type of solvent, including traction motor electrical, governor, and air brake cleaners. Such solvents are best suited to those situations where chlorinated solvents cannot be used and quick drying is essential. They are volatile and may be considered hazardous air pollutants (HAP). Due to their nature, they should only be used in places with adequate ventilation and no open flames.

High flash point solvents are those which have a flash point above 140° F, and are called combustibles. They are also known as safety solvents or high flash mineral spirits. They will burn readily and can be ignited by welders or cutting torches. Many grades of these solvents exist and two in particular need to be discussed. These are hydro-treated and non-hydro-treated. Hydro-treated solvents are more expensive and cleaner than the non-hydro-treated and contain reduced levels of hazardous components such as benzene and xylene. Such contaminants are generally considered air and water pollutants and are carcinogenic.

As good as the organic solvents are, there are situations where flash points, whether high or low, are unacceptable. We know that chlorinated solvents are non-flammable but these have been discontinued in the railroad industry except in rare instances. So the question is, is there anything else available when flammability is an issue? Yes, fluorinated solvents, another of the halogenated types. The best know of these is trichlorotrifluoroethene or liquid freon. It has many of the characteristics of chlorinated solvents and has a higher threshold limit value (TLV). Although it is still used in the electronics industry, usage in the railroad sector is greatly limited because of the fluoride content, initial expense, and disposal cost.

The Impact of Application Systems on the Safe Use of Chemical Cleaners

While the ingredients of the chemical cleaners themselves have a definite impact on the safety, the application methods are equally important. The methods are numerous, each having its advantages and drawbacks. No one method is ideal for all situations.

Atomization of a cleaner is a definite issue. Atomization is the reduction of a liquid into tiny particles or a fine spray or mist. This is most often accomplished by forcing the cleaner through a nozzle or heating the cleaner. Atomization increases the possibility of skin, eye contact and inhalation. Depending upon the cleaner, atomization can produce no effect, mild irritation, or dire consequences.

The first and most obvious method for surface cleaning is hand cleaning: a bucket and a cleaning rag. Its principal advantage is that it can be used virtually anywhere. The cleaner is usually applied only to the areas to be cleaned and atomization is essentially non-existent. However, it poses an increased risk of personal injury and exposure. It will tend to cost more because it is labor-intensive and the cleaner may be over-applied, under-applied, or misapplied, producing inconsistent results.

Hand spray application is a further step up. It has many advantages over the previous method, shares many of the disadvantages, and can be extremely finicky. This application increases the probability of atomizing the cleaner. If the spray-on application nozzle is not the right type or is improperly maintained, the cleaner will not be properly applied, wasting time and cleaner. The rinse process uses high pressure water and is normally extremely thorough.

Foam application is similar to hand spray application. However, instead of applying liquid cleaner to a surface, a foaming solution is used. The advantages are:

- the foam will remain on the surface (whether horizontal or vertical) for a longer time, providing greater cleaning power for a given amount of cleaner;
- with the proper applicator tip, there is reduced atomization;
- for a given cleaning job, a smaller amount of cleaner is needed because the foam allows you to see where you've already applied cleaner;
- waste recovery is facilitated due to the presence of less chemical in the waste water.

This method, too, is labor intensive, but is more consistent in application and end result. It may also be more cost-effective when

compared to other methods because of its consistency.

If reduction of personnel costs and exposure of personnel to chemical cleaners is of utmost concern, automated, or robotic, locomotive wash facilities are available. They are quick, relatively thorough, and are available 24 hours a day, 365 days a year, and require few personnel resources. They are also expensive, relatively immobile, require greater maintenance and specific cleaners, rather inflexible, and limited to exterior cleaning.

Many options exist for cleaning your rolling stock and parts. The preceding are primarily for cleaning both interior and exterior surfaces. If your concern is cleaning parts, the following are some of your options.

The first is the original - hand cleaning. It has the same advantages and disadvantages as it does above. But let us emphasize personnel exposure. For cleaning parts, the cleaner of choice would probably be a strong alkaline cleaner or a solvent degreaser, each with its attendant risks. This should rank very low as a viable option.

A step up is soak tank cleaning. Typically, a strong alkaline cleaner will be used with this method. There will still be personnel exposure and soak times can be lengthy. The principal advantage for this method would be low equipment cost.

Mechanical agitation tanks offer better cleaning than soak tanks. They are often used in solvent degreasing and require less time than a soak tank. If the parts are small and solvent degreasers can be used in the location, this may be the method of choice.

Automated parts washers are another option. To a great extent, they have replaced soak tanks and solvent cleaners. They use a controlled environment and water pressure to accomplish the cleaning. A mild alkaline cleaner is recommended with these units. They do require proper venting, however, because they use very high temperatures and high pressures and produce hazardous vapors.

Material Safety Data Sheets

Along with the general knowledge of chemical cleaners and safety procedures, the material safety data sheet is an important element in a safe use of chemical cleaners. The data disclosed in the MSDS is relevant and necessary. And, as with most things that deal with humans, the MSDS is an imperfect instrument.

From the MSDS, one can obtain information about the cleaner such as:

- what type it is (caustic, non-caustic, acid, solvent)
- hazardous ingredients
- its physical characteristics
- how flammable it is

- whether it is an oxidizer or not
- how stable or reactive it is
- what health hazards it represents
- how to deal with those health hazards
- how to dispose of both spent and active forms of the cleaner
- what to do in the event of accidental spills or other environmental exposure
- what types of protective equipment are necessary

The hazards that it discloses are somewhat generalized and may not pertain to everyone. There are many gray areas when dealing with chemicals.

Further, no manufacturer discloses the actual formulae of its blends, including the actual amounts of each and every chemical and compound used. Since some of these cleaners are made with blends from other manufacturers, even the final manufacturer may not know the exact composition of its product. This gives rise to a situation in which there may be some chemical combinations that have unknown effects. Does this mean that the MSDS is useless? Hardly. What it means is that the more knowledge you have regarding chemical cleaners, the greater should be your respect and adherence to safety procedures

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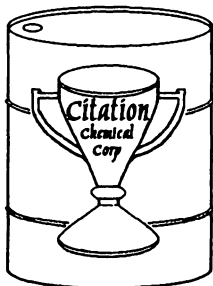
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when you use them. Chemical cleaners are much like electricity. They have become a pervasive, necessary part of our modern lives, given their ability to make our daily lives easier and better. But they have the potential to cause severe injury, damage, and even death when not handled properly.

I would like to acknowledge and thank Jim Secretarski of Citation Chemical Co. for providing much of the information used for this paper.

II. DEVELOPMENT OF A LOW EMISSIONS, DUAL FUEL LOCOMOTIVE

by David Meyers,
Southwest Research Institute

Abstract

In September 1993, Southwest Research Institute (SwRI) began a cooperative research program (GasRail USA) aimed at demonstrating the environmental and economic benefits of using natural gas as a locomotive fuel in California and other parts of the United States. The gas locomotive technology to be demonstrated focuses primarily on low exhaust emissions.

Although the specific interests of the participants may vary, the program has proven its ability to address the individual needs of each participant. Participation in the program includes both government and industry, manufacturers and end users, as well as regulators and fuel suppliers. The consortium-member participants include the Southern California Regional Rail Authority, the U.S. Department of Energy, California Air Resources Board, South Coast Air Quality Management District, General Motors' Electro-Motive Division, Gas Research Institute, Union Pacific Railroad, Amoco, and Southern California Gas Company.

Background

The overall objective of the program is to develop and demonstrate a natural gas

powered commuter locomotive with a 75 percent reduction in NO_x , compared to baseline diesel engine operation. To that end, six natural gas combustion technologies were designed, tested and evaluated on an Electro-Motive Division of General Motors (EMD) single-cylinder 710 engine. This was done in order to make reasonable comparisons between each technology, and to develop a database (which did not exist) for determining the direction of the optimization and integration phases of the program. Combustion systems that were evaluated included conventional dual-fuel (CDF), mini-pilot open chamber dual-fuel (MPOC), micro-pilot prechamber dual-fuel (MPPC), late-cycle high injection pressure dual fuel (LaCHIP), spark-ignited open-chamber (SIOC), and spark-ignited prechamber (SIPC). Each technology was tested at Notch 5, 100 percent load, Notch 8, 80 percent load, and Notch 8, 100 percent load conditions [1]. The technologies were evaluated based on test results and best engineering estimates for reliability, durability, development costs, and operating costs, as well as a number of other criteria that could not directly be measured in the testing. In general, all of the technologies produced significantly lower emissions than the baseline diesel engine. However, based on the very encouraging results obtained with the LaCHIP combustion technology, it was determined that it

would be developed and optimized for the passenger locomotive application. The locomotive that is currently being modified is an EMD F59PHI equipped with a 12-710 engine that produces 3200 bhp at full load.

In addition to the GasRail USA program, there have been several other programs looking at the prospects of using natural gas [2]. Energy Conservation, Inc. developed a low pressure gas, dual fuel system for an EMD 645 engine that was demonstrated by Burlington Northern in the early 1990's [3]. Morrison Knudsen developed a low pressure gas, spark-ignited system for a Union Pacific switcher application in the mid 1990's. High pressure gas dual fuel combustion was utilized on two separate programs conducted by General Electric [4] and EMD for Union Pacific Railroad freight applications in the mid-1990's.

LaCHIP Combustion

The term LaCHIP is an acronym for Late Cycle High Injection Projection and is a dual fuel (gas and diesel) combustion system. It was first attempted at SwRI on an EMD 2-567 for the Department of Energy in the early 1980's [5,6]. It has since been utilized, with limited success, on two separate programs for the Union Pacific Railroad. However, through careful analysis and gas injector development, the GasRail USA program has shown that the current LaCHIP technology is able

to substantially reduce NO_x emissions compared to the baseline diesel engine, while maintaining very low emissions of carbon monoxide and total hydrocarbons.

In the LaCHIP technology, high pressure natural gas is injected directly into the combustion chamber and burned in a diffusion combustion (diesel) cycle. A small quantity of diesel fuel is injected to initiate the ignition process. Figure 1 depicts a typical LaCHIP combustion process on an EMD uniflow-scavenged two-stroke engine. Air enters the cylinders through the intake ports at the bottom of the cylinder liner when the piston is near the bottom of the cylinder. The piston moves upward, covering the intake ports which stops the flow of air into the cylinder. Shortly after, the exhaust valves are shut and the compression process begins. At a point in the compression process, near top-dead-center, a small quantity of diesel fuel is injected into the cylinder followed by the main natural gas injection. The pilot fuel ignites and subsequently ignites the gas which is burned in a diffusion type combustion process where the rate of combustion is controlled by the rate of injection.

Due to diesel-cycle type operation, the LaCHIP technology provides the following advantages over the other technologies tested:

- Reduced air box temperatures are not required to prevent end gas knock (MPOC, SIOC)

- Idle and light load do not require air throttling (SIOC, SIPC, MPPC)
- Stock pistons and diesel injectors are retained (SIOC, SIPC, CDF, MPOC, MPPC)
- The use of stock diesel injectors for pilot fuel injection enables full diesel backup capability should the natural gas fuel handling system fail (SIOC, SIPC)
- Engine efficiency is inherently higher than other technologies at comparable NO_x emissions (SIOC, CDF, MPOC, MPPC)

Engine modifications are minimized with the LaCHIP technology, requiring only a new cylinder head and the addition of a gas injector. The newly designed cylinder head allows the gas injector to protrude into the combustion chamber. The gas injector hole is located as close as possible to the diesel injector to keep the gas injector as centrally located as possible. The gas injector is mounted in the cylinder head at an angle of 26° from the vertical to allow the top side of the gas injector to clear the stock diesel injector's coil. Figure 2 depicts an actual cutaway of an EMD cylinder with the twin injector configuration.

The gas injector itself is a hydraulically-actuated, electronically-controlled valve built by Moog Controls. The injector

valve was designed using specifications supplied by SwRI. The unique operating features of this injector consist of:

- Minimum pulse width of ~1 ms means turndown ratio of at least 14:1
- Extremely fast opening (<0.4 msec)
- Extremely fast closing (<0.3 msec)
- High-temperature tip operation (1300°F to 1500°F) without benefit of liquid fuel cooling.
- Zero fuel gas leakage into cylinder, crankcase, and hydraulic oil
- Minimal hydraulic seal oil leakage into cylinder (<0.005 in.³/min.)
- Hydraulically-actuated design with abort spring
- No fuel flow upon loss of hydraulic oil

In its current configuration, the injector is actuated with engine oil. The injectors do require an external pump to pressurize the oil up to 3800 psi to overcome the gas pressure and actuate the needle.

Additional engine hardware consists of a gas/hydraulic manifold bolted to each side of the engine, an additional wiring harness, and a second control system to actuate the gas injectors and communicate with the diesel injector control system.

Technical Achievements

Initial LaCHIP development took place on a single-cylinder EMD 710 engine. During this phase of development, a strong correlation between diesel fuel flow rate and NO_x emissions was established. Therefore, a significant need was identified to reduce the pilot flow rate to as low as possible. It was originally believed that the stock EMD 710 electronic unit injector's turndown ratio was such that a 75 percent reduction in NO_x was not attainable. However, recent tests on a 16-cylinder engine have demonstrated a 75 percent reduction with the stock EMD 710 injector. The pilot flow rate for LaCHIP combustion is between 5 to 8 percent of the total energy input to the engine. It should be noted that the stock diesel injectors provide 100 percent diesel backup capability at normal diesel efficiency, should there be an interruption in LNG supply.

Upon completion of single cylinder engine development, the technology was applied to an EMD 16-710 engine currently installed in a test cell at SwRI. The engine has been mapped under steady-state conditions. Comparison between

stock mechanical unit injector (MUI) diesel engine results [7] and LaCHIP combustion results are shown in Table 1.

The LaCHIP combustion system has been able to produce full power at Notches 3 through 8 while producing very low emissions of NO_x. LaCHIP combustion, however, is only used during Notches 3 through 8, while 100 percent diesel fuel is used for idle, dynamic brake, and Notches 1 and 2. In addition to a large reduction in NO_x, it should also be noted that burning natural gas reduces CO₂ emissions by approximately 25% compared to diesel fuel due to the chemical make up of the two fuels.

Status of Gas Rail USA Program

The project's present focus is on integration of the liquefied natural gas fuel system into an EMD F59PHI locomotive that will operate in commuter service in the Los Angeles area beginning in mid-1999. The final engine calibration is being developed on a multi-cylinder EMD 710 engine presently installed at SwRI's large engine facility. Details of the current status of the program are given in the following sections.

TABLE 1. LaCHIP COMBUSTION EMISSIONS

Emissions	Diesel Baseline	LaCHIP Combustion
Notch 3-8 NO _x (g/bhp-hr)	10.0 - 16.2	1.8 - 2.3
Notch 3-8 THC (g/bhp-hr)	0.2 - 0.4	1.0 - 1.2
Notch 3-8 CO (g/bhp-hr)	0.3 - 1.1	1.2 - 2.5

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Engine Testing

A 16-cylinder EMD 710 locomotive engine is installed in a test cell at SwRI. The engine has been mapped out for steady-state operation and is currently being mapped for transient operation. Algorithms are being developed to precisely control the two fueling events during notch transitioning. Upon successful demonstration, these algorithms will be installed into two EMD-developed control systems for application on the locomotive.

The engine will also undergo 200 hours of steady-state Notch 8 durability testing. This will be followed by 100 hours of cycle durability testing. These two tests will identify areas of additional required development prior to placing the locomotive in revenue service.

Locomotive Integration

The low emissions gas engine technology will be demonstrated on an EMD F59PHI commuter locomotive (Figure 3) operated by the Southern California Regional Rail Authority (SCRRA) in the South Coast Air Basin. In its currently designed configuration, the LNG storage and delivery

system will be skid mounted in an auxiliary car behind the locomotive for demonstration purposes. In an OEM developed application, this skid would likely be located in the area currently occupied by the diesel fuel tank, the air reservoirs, and the batteries. To get high pressure gas to the engine, cryogenic pumps will be utilized to pump the liquefied natural gas up to pressure, where it will then be vaporized and regulated to the appropriate pressure. Since diesel fuel is still required in the LaCHIP configuration, the diesel fuel tank and associated hardware will be retained. Specifications of the fuel system are given in Table 2.

Additionally, a second head-end power (HEP) unit will be converted to operate on low pressure natural gas and installed in the auxiliary car. The stock HEP unit is a diesel-powered Caterpillar 3412 engine. Caterpillar currently offers this engine in a natural gas configuration for industrial use, but has not offered it as an HEP unit for locomotive applications. The GasRail USA program is working with Caterpillar to incorporate a low emissions gas powered HEP unit in the auxiliary car. This will

TABLE 2. FUEL SYSTEM SPECIFICATIONS

Diesel Tank Volume	300 gallons
LNG Tank Volume	1300 gallons
LNG Tank Pressure	30 - 150 psig ¹
Delivered Gas Pressure	1500 - 3800 psig ²
1 - Tank pressure determined by gas temperature and fuel usage 2 - Supply pressure is a function of Notch	

provide several benefits. First, it will allow further reductions in NO_x to be realized from the locomotive. Second, the gas powered HEP unit will run off vapors within the LNG storage tank, which will reduce the tank pressure and prevent premature venting and fuel loss.

Field Demonstration

Upon successful integration of the necessary systems on the locomotive, a field demonstration is scheduled to take place in Southern California in mid-1999. The low emissions, gas-powered locomotive owned by the Southern California Regional Rail Authority, will be operated in Metrolink revenue service between Los Angeles and Riverside, California. Data gathered during this demonstration phase of the program will yield fundamental information regarding the environmental and cost implications of operating locomotives powered by natural gas.

Conclusions

An innovative natural gas combustion technology known as LaCHIP has been developed for locomotive engine application. Through improved gas injector design and detailed engine development, the LaCHIP technology has demonstrated the ability to produce full power with a 75 percent reduction in NO_x with low carbon monoxide and total hydrocarbon emissions. Additionally, CO_2 emissions, a

globally recognized greenhouse gas, have been reduced by nearly 25 percent compared to comparable diesel engine operation. A slight penalty in fuel economy is realized to meet the 75 percent NO_x reduction. However, a 50 percent reduction in NO_x emissions can be obtained at diesel equivalent engine efficiency with the LaCHIP combustion technology.

The technology is currently being applied to an EMD F59PHI commuter locomotive to be demonstrated in the Southern California area. The demonstration will provide essential data regarding the environmental and economic benefits of operating locomotives on natural gas.

Results from this program will significantly impact commuter rail programs across the U.S. The program will provide technology capable of meeting stringent emissions standards using internal combustion powered locomotives without resorting to electrification. Furthermore, a large portion of the technical developments realized from this program are applicable to future freight locomotive applications where emissions reduction is also of concern.

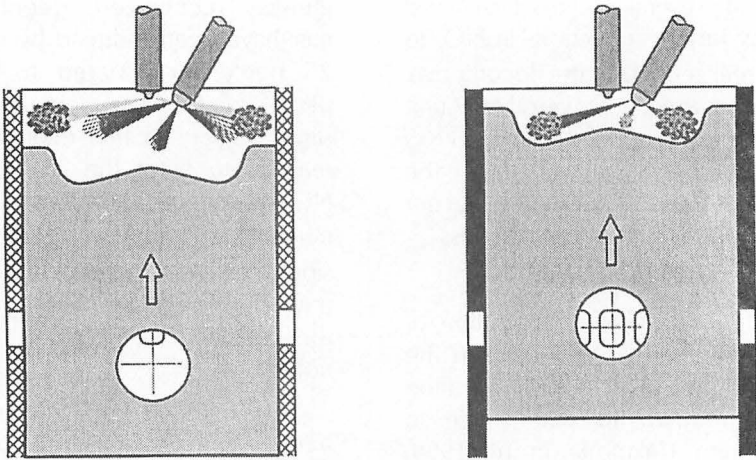


FIGURE 1. LaCHIP COMBUSTION PROCESS

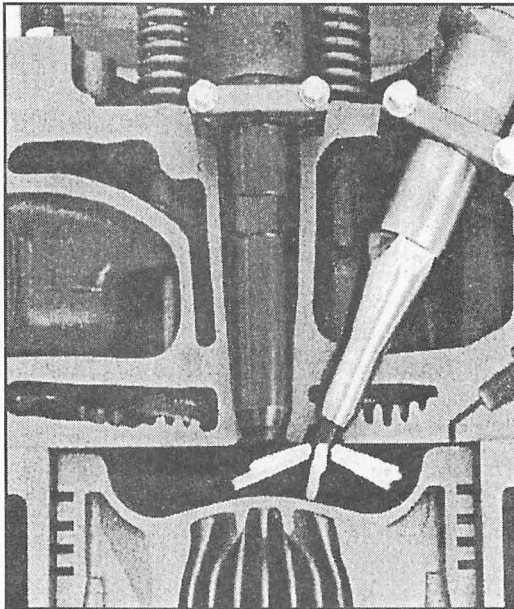


FIGURE 2. CUTAWAY OF EMD 710 ENGINE WITH LaCHIP TECHNOLOGY



FIGURE 3. F59PHI LOCOMOTIVE TO BE USED FOR DEMONSTRATION

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III. FUEL OIL STABILITY UPDATE

*by: Dr. Cline A. Tincher
Lyondell Lubricants*

This is an update of the Diesel Fuel Stability Task Force of ASTM (American Society for Testing and Materials) Section D02.E.2 efforts to develop a fuel stability standard and test procedure.

Interest in diesel fuel stability within the LMOA Fuel, Lubricants and Environmental (FL&E) Committee was initiated in 1996 when several major railroads experienced locomotive fuel filter plugging due to particulates formed from fuel with poor thermal stability. Research into the ASTM D975 standard for diesel fuels, revealed no requirements for thermal stability and no practical and recognized method of measurement.

LMOA FL&E initiated efforts with ASTM to address the need for a diesel fuel thermal stability standard. This effort was bolstered when fuel filter plugging problems were also identified within a California truck fleet. Chevron Research and Technology investigated the problem and concluded that poor thermal stability was responsible for the filter plugging. The stability problem was attributed to the interaction between naturally occurring insoluble precursors in certain fuel and added 2 ethylhexyl nitrate cetane number improvers. This problem may be more prevalent in California diesel fuel where the use of additives to meet the low aromatics cetane requirements is more common.

Also, the lower aromatics content of low sulfur (hydro-treated) California fuels may reduce the solubility of the potential sediment and coincidentally affect the observed thermal stability.

ASTM's interest in fuel stability has been renewed with the recognition of filter problems within two different industries. A Diesel Fuel Stability Task Force has been formed and charged with the task of developing a standard diesel fuel thermal stability test procedure. Until a standard test procedure is recognized and approved, a stability specification cannot be written into the ASTM D975 standard.

The procedure required to develop an ASTM standard is very exacting, requiring first a selection of a procedure and then a detailed round robin study and analysis of the results. Unless the procedure meets ASTM standards for repeatability, reproducibility and discrimination, it cannot be an accepted ASTM standard.

The thermal stability procedure selected by the Diesel Fuel Stability Task Force is an adaptation of the DuPont F 21 fuel stability test, a procedure used by the railroad industry for over 40 years. Diesel fuels are evaluated by heating the fuel sample for a specific period of time and filtering the sample. The filter is evaluated for color change, and the fuel stability rating is assigned.

The Diesel Fuel Stability Task Force is now planning the round robin study with the expectation that it will be completed during the third quarter of 1998. Objectives for the round robin study are:

1. Evaluate the suitability of the test method for measuring the thermal stability of distillate fuel.
2. Determine the repeatability and reproducibility of the test standard and its ability to discriminate between fuels with different levels of thermal stability.
3. Establish (if possible) a basis to decide the ASTM acceptance criteria for the thermal stability of distillate fuels.

Nine laboratories are participating in the round robin test with 10 fuel samples specially formulated for the round robin test being evaluated. Each participating laboratory will be sent two samples of each fuel - twenty in all. Each sample will be coded so test operators will not know which fuel samples are identical.

Fuel samples will be heated at 150° C for 1.5 and 3 hours and filtered. The filter pad for each fuel sample will be evaluated by reflectance ratings instead of a visually obtained rating. This modification of the DuPont F 21 procedure eliminates variations in results which can occur from rater to rater and improves the precision of the results, especially when obtained by different laboratories. Two sulfur levels, high and low, are

also being evaluated in the round robin to determine their effect on the fuel stability.

When the duplicate samples of the 10 unique fuel samples have been completed by all nine laboratories, a minimum of 960 test results will have been generated. The data will be collected by the Test Program Coordinator and statistical procedures will be used to analyze the reported results to quantify repeatability, reproducibility and discrimination. First, the data will be evaluated for uniformity and for outliers. All anomalies will be checked with the laboratory which submitted the data to determine if the values are valid or if the tests should be repeated.

After the data have been statistically evaluated, the results will be examined to determine if the fuel stability test methods are suitable for measuring the thermal stability of diesel fuels. Also, the data will be evaluated to determine if the test methods yield reproducible and repeatable values. Finally, the data will be assessed to determine if ASTM acceptance limits for thermal stability of distillate fuels can be proposed. Upon completion of the evaluation of the round robin test data, the task force will be able to decide if the accuracy and discrimination of the thermal stability tests is sufficient to warrant inclusion of one of these methods in the ASTM D975 specification for diesel fuels.

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IV. "TEN QUESTIONS" ON EPA'S LOCOMOTIVE EXHAUST EMISSION REGULATIONS

by Steven G. Fritz, P.E.,
Southwest Research Institute
San Antonio, Texas

Over the last five years, the LMOA FL&E Committee has provided updates on locomotive exhaust emission regulations that were being proposed by the U.S. Environmental Protection Agency (EPA). Officially proposed in January 1997, the final rule for locomotive exhaust emission standards was published in the Federal Register on April 16, 1998. Presented below are "ten questions" about the regulation, with accompanying discussion of how it will affect the railroad industry.

Question #1: Who Is Subject To These Regulations?

in the preamble to the regulation, EPA noted that this rule will apply to "manufacturers, remanufacturers, and importers of locomotives and locomotive engines, and railroad owners and operators." On the surface that pretty much includes everybody in the motive power business. Clearly, the major builders (EMD and GE) will bear the brunt of the responsibility for supplying new locomotives that comply with these regulations. These regulations also cover existing locomotives manufactured since 1973. Railroads are counting on the original equipment manufacturers (OEMs) to provide "certified kits"

that, when installed in a locomotive engine at time of overhaul, will result in a locomotive that meets the applicable EPA regulations.

EPA is exempting locomotives owned and operated by "small railroads." Clearly, railroads wholly owned by Class 1 railroads will not be exempt. Unfortunately, the definition of a "small railroad" is not clear. EPA defined a "small railroad" as a railroad that is classified by the U.S. Small Business Administration (SBA) as a small business. An informal inquiry to the SBA revealed that the SBA defines a "small freight railroad" as one that has less than 1,500 employees, and a "small terminal and switching railroad" as one that has less than 500 employees. These things get confusing when a small railroad is owned by a larger parent company. EPA is expected to issue a guidance document in the future addressing this issue. Another possible twist to this exemption story is that if a small railroad is exempt from EPA regulations, it may be subject to State regulations.

Question #2: When Do The Regulations Take Effect?

All aspects of the regulations will be in place beginning January 1, 2002. The effective date of the regulation is January 1, 2000, when interim provisions for 2000 and 2001 begin. Some new locomotives manufactured during these two years will have to meet regulated emission levels. These

Interim provisions will affect how locomotives originally manufactured in the 1990's will be overhauled.

Question #3: What Model Year Locomotives Are Subject To Regulation?

The proposed rule separates locomotives regulations into three groups, or "tiers", based on the date the locomotive was manufactured. Note it is the date that the locomotive was originally manufactured that affects applicability, not the model year of the engine in the locomotive.

"Tier 0" covers locomotives originally manufactured in 1973 through 2001.

"Tier 1" covers locomotives manufactured in 2002 through 2004.

"Tier 2" covers locomotives manufactured in 2005 and later.

Locomotives manufactured before 1973 are not covered by the rule unless the owner upgrades them to Tier 0 standards.

The final rule also included a provision that passenger locomotives are exempt from Tier 0 regulations until 2007. However, new passenger locomotives purchased in 2002 will have to meet Tier 1 standards.

EPA will prevent railroads and other locomotive owners from avoiding standards by defining a remanufacturing event on a cumulative basis. After January 1, 2000, any engine that has all

power assemblies replaced within the last five years will be considered to have been remanufactured and must meet the applicable standards.

Question #4: What Are The Standards That Have To Be Met?

Table 1 gives three tiers of regulated exhaust emissions for hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and particulate matter (PM). Table 2 gives the maximum allowable smoke capacity values.

The regulated emission levels given in Tables 1 and 2 are maximum levels that cannot be exceeded when the locomotive is tested using procedures detailed by EPA in the Federal Test Procedure (FTP).

In several respects, the locomotive regulations are generally regarded as much more stringent than other mobile sources, not in the absolute level of tailpipe emissions levels, but because the rule requires that locomotives must meet the applicable standards at ambient temperatures ranging from 45 to 105°F, and at altitudes from sea level to roughly 4,000 feet, plus the additional requirements described below.

Question #5: Do Locomotives Just Have To Meet The EPA Standards When New or After Rebuild?

The emission standards limit emissions from locomotives over their full (actual) useful life. This is

TABLE 1 - EPA LOCOMOTIVE EXHAUST EMISSION STANDARDS

Duty Cycle	HC (g/hp-hr)	CO (g/hp-hr)	NO _x (g/hp-hr)	PM (g/hp-hr)
Tier 0 (1973 - 2001)				
Line-Haul	1.00	5.0	9.5	0.60
Switch	2.10	8.0	14.0	0.72
Tier 1 (2002 - 2004)				
Line-Haul	0.55	2.2	7.4	0.45
Switch	1.2	2.5	11.0	0.54
Tier 2 (2005 and after)				
Line-Haul	0.30	1.5	5.5	0.20
Switch	0.60	2.4	8.1	0.24

TABLE 2 - EPA LOCOMOTIVE SMOKE STANDARDS

Locomotive Classification	EPA Locomotive Smoke Standards, Maximum Percent Opacity for a 1-Meter Path Length		
	Steady-State	30-sec Peak	3-sec Peak
	Tier 0	30	40
Tier 1	25	40	50
Tier 2	20	40	50

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unprecedented in mobile source emission regulations, and is far more stringent than the requirement for car, truck, and non-road diesel engines. EPA has defined useful life as 7.5 times the rated horsepower of the engine. For example, this means that for a 4,400 hp GE C44-9, exhaust emissions must be below the standards even after the locomotive has performed 33,000 MW-hr of work! This is much longer than GE's current rebuild recommendation of roughly 28,000 MW-hr for these locomotives. For older locomotives not equipped with MW-hr meters, useful life is defined by EPA as 750,000 miles, or 10 years, whichever comes first.

Manufacturers of new locomotives and "certificate holders" must provide an emissions warranty for the first 1/3 of the useful life of the locomotive.

Question #6: Who Can Provide "EPA Certified" Kits?

One question last year was whether the EPA would "allow" any interested party to be a certificate holder for remanufacturing kits. The certificate basically covers an engine family that the remanufacturer defines by engine specification and that has a certified level of emissions determined using the FTP. The remanufacturer defines a "kit" that is installed in the engine family by the installer at the time of the top-end overhaul. While it is expected that the installer will not have to hold

the EPA certificate, he must obtain the use of it for every Tier 0 and later engine he overhauls starting in 2002.

What will constitute a "kit" can vary quite a bit. It must include instructions for installation, inspection, maintenance, and repairs for the life of the engine. Some kits may include parts, while others may include a specific parts list for the installer to buy. Other remanufacturers may specify an assortment of parts by providing a list of acceptable part combinations, or leave it to the installer to select the parts.

The market place will decide the content and price of the kits. Remanufacturers will likely spend hundred of thousands of dollars per engine family to develop and certify their kits, and they will assume considerable liability for auditing installers, conducting in-use testing of the engines and solving any problems that are identified by in-use tests. So remanufacturers will expect to recover their investment either in license fees or in the sale of parts. EPA estimates that the extra cost of remanufacturing to Tier 0 standards is \$80,000 per locomotive.

The final EPA rule allows anyone to hold the certificate. The likely certificate holders will include the OEMs (General Electric, General Motors Locomotive Group, and Motive Power with Caterpillar); some after-market suppliers; some non-railroads, non-OEM locomotive engine rebuilders; and possibly one or more railroads.

Question #7: Is EPA Going To Check To See If Locomotives Are Meeting The Standards?

The regulations for locomotive exhaust emissions reflect EPA's current emphasis on in-use compliance. In addition to the initial certification of a new locomotive or a retrofit kit, production line testing is required to ensure that locomotives coming off of the assembly line meet the applicable standards. The regulations also require emission checks at a point between one-half and three-quarters of the useful life of the locomotive. In addition, beginning in 2005, railroads will be responsible for testing 0.15 percent of their fleet (1.5 locomotives per thousand). EPA has stated that ***"these requirements, taken together, form one of the most comprehensive mobile source compliance programs that has ever been implemented by EPA."***

Question #8: How Will These Regulations Affect Maintenance Practices?

Proper maintenance will be defined by whoever holds the EPA certificate on the engine family. These engines must be properly maintained throughout their lives.

It is important to note that the EPA will not allow any form of "tampering" with engines covered by these rules. Engine maintainers must always use parts that are equivalent to those specified by the certificate holder, and must

maintain locomotive engines according to the certificate holder's instructions for inspection, adjustment, maintenance, and repair of engines. If a railroad or other engine maintainer knowingly changes the emissions characteristics of the engine, even to "improve" the performance of the engine, they have committed a Federal crime.

Unacceptable maintenance is knowingly installing parts that affect the emissions level. This includes parts that might even claim to "improve" emissions. When an engine is modified to change emissions, it is almost impossible to reduce every one of the pollutants coming out of the engine. If one or two pollutants go down, something else inevitably increases. Beware of claims pushing products that allegedly reduce emissions. If the part is installed with the expectation of affecting emissions, and there is not a reasonable basis to ensure that the applicable EPA standards are met, you are breaking the law.

Question #9: Can I Use Aftermarket Parts for Repairs?

The EPA regulation specifically forbids certificate holders from specifying the exclusive use of their parts for service or repairs. Suppliers of parts that can affect exhaust emissions can petition EPA for advance approval of their parts, and must convince EPA that their

parts are functionally equivalent to the OEM parts based on engineering analysis or on emissions test data. Parts suppliers are ultimately responsible for how their parts perform in a regulated engine. The regulation specifies that suppliers can be held liable for any in-use nonconformities attributable to that part. If the part was used during the remanufacture of a locomotive, it is subject to recall. If the part was used during repairs, the suppliers may be liable for a tampering violation. Section 40 CFR 92,1106 spells out the civil penalties of not more than \$25,000 for each violation. Each locomotive affected constitutes a separate violation.

As an example, a builder cannot specify that you use its branded fuel injectors during maintenance or repairs. It can simply dictate the maintenance interval and the part number of the injector. The end user can choose any supplier for the functionally equivalent injector. However, it is the end user's responsibility to make sure that the supplier has some basis on which to expect equivalent emissions performance of its product.

The railroads and other engine rebuilders must know the identification of the kit certifiers. These kits must include a package of installation, inspection and maintenance instructions for the engine, with proper EPA documentation on the certificate.

Question #10: Where Can I Get More Information About The EPA Regulation?

The entire rule can be obtained over the internet. The address is: <http://www.epa.gov/omswww/locomotv.htm>.

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PERSONAL HISTORY

Timothy A. Frederick

Timothy A. Frederick was born in Pittsburgh, Pennsylvania on Sept. 1, 1954. After his high school education he studied at Pennsylvania State University where he received a Bachelor of Science degree in Mechanical Design Engineering Technology in 1976.

He began his railroad career as a trackman with the Penn Central Railroad in Pittsburgh while attending college. Later he was hired by Consolidated Rail Corporation as a Management Trainee in October 1977. In Sept. 1978 he was transferred to Altoona as a Supervisor of Quality Control. In Dec. 1980 he transferred to the Mechanical Engineering Department. He served as the Resident Mechanical Engineer at the Altoona Locomotive Shop thru October 1987.

Timothy was promoted to Sr. Mechanical Engineer and transferred to corporate headquarters in Philadelphia. He was promoted to Assistant Manager - Mechanical in August 1988 where he supervised five fellow engineers. In March 1994 he was transferred to the Mechanical Department as Manager Mechanical Systems, the position he now holds.

Timothy's hobbies include golfing, hunting, sporting clays, reloading, motorcycling, and masonry.

Timothy and his wife Joyce Renee, have four children: Timothy Jr. 24, Cheryl 21, Steven 20, and Jennifer 17, and one grandson, Andrew, 3. They currently live in Glenmoore, Pa.

I. EXPERT SYSTEMS

*by Keith Challenger,
National Electrical Carbon
Products, Inc.*

Why would we want to isolate faults on locomotives? Well, if $\text{availability} = \text{mttf}/(\text{mttf} + \text{mtrr})$ (mean time to failure, mean time to repair), then reducing mtrr by diagnosing problems more effectively increases availability. Rapidly advancing technology and the diminishing supply of skilled maintenance personnel are causing some of the larger railroad and major original equipment manufacturers to consider the application of expert systems to supplement their locomotive maintenance capabilities.

Expert systems is known as a branch of artificial intelligence, because such systems are designed to simulate human judgement. More than twenty years ago, researchers at Stanford University were the first to experiment with computer programs which would be capable of emulating the way in which people think. The initial work was done to help diagnose infectious blood diseases, but the concept has since been broadened to encompass almost any profession which relies on the application of knowledge and experience.

When we are faced with a technical problem, we rely on a group of interdependent thought processes which draw information and data, usually from both practical and theoretic intellectual

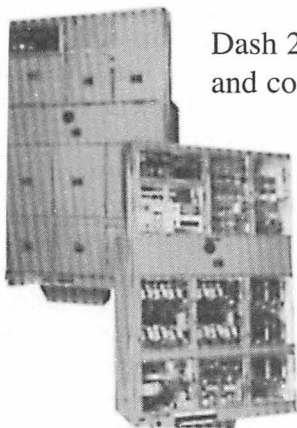
resources. These resources include typically human attributes such as experience of addressing similar problems in the past, intuition (so-called gut feeling), and a frame of practical reference. It was always considered that these attributes were too complex and subjective to be emulated by a computer, but the Stanford researchers were able to push the boundaries of conventional computer programming. Data is normally processed sequentially, but expert systems process data based on the information available and the information desired - exactly the way that the human thought process works.

The Anatomy of an Expert System

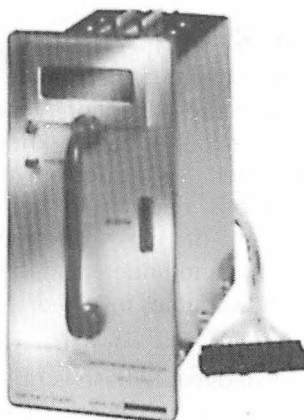
Expert systems generally consist of three parts: the user interface (sometimes called an explanation generator), an interface engine, and a knowledge base. Let's look at these parts in more detail.

The heart of any expert system is the knowledge base. This is the actual information which describes symptoms, causes and cures. This information is usually obtained by people called knowledge engineers who are skilled at debriefing experts in selected fields, accumulating information, and massaging it into a form which is digestible by the inference engine. This is not usually an easy task because of the non-linear human thought process and the fact that humans can use reason where computers cannot. Most experts

MAXITRAX

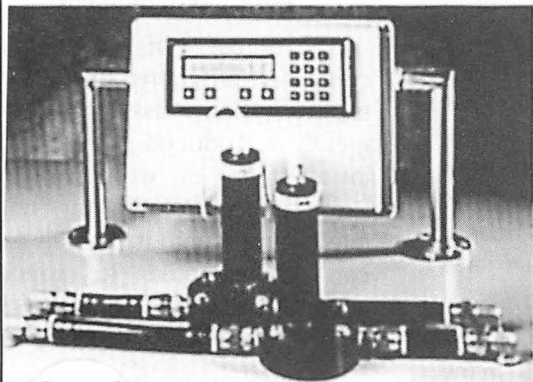


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find it difficult to explain how they solve problems, particularly in the case of a locomotive control systems where there may appear to be more exceptions than rules. An experienced knowledge engineer is inquisitive and tenacious enough to get to the bottom of the troubleshooting process and understand the nature of the variables involved.

Even the most extensive knowledgeable base is of little use without a framework of rules by which the knowledge can be arranged. Imagine for instance, a library without a filing system. In the case of an expert system, a straightforward computer program is simply not adequate. A database or set of index cards explaining symptoms and causes is of little use if the records are used one-at-a-time and in sequence. The computer programming rules used by an expert system creates what is called an inference engine. This is a process which gives the computer the capability of chaining information or deriving new facts from existing data, then employing this inferred information to dig deeper than the original data would have allowed.

The user interface part of the expert system can take many forms. The most basic is a simple question-and-answer format which can be followed similar to a traditional logic diagram. If conditions A and B exist, then the diagnosis is X with a confidence factor of Y%. Of course, you don't

need an expert system for this type of analysis. Faultfinding charts have been used for years for this purpose. However, the user interface of an expert system can be linked to automatic sensors to verify information, for instance, or can be made to recognize and question contradictory inputs. Other types of interface may not require input from the user at all. For instance, an expert system could be used to monitor the performance of a locomotive being operated by a particular driver and build a computer model of driving habits. A change in the operating profile or efficiency of the locomotive might be used to pinpoint anything from reduced fuel efficiency or substandard traction motor performance, to driver fatigue or poor track conditions.

Expert System Shells

The cost of developing computer programs to perform expert system tasks has been greatly reduced by the introduction of expert system shells which contain the basic inferencing computer code and can be adapted to specific applications based on the user's data or available knowledge base.

A number of expert system shells are in common use; two of the most popular are knowledgeable or rule-based and case-based systems. In situations where a lot of data are available (from condition monitoring equipment for example), a rule-based expert

system is often the most practical because it uses a programming technique called backward chaining. This starts with a statement such as "Engine Temperature Is Out of Range", and a set of rules leading to the statement, then works backward, matching the rules with the information from a database of facts, a process called pattern-matching. It will compare many other pieces of data such as input from thermocouples, coolant pressure and fan speed transducers until it finds one or more "untrue" statements which it will then process into possible causes and suggest solutions.

Case-based systems, on the other hand, use a reasoning approach which relies on stored representations of previous solved problems and their solutions. Each problem and solution is contained in a "case" where all available inputs are logged in a uniform manner. When a new problem occurs, the available data is compared to all previous cases containing the same symptoms. The expert system shell then uses probability-based reasoning to select similar cases and uses these to suggest solutions. In a case-based system, the answers to a series of questions creates a case for the problem which can then be compared to a database of other cases. It is clear that a certain amount of data can be missing but the case-based system will still provide possible solutions, although each will have a lower

probability until further data is added. Therefore case-based systems tend to be more popular where data input is limited.

An unlimited number of problems can be solved using an expert system. In theory, any decision-making process can be converted to an expert system, although this is not always practical. For example, a problem may be incompletely understood or be just too large or complex for conversion to a rule-based system.

Where to Start

The most important first step in developing an expert system is to define an appropriate problem. Often, even if a large problem cannot be solved, part of the problem can be. Factors that should be considered in defining a problem for the expert system include:

1. Does a human know how to solve the problem?

If no human expert can solve the problem, it is not possible to develop rules or cases describing the solution. The techniques of solving the problem must be known and defined in order to create an expert system.

2. Does the problem have a definable solution?

Most expert system shells are designed to select one or more possible solutions from a group. If all the possible solutions cannot be specified, writing rules to solve the problem is

difficult. Some problems can be handled, even if they have a very large number of solutions, as long as all the solutions are definable.

3. Is the level of understanding and scope appropriate?

Figure 1 shows a graph illustrating the level of understanding on the horizontal axis, which ranges from limited (a simple well-defined solution), to a deep understanding (a solution requiring insight and innovation). The vertical axis represents the scope of the problem, ranging from very specific to very wide or diverse problems. Defining the problem to fall within the shaded area is very important. A problem that has too wide a scope or that requires too deep a level of understanding is not appropriate for an expert system solution. Expert systems cannot emulate deep understanding with insightful solutions to new problems, although case-based systems can grow exponentially to encompass new problems and solutions as they arise and are learned. A rule-based system usually requires that the scope of the problem be narrowed so that it can be addressed in stages, each building on the last, until the final solution is reached. Keeping realistic goals is also very important. A human expert cannot be captured in a computer; only a small part of the problem-solving skill can be expressed in an expert system.

A human expert can solve new problems based on experience and intelligence; a computer cannot. However, the expert system can solve the specific problems it has been designed for and will do so for many non-expert users, 24 hours a day. It will also give consistent answers and usually faster than the human expert can.

4. Has the technique for solving the problem been documented?

A vast number of problems meet the requirements for successful, worthwhile, and effective expert-system development. Remember, an expert system does not have to solve a major problem to be worthwhile. Any area where one person possesses a problem-solving skill that is needed by others is often well documented and has good potential for an expert system. The areas may seem very mundane or uninteresting, but these are often the best of expert system development because they are well understood and well documented. The knowledge to address the problem may be contained in a decision tree, manual procedure, regulations, or specific set of written instructions. Such well-defined problems can be easily converted to expert systems, making the solution more accessible to end users. Solving a problem with an expert system is much easier than looking procedures in a manual and less prone to error.

Practical Application

On a locomotive, the expert system would usually act in conjunction with a data acquisition or condition-monitoring device capable of supplying the system with fault data. Among the many issues being faced in the early stages of implementation in the locomotive environment is the physical location of the expert system hardware and software. On the one hand, it makes sense to have the system installed on board the locomotive so that diagnostic resources are available wherever the locomotive happens to be. The problems with these distributed systems include the high initial cost, plus the logistical difficulties of maintaining a large number of hardware and software installations in current condition. A centralized expert system eliminates much of the installation cost and creates a simpler environment, so installation on every locomotive would be redundant.

Ironically, another issue facing the designers of monitoring equipment for locomotives is the availability of sensing devices or transducers substantial enough to withstand the rigorous duty to which they are often exposed in the railroad environment. Often, fault indications are caused by failure of the sensor itself, rather than the piece of equipment that the sensor was monitoring.

There are already practical applications of expert system beginning to be implemented in the locomotive maintenance field.

One of these is the EMD Expert, an on-board rule-based system which works in tandem with a module called integrated condition monitoring (ICM). This supplies real-time operating situation information to the locomotive driver as well as repair technicians. The ICM unit collects operating data from sensors, then displays the data on a train status indicator (TSI). When the input from one or more sensors indicates a problem condition, the EMD expert can be invoked on the TSI screen and will immediately prioritize active faults in a list. By selecting any active fault from the list, a "fault description" can be viewed in detail, and the expert system software in the unit will suggest "probable causes". Supplemental data such as graphic illustrations of components or relevant circuit diagrams can also be displayed. The EMD Expert is already implemented on some 8000-8074 class SD90MAC locomotives at the Union Pacific Railroad.

Bayesian Networks

Although case-based systems can work with large amounts of incomplete data, thus overcoming some of the limitations of rule-based systems, they still cannot always offer the optimum solution. Case-based systems "learn" or become more versatile as more cases are supplied, but because they rely on previously-encountered problems, they cannot be programmed to predict the unforeseen. If the system has never been presented with the data

representing an open circuit in the dynamic braking resistor grid for instance, it will not recognize the symptoms. Ambiguous information has continued to plague both the rule-based and case-based expert systems.

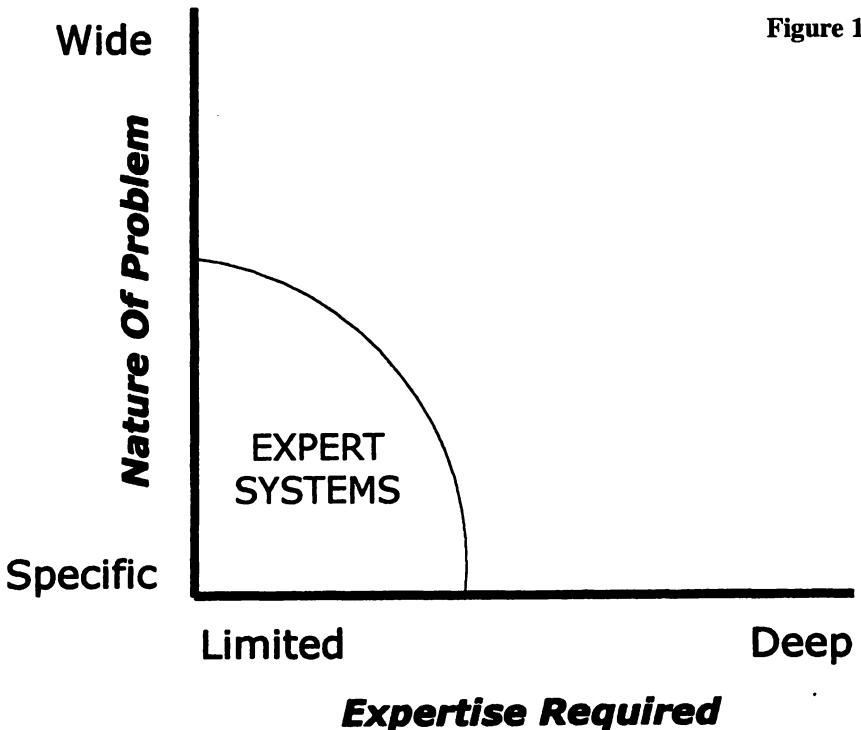
The future of expert system shell development may emerge in the form of Bayesian networks. An essay by the Rev. Thomas Bayes was published posthumously in 1763 and suggested a mathematical formula for calculating probabilities among several variables that are related by causes, but whose relationships cannot easily be derived by experimentation. Early students of Bayes' work applied his formula to such highly speculative tasks as investigating the existence of God. Bayesian networks remained little more than a mathematical curiosity until the late 1970's and early 80's when rapid progress in computer power made it possible to compute Bayesian networks with enough variables to make them useful in practical applications. A recent application of expert systems based on Bayesian network principles is being used by credit card companies who can now routinely pick out transactions which appear unusual based on a the consumer's past spending behavior.

Understanding the failure mode of most locomotive systems and components requires a combination of meticulously-gathered historical data, combined with less

precise but more intuitive knowledge of experts who understand how the component or system works. This of course presents a very difficult set of circumstances. Add to the confusion the fact that essential pieces of data could be missing altogether, and the task seems akin to determining gambling odds (which happens to be one of the early applications for which Bayesian networks were used). Early claims of the so-called intelligent computer pioneers were exaggerated and failed to deliver the benefits for which they were created. Consequently, the study of computerized artificial intelligence has been relegated to the level of curiosity rather than serious practical development. The introduction of expert system shells based on Bayesian network principles is beginning to move the study of artificial intelligence back into the mainstream. Of course, the most essential part of any expert system is and will continue to be the knowledge base itself, in the same way that a database can only be as useful as the data that it contains.

Expert systems should be viewed as a tool to increase the effectiveness of maintenance personnel. The skills and intuitive problem-solving capabilities of an experienced maintenance engineer cannot be replaced, only supplemented by expert systems. However, as original equipment manufacturers continue to introduce greater levels of

technical sophistication into their products, it is unrealistic to expect maintenance engineers to keep pace. Expert systems are one way in which actual trouble-shooting expertise can be passed along from the system designer to the maintenance engineer without the need for direct communication. This can make the experts more efficient and provide the maintenance engineer with an invaluable tool to help enhance service to the customer by reducing mtrr, thus increasing locomotive availability.



IIA. EMD SD90MAC 6000 HP LOCOMOTIVE - WHERE ARE WE TODAY?

*by Craig R. Prudian, EMD,
General Motors Corporation.*

The SD90MAC locomotive is EMD's latest offering to the railroad industry; a 6000 horsepower locomotive that is prepared to help our customers realize the maximum potential of their motive power assets. This paper will briefly cover this new locomotive, primarily from the standpoint of new maintenance procedures required. Many of the maintenance changes are brought about by new technology advancements, and result in new procedures relative to those already in place in today's shops that service EMD locomotives.

Overview

The SD90MAC locomotive is a culmination of many years of effort toward development of a new model. With reference to Figure 1, we consider this latest version of the SD90MAC locomotive a "platform" offering, specifically developed to be the basis of all new high horsepower mainline models to come. At the center of this locomotive is, of course, EMD's new "H" engine. In conjunction with this higher horsepower engine comes a new TA20 main generator and CA9 companion alternator. The cab is the latest version of our isolated cab; the EMD WhisperCab, with some notable changes to be outlined later. As well, we use a

new higher capacity dynamic brake system. Notable here is the location of the grids at the rear of the locomotive, reducing grid blower noise conducted into the cab, and helping to retain the locomotive balance. The standard air compressor is a three cylinder unit, shaft-driven from the engine, although it can alternately be provided motor-driven as an option. Underneath the locomotive is a newly designed fuel tank, developed to be integral to the locomotive structure.

EMD has given special focus to maintainability of this locomotive model. Targeted for 122-day maintenance intervals, this offering will use the best of our design and field experience to provide these exceptionally long maintenance intervals. Figure 2 shows, among other details, principal maintenance access points of this locomotive. First, the location of the batteries is now on the engineer's side of the locomotive, directly behind the cab. 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. Starting from the front, we find an inertial filter hatch and then the turbo & generator hatch. Behind those is the engine hatch. The fan and radiator hatch follows. The last removable hatch is for the dynamic brake system. This unit is separate, because it is part of the 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.

New "H" Engine

At the heart of the locomotive is our new engine (Figure 3), designed specifically for locomotive application. This power plant carries a new designation, 16V265H, which is in keeping with the accepted metric system of 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. For those interested in displacement criteria, this engine is sized at 1010 cubic inches per cylinder. It develops 6300 brake horsepower, 6000 for traction. The design and development was overseen in-house by EMD's engine development group in LaGrange.

As mentioned earlier, the engine carries a metric designation. Does that mean it uses metric fasteners? Sure does. However, given that the engine is metric, EMD has designed the interface of the engine to the locomotive as standard SAE. What that essentially means, is if you're removing the engine from the locomotive or working with its attendant system, no metric tools are required, but if you have to do any work to the engine itself, you'll need your metric tools. To

reiterate, **you need no metric tools to take the engine out of the locomotive.**

Another new feature, at least for EMD, is the introduction of a 4 stroke cycle to the engine. With this engine, comes some new features as well. One of these is an anti-freeze based coolant in the engine. No more worries about auto-drain problems or coolant freezing in the radiators. The design is such that no engine purge cycle is needed on startup. So when the engine is started, there is no delay while the purge cycle operates. Another notable change is the twin turbo configuration. Because of the 4-stroke design, the turbos are now free-wheeling, without the need for a geartrain and overrunning clutch. Also, each of the turbos is much smaller than the style used in 710 engines. This allows for a fast spool-up rate, quick dead load pickup and fast engine acceleration.

On the issue of periodic engine maintenance, we expect that, following the recommended maintenance instructions, the average shop hours will be less for this engine than a comparable 710. 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. We have designed this engine to operate 6 years between major overhauls or 41,500 megawatt

hours. There will also be a recommendation on an oil change frequency, but until these engines get more running time, we'll rely on spectral analysis, railroad experience and further testing in-house to dictate oil changeout periods in the near term.

What about shop equipment? There should be no need for "EMD shops" to change any of their basic infrastructure. Obviously, some of the components that shops will be pulling out of the locomotive are heavier than before, and this means that some cranes will be busier; but the good news is that, overall there should be fewer hours overall, dedicated to engine maintenance.

Using these same basic shop systems in place now, there are some things that are new. One of the larger changes to be seen, involves the need now for hydraulic tensioning equipment. For more information on this technology, please reference the paper given this year by the Shop Equipment Committee, included as part of these proceedings.

The biggest reason behind the switch to hydraulic tensioning is a commitment to quality of the finished work. There is an element of repeatability using hydraulic tensioning that never existed before. Proper bolt stretch can now be assured repeatably. The achieving of proper torque is influenced by a number of metallurgical factors, like thread quality and lubrication. With hydraulic tensioning, these factors

are minimized. In short, the way this technology works is to achieve proper bolt stretch before a nut is run up against its mating surface. EMD plans to use this method in our most critical areas, including power assemblies and main bearings.

Engine Support Systems

Looking at some of the engine support systems, engine cooling is noteworthy for its differences (Figure 4). As mentioned before, the engine can be made to run on 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 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. EMD has developed a more efficient two-speed fan operation that reduces fan contactor count from 9 to 4. The familiar 48" fan is retained for this model, but as can be seen in the figure, 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.

Figure 5 shows other notable engine support system changes. The engine-driven primary fuel pump is another new feature for the SD90MAC. 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 load 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 changeout, with easy access also provided to new door-mounted inertial filters.

Engine starting is also different. With this model, we are proposing an air start system. We will be using a dedicated third air reservoir solely for this function, so that if locomotive air is depleting, engine start can still be accomplished.

Back in the equipment rack area, we will use a single lube oil filter tank, with tiered filters, one set behind the other. This affords a space-efficient way to achieve the longer change-out intervals desired. Dual primary fuel filters are also located in this area.

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

Traction Systems

As far as the traction systems are concerned, most of the AC electronic equipment remains basically unchanged. The traction converter cabinet (TCC), located directly behind the cab, has undergone some changes, mostly performance updates. What has been done to improve maintenance was an emphasis on quick-release covers for ease of access, and where practical, the use of captive fasteners, so that there's not a pile of hardware on the floor after a maintenance or repair operation.

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. Other than the larger 5 1/2 megawatt rating, this system too, remains much the same as previously offered.

Auxiliary Electrical Systems

With other electrical auxiliary systems, ease of maintenance is primary. For instance, the two traction motor blowers now utilize more standardized componentry than previously offered.

The auxiliary generator, long a standard component in EMD locomotives, is now gone. Replacing it is a solid-state auxiliary power converter, located in the inverter cabinet. This unit is maintenance free and is driven directly from the companion alternator. It is rated a 30 kW for auxiliary loads, a performance upgrade from earlier 24 kW aux gens.

Carbody and Structures

Relative to the carbody structures, many improvements have been incorporated there, as well (ref. Figure 6). The ends include redesigned access steps. Earlier models had steps of varying width; we have now standardized on a common width step, both on the front and back of the locomotive. The traditional EMD heavy collision structure is maintained in the short hood, ahead of the cab. As with previous offerings, the isolated cab is standard, reducing underframe-borne noise and vibration.

Impact Resistant Fuel Tank

It was earlier stated that 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 in excess of 6000 gallons of fuel, maximizing the locomotive operating range. Being so large, we have made the tank structural, meaning that it will be integral to the underframe, responsible to transmit some of the service loads normally carried through the locomotive. This also means that the tank is not unit replaceable in a traditional sense, but must also be considered as part of the underframe structure when maintenance is contemplated. Other changes are more subtle, although no less significant. 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

The traditional EMD Whisper-Cab™ will also undergo some changes for maintenance improvements, albeit these more of a minor nature. The number boards will now become fiberoptic driven, for reliability and increased brightness. Sand box access will also change - the fills will be lowered so that sanding can be performed from the walkway in both the front and back of the locomotive. Inside the toilet area, we will be utilizing fiberglass interior panels, to make cleaning of the area easier to accomplish.

Electrical Control and Display System

Used in conjunction with our standard EM2000 central control computer, EMD has developed our next generation system for integration of third-party cab and support electronics, known as *FIRE™* (Functionally Integrated Railroad Electronics), shown in Figure 7. The real power of *FIRE™* lies in its PC-based networked computer/display system and the integration lab which support this system. This 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 utilization of the AAR LSI standard communications protocol, EMD plans to integrate third party functions **at the software level** into *FIRE™*. This means that we can provide all the functionality without the need for separate black boxes, processors and additional connections between systems. This will greatly reduce the repair and maintenance required for these added cab functions.

Our *Integration 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 production and field application, ultimately providing high reliability and thus greater locomotive availability. *FIRE™* combined with *I-Lab* is just the latest example of EMD's commitment to reliability.

Conclusion

There are many more new features that are included in this, our latest new locomotive offering. The information presented here is just the quickest of overviews on some of the changes expected with these new SD90MAC locomotives. We look to this locomotive to be the most reliable, most efficient model we have built to date. EMD has many high hopes

for this product and trusts that, as customers get more familiar using the SD90MAC, they'll find even more new and innovative ideas to apply to this product to best focus it for their specific needs. We are looking forward to working with our customers to explore all the possibilities of this new design, as we together forge new trails toward maintaining the rail freight industry as a leader in North America for modes of transportation.

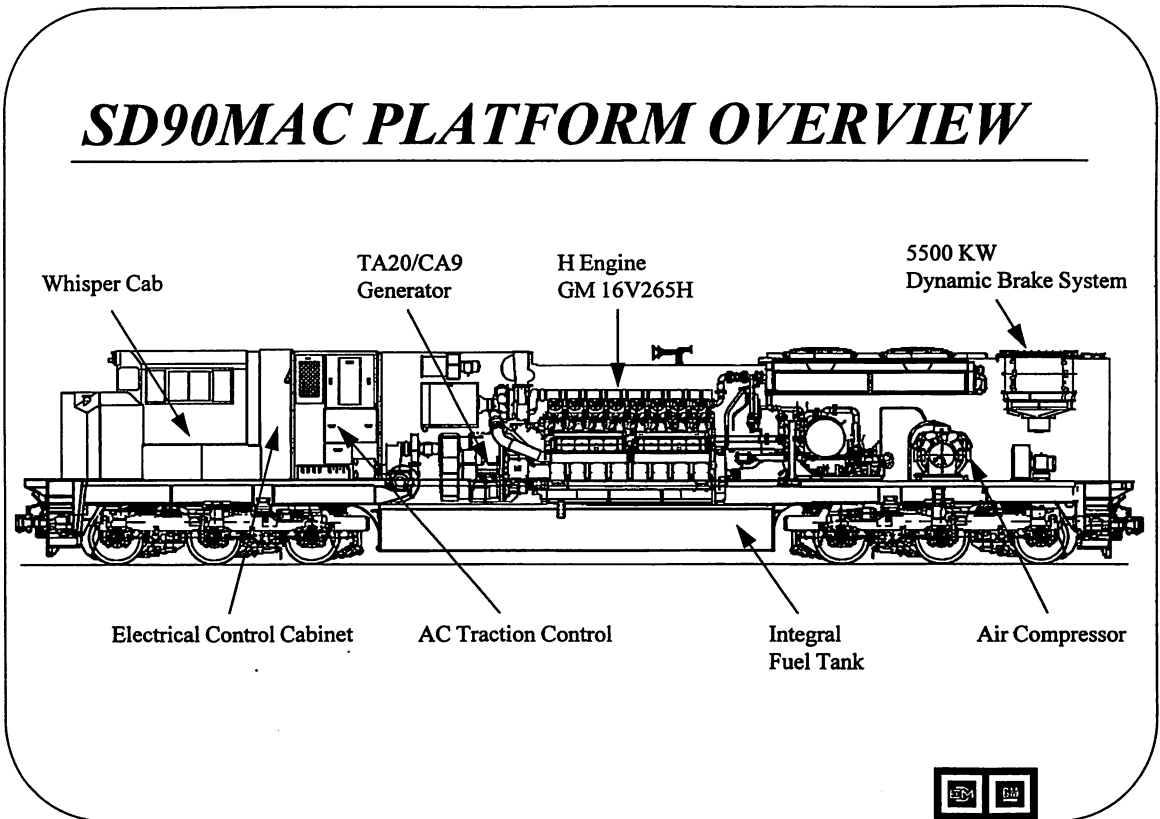


Figure 1



Maintenance Access

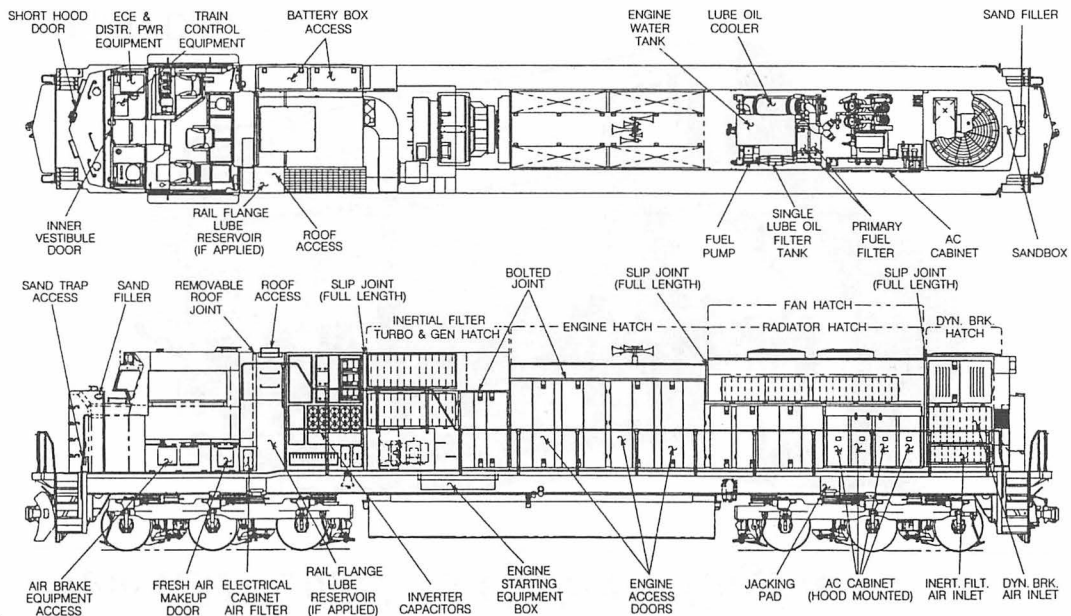
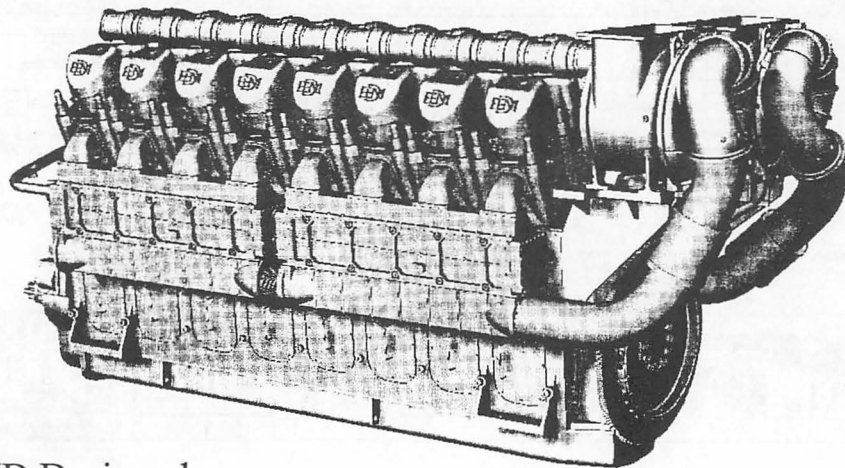


Figure 2

New GMV265H 16 Cylinder Engine



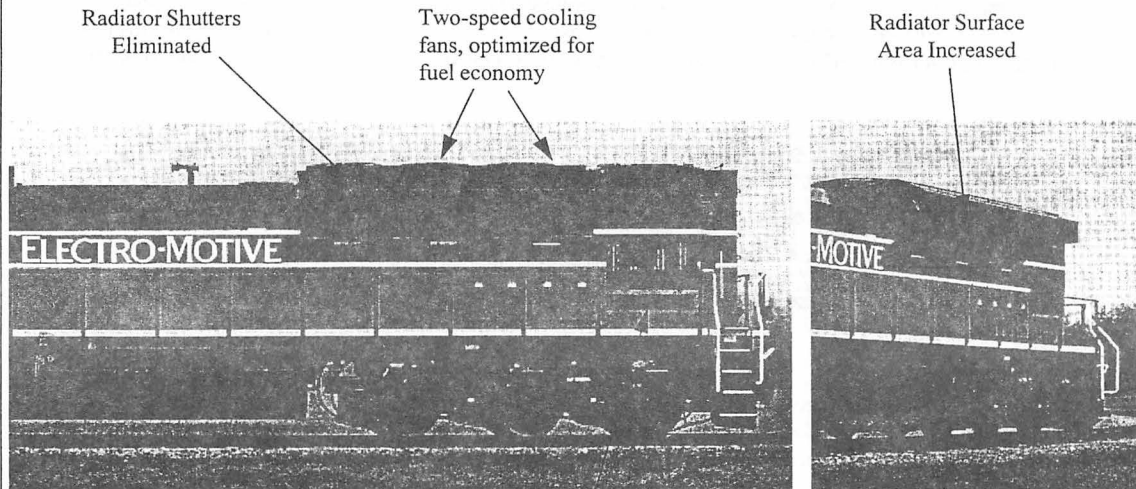
EMD Designed

Provides 6000 Traction Horsepower

Figure 3



ENGINE COOLING SYSTEM



Anti-freeze Based Engine Coolant

- Eliminates automatic drain valves
- Propylene Glycol solution

Fan contactor count reduced from 9 to 4

Figure 4



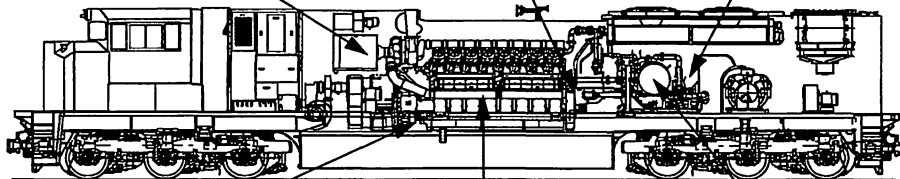
ENGINE SUPPORT SYSTEMS

Engine Air Filter System

- Hinged door / no tools req.
- Inertial filters on doors
- "No Tools" Baggie replacement

Engine Driven Primary Fuel Pump

- ## Combined pre / post lube system Integrated Priming Pump / Motor
- Both motors brushless



Air Starting

- Electrical Cranking Eliminated
- Reliable Starting
- Dedicated 3rd reservoir

High Capacity Aftercoolers

- Solid railroad performance
- Lower cylinder temperatures

Single Lube Oil Filter Tank

- Raised for easy access
- Decreases time to change filters

Figure 5



CAR BODY and STRUCTURES

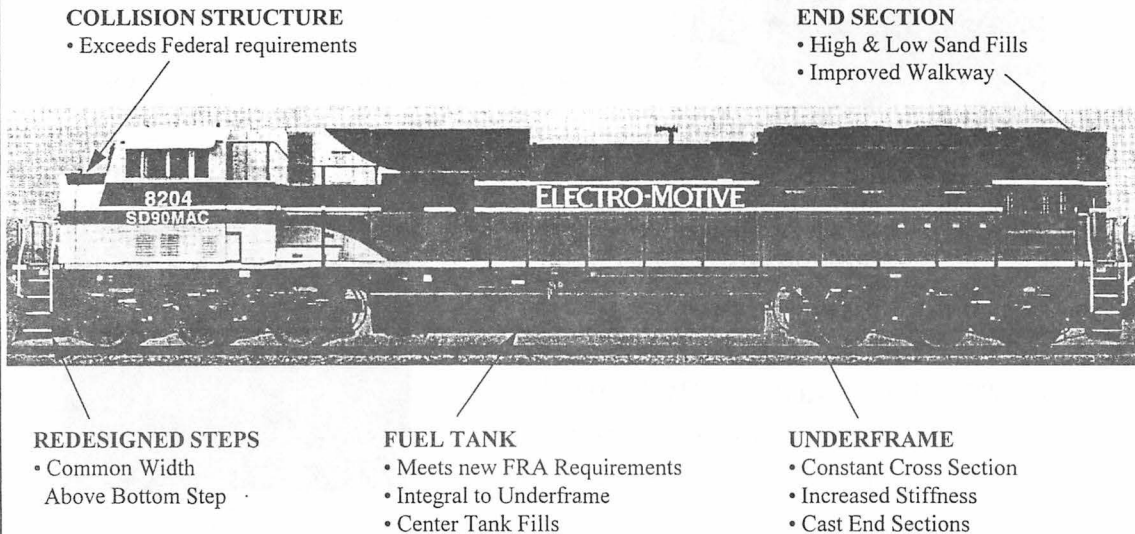
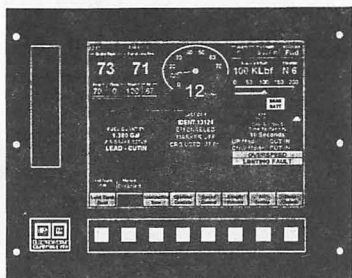


Figure 6



FIRETM

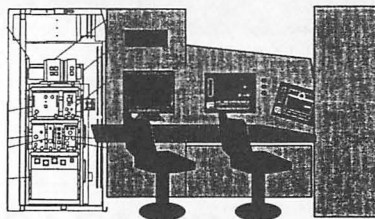
and *I-Lab*



FIRETM display

- Computers networked for redundancy
- Hardware can grow with PC market
- Expandability keeps *FIRE*TM ahead of the railroad electronics technology curve.
- Faster software and data uploads/downloads of system through one access port
- Extended backlight life; Replacement of backlight and keypad can be quickly performed onboard locomotive

- Provides complete configuration of all AC cab electronics
- Each software configuration tested prior to production
- Improved software configuration management



I-Lab (Integration Lab)



Figure 7

IIB. GE AC6000CW™ - WHERE ARE WE TODAY?

*by: Bruce Colton,
GE Transportation Systems*

This summer GE Transportation Systems launched its latest and most powerful diesel-electric locomotive; the GE AC6000CW™. This paper provides an overview of the AC6000 locomotive from a maintenance perspective. Ensuring maintainability involved three elements - using proven components, lengthening the maintenance interval and simplifying maintenance activities.

GE sincerely recognizes the importance of the CSX and Union Pacific partnerships in introducing the AC6000. Their significant contributions extended from participating in early design activities through utilizing thirteen pre-production AC6000's in revenue service.

Overview

The AC6000's new components or systems are its 6000 traction horsepower 7HDL16 engine, GMG201 alternator, 6200 useable gallon fuel tank, locomotive control network and ICON™ control system. Most other locomotive components are proven designs used on previous GE locomotives. The AC6000 and AC4400 share a common propulsion system. Other proven components include the dynamic brake packages, radiator fans, traction motor blowers, and motor-driven air compressor.

The AC6000 design has been focused on extending the maintenance interval to 122 days. Air, fuel, and lube filtration capacities have been increased to accommodate longer maintenance intervals. All filters and brushes are previously stocked components from other GE locomotive models, so no new parts are needed to perform periodic maintenance. Also where practical, "no tools" designs were implemented.

7HDL16 Engine

The 7HDL16 engine's first noticeable feature is its twin turbocharger design which enables faster engine response, superior high altitude performance and improved fuel economy. The coupled engine/alternator is soft-mounted or isolated from the locomotive platform to minimize vibrations "at the source." This isolation improves both operator comfort and component reliability. The HDL engine design also provides direct access to the crankcase, individual replacement of cam sections, and replacement of an integrated fuel pump assembly.

Since HDL engines are being sold worldwide, the engine fasteners are metric. Connections to the engine are SAE. Hydraulic tensioning of fasteners is employed for joint consistency on main bearings, power assemblies are connecting rods. This torquing technique stretches the bolt precisely for these larger, important fasteners.

To gain railroad and maintenance experience, 13 pre-production AC6000's were delivered in 1996 to CSX and Union Pacific for revenue service. To validate engineer designs, several planned engine dis-assemblies and detailed inspections have been conducted for both GE test bed engines and field engines.

At CSX, oil life of 122 days or more has been demonstrated. The locomotive overhaul interval is a 40,000 MW-hrs design.

Engine Support Systems

To handle the 36% percent increase in horsepower, two duty-balanced radiator fans are utilized in the cooling system design. A pre-lube pump was added for proper lubrication of the engine prior to engine start. Locomotive start is now comfortably performed from the operator cab. Both the pre-lube pump and engine cranking are driven by traction inverters for simplification and improved reliability.

AC Propulsion

All GE AC locomotives feature the air-cooled, single inverter per axle design with readily replaceable inverter components. The GEB13 traction motor and true ground speed sensor are other common components. Due to the increased power requirements, a higher capacity GMG201 alternator and ventilation system have been installed.

Understanding the importance of safety, numerous paths exist to safely discharge the inverter's capacitors - auto discharge when the reverser is centered, individual inverter bleed-off resistors, and a discharge barrier bar at the entrance to the auxiliary cab. Also, LED's at the auxiliary cab entrance indicate each inverter's charge state before entering the cab.

Carbody and Structure

The AC6000 locomotive structure spans 76 feet from coupler to coupler. Similar to other GE models, the AC6000 locomotive satisfies the AAR S-580 crashworthiness and the AAR RP-506 fuel tank integrity requirements. To meet customer fuel range needs, a new, high capacity 6200 gallon fuel tank is available.

Maintenance access throughout the locomotive cabs is similar to existing GE models. To accommodate the HDL engine, a new engine cab was designed enabling access to both banks of power assemblies, intercooler, and turbochargers without cab removal.

Due to a combination of larger coolant, oil, and fuel capacities, along with a heavier engine and platform structure, the AC6000 weighs 425,000 pounds. While this weight exceed other current locomotives, it has a lower bridge loading factor than 286,000 pound coal cars.

Operator Cab

How does this 6000 horse-power locomotive ride? Cab noise and vibration are greatly reduced because of the isolated engine and cab insulation. Other cab comfort options include air conditioning, strip heaters, and overhead cab fans. The locomotive control system, ICON™, provides the man-machine interface.

ICON™ System

The GE-Harris' ICON™ control system is a design for the future. This open architecture design is based on the VME industry standard utilizing the AAR LSI standard communication protocol. Advantages of the ICON™ system are improved reliability, diagnostics, and greater expendability. ICON™ serves as the brain of the locomotive connecting to the overall control network. This control network links and shares data between 23 components and over 100 analog and digital signals.

Third party functions integrate at the board level or even software level including vital systems like cab signal and PTC. A developer's kit will be available this year to provide open access to vendors. GE-Harris will provide certification for component integration to ensure trouble-free installations on new or current fleet locomotives.

Locomotive Monitoring and Diagnostics

Numerous locomotive sub-systems can be monitored on the AC6000's, such as engine, engine cranking, cycle skippers, inverter control, propulsion and excitation.

Display screens show typical operating conditions useful for diagnosing the locomotive.

The AC6000 control system was designed with diagnostics in mind. A sophisticated knowledge-based, Bayesian diagnostic system analyzes locomotive incidents to represent the most likely root causes, simplifying the diagnoses and minimizing repair time. The diagnostic system generates interactive questions to narrow the diagnoses, as well as to prioritize the list of components to check or replace.

Summary - AC6000 Commonality

The similarity of components used on GE locomotive models is illustrated on the final page. The upper part of the page depicts the commonality of filters. The lower part of the page shows that the AC6000, while the latest in technology, has been built using many familiar components.

Conclusions

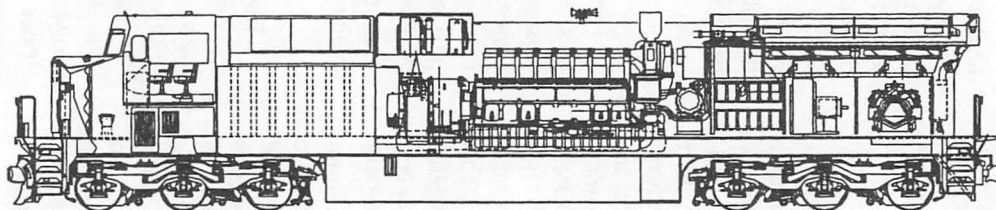
This paper has provided a quick overview of what's new and not so new on the GE AC6000 locomotive. GE Transportation continues to work diligently to make the AC6000 not just the most powerful locomotive, but also the most reliable and productive locomotive.



GE Transportation Systems

GE AC6000 Overview

		<i>GMG201 Alternator</i>		
<i>ICON™</i>	<i>Loco control</i>		<i>7HDL16</i>	
<i>Control system</i>	<i>network</i>	<i>Fuel tank</i>	- 6000 THP	<i>Two radiator</i>
		<i>6200 usable gal</i>	- Twin turbo	<i>fans</i>



<i>GEB13</i>	<i>Individual</i>	<i>Dynamic brake</i>	
<i>Traction</i>	<i>axle control</i>		<i>Air compressor</i>
<i>motor</i>			- Air cooled
			- Motor driven

Italics - new components on AC6000



GE Transportation Systems

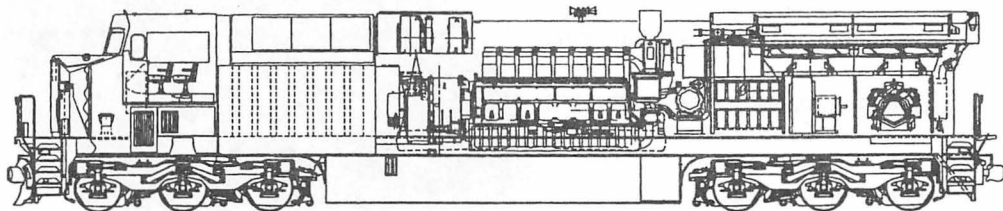
Standard Maintenance

Operator's Cab

A/C filter
LSI blower
filter

Fuel filters (3)
- No tools

Engine air
filters (6)
- No tools



DB motor (3)
brushes

Electronics
air filters (8)
- No tools

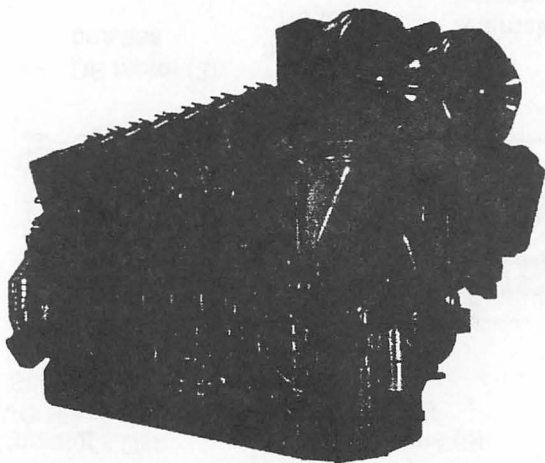
Alternator
brushes

Oil filters (14)

Air compressor
filters (2)



GE Transportation Systems



7HDL16 6000 Traction Horsepower

Twin turbo's - Faster response,
High altitude performance,
Significant fuel savings

Isolated engine/alternator to reduce
overall locomotive vibration levels

Metric fasteners on engine
External connections to engine - SAE

Hydraulic tensioning - Main bearings,
Power assemblies, Connecting rods

Overhaul interval 40000 MW-hrs

In Revenue Service Since September 1996



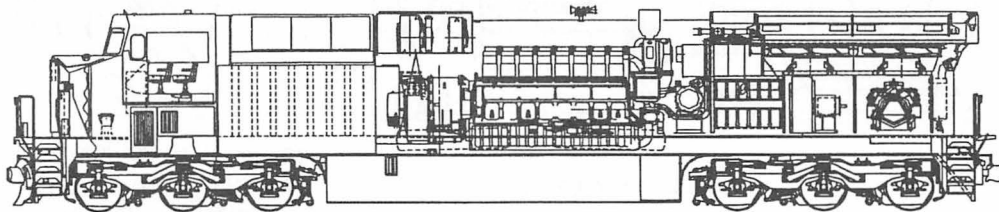
Engine Support Systems

Operator cab engine start
- Traction inverter driven

Engine pre-lube
- Traction inverter driven

Simplified cooling piping

Two radiator fans
- Duty balanced



Fuel filters (3)

Engine air
filters (6)

Oil filters
(14 total, 7 per side)

Italics - new components on AC6000



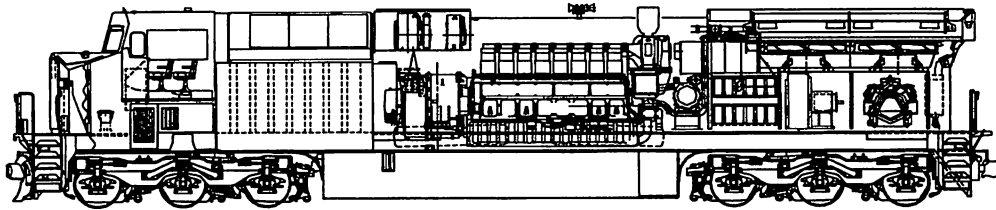
AC Propulsion

Single inverter per
axle control

- Air cooled
 - Readily replaceable units
- GEB13 Traction Motors
- Common with AC4400

*Equipment
ventilation
system*

GMG201 Alternator



Clean face
of radar speed
sensor

DB Blower
motor brushes

Electronics
air filters (8)

Alternator brushes

Italics - new components on AC6000



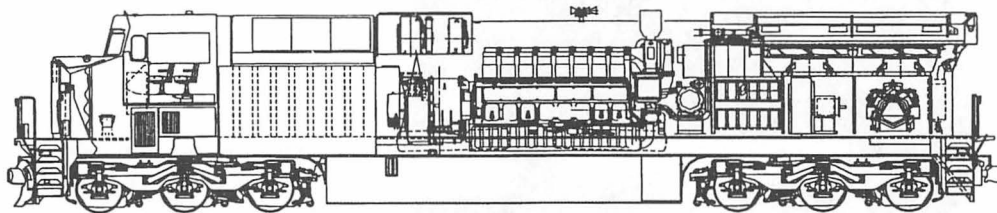
Carbody and Structures

S-580 Crashworthiness compliance

Engine cab

- Access to power assemblies, turbo's, intercoolers

76 Foot length



Fuel tank

- 6200 gallon
- RP-506 compliance

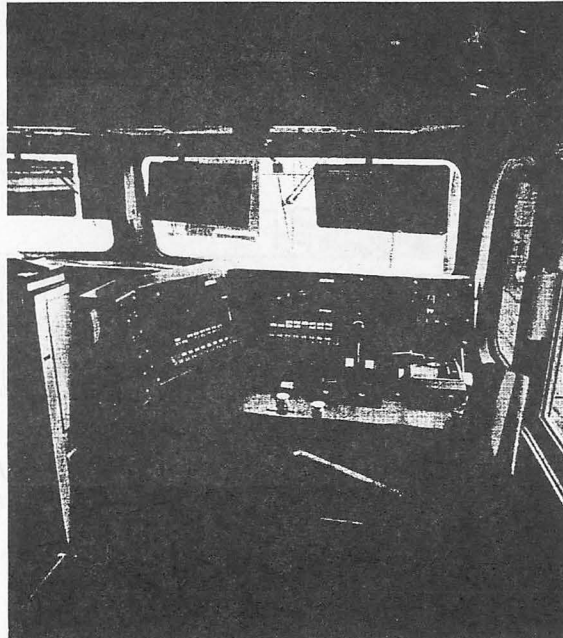
Locomotive Weight to 425,000 lb.
Larger Cooling, Lube & Fuel Capacities - Heavier Engine, Platform

Italics - new components on AC6000



Operator Cab Features

- Isolated engine reduces cab noise and vibration
- Cab fans, HVAC with temp control
- ICON™ control system
- One piece fiberglass toilet compartment for cleanability

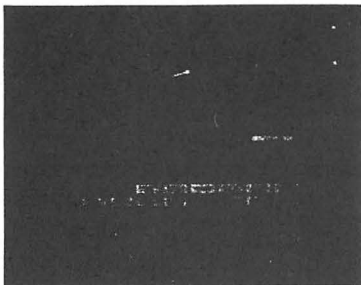


LSI blower
filter

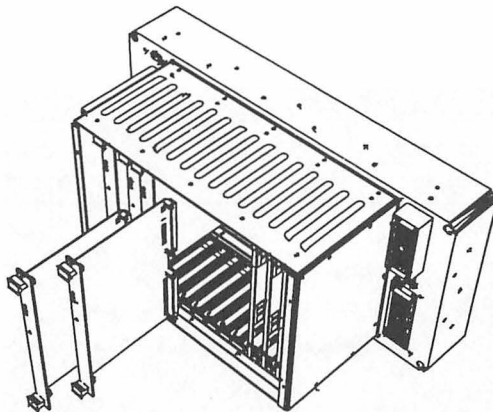
HVAC filter



ICON™ System



- Intuitive screen layout
- Improved reliability
- Extended backlight life
- Easier bulb replacement
- Integrated diagnostics



- VME standard backplane, LSI communications
- 14 slots for expandability
- Card level or software only integration
- Developer's kit available in 1998
- Reliability, simplification through integration



Locomotive Monitor and Diagnostics

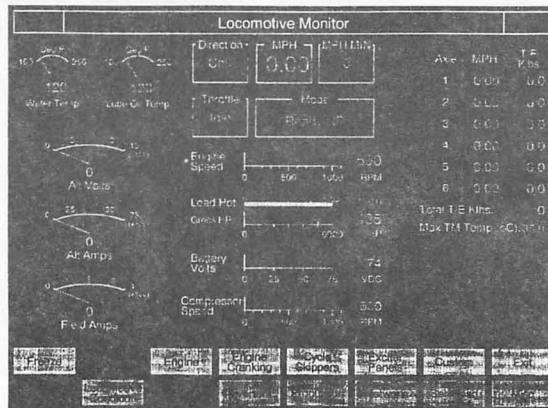
Locomotive monitor screens

- Locomotive general
- Engine
- Engine cranking
- Cycle skippers
- Inverter control
- Propulsion
- Excitation

Monitor screens are Level I accessible

Bayesian diagnostic system

- Analyzes locomotive incidents
- Prompts user to narrow diagnosis
- Generates prioritized list of root cases





Summary - AC6000 Commonality

	<u>Dash 9</u>	<u>AC4400</u>	<u>AC6000</u>	
Filters (fuel, oil, air)				
Fuel	X	X	X	
Oil	X	X	X	
Air Engine	X	X	X	
Electronics	X	X	X	
Air compressor	X	X	X	
HVAC system	X	X	X	} same filter
LSI blower			X	
Engine				
Fuel injector/pump	X	X		
Power assembly	X	X		
Turbo	X	X		
Truck		X	X	
Brake shoes	X	X	X	
Combo/Traction Motor		X	X	
Inverter		X	X	
DB blower	X	X	X	
Traction Motor Blower/motor	X	X		
Radiator	X	X		
Radiator fan	X	X	X	

X - common parts & access

III. REFINEMENTS IN MEASURING LOCOMOTIVE FUEL EFFICIENCY

by Robert S. Runyon, P.E. Norfolk
Southern Corporation

Introduction

The subject of locomotive fuel efficiency measurement was discussed in detail in 1991, in an excellent report from the Diesel Mechanical Maintenance Committee of the LMOA. The present report is intended to expand on the former to include refinements and related issues that have been revealed to the author through practical experience, and which are not often covered in a basic treatment of the subject. The fundamental methods will be reviewed to establish the necessary background for discussion, but in less detail and with most of the math omitted.

In this report the terms "main generator" and "main alternator" are used interchangeably to refer to the locomotive traction generator or alternator, without regard to which type machine is installed on a particular locomotive. Therefore, unless obvious from the context of discussion, no inference should be drawn from the term selected.

Selection of Method

There can be a variety of evaluations in which fuel efficiency is an important consideration, such as the following:

1. To compare the performance of two locomotives

2. To compare the performance with a previous test of the same locomotive, evaluating the effects of age and wear.

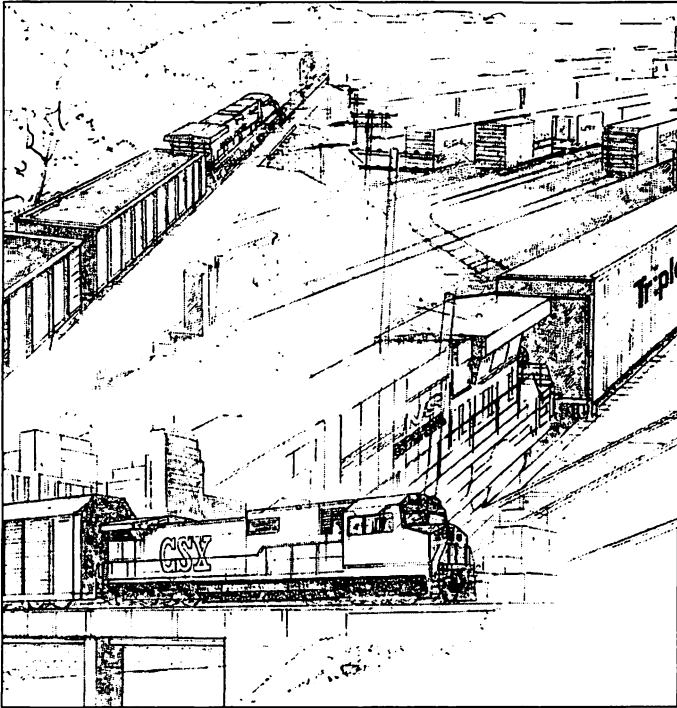
3. To compare the performance with OEM standards.

4. To evaluate alternate-source or modified engine components.

5. To evaluate the claims made of a fuel additive.

The procedures for measurement of locomotive fuel efficiency fall primarily into two broad categories: static, whereby the locomotive is connected to a stationary test installation, and over-the-road (OTR), in which all measurements are made while operating a train in typical service. The static test method lends itself to short runs of a few minutes each, permitting many of the test conditions to be controlled and the others to be measured and appropriate corrections applied. Further, more and better options for fuel measurement are available with stationary test equipment.

The OTR method by nature requires a test run to extend over the full length of a trip or a substantial part thereof, so those conditions that might vary slightly during a static test run will now be prone to much larger variations. Other parameters normally controlled in a static run, such as engine load and throttle position, will become variable subject to the requirements of handling the train. As no two train trips are exactly



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alike, even with the same train over the same track, any comparison between two OTR test runs is uncertain.

Proponents of the OTR method argue that a static test is misleading failing to account for the actual conditions encountered in typical service. This is correct when the purpose is to compare alternate trains, routes, or operating scenarios. However, when the topic of concern is engine performance, such variables that result from train handling are largely extraneous and irrelevant to the issues. At a given throttle position, all data method, and the relative weight to be assigned to each throttle position can be determined from the representative duty cycle.

Therefore, further discussion in this report will be confined to the static method. Specific illustrations will reflect the equipment and procedures in use at the Norfolk Southern test site in Roanoke, Virginia.

Fuel Measurement System

The energy content of a given batch of diesel fuel, and therefore its ability to produce useful work, is directly proportional to its weight. For this reason, direct measurement of fuel weight will lead to a more straightforward, and probably more accurate, test result. Because fuel density varies with temperature, volumetric measurements must be converted to weight values to obtain a useful

result, and the instruments available for such measurements are typically less accurate than a high-quality scale. Bubbles caused by aeration or cavitation can expand the fuel volume and lead to further errors. With the above facts in mind, fuel measurement by weight is generally accepted as the best approach for a static test.

The fuel test facility at Roanoke employs a digital platform scale supporting a cylindrical fuel barrel, the latter being fabricated of stainless steel to prevent corrosion. Referring to Figure 1, note that both the suction and return lines extend almost to the bottom of the barrel. The return line could have been left unsubmerged, as has been done in other installations, but this can cause aeration of the fuel and fluctuations in the scale readings due to agitation of the surface.

Note also that the ends of both lines are terminated with diverging elbows, so that the warmer return fuel will tend to diffuse upward through the barrel instead of being immediately swept back into the suction line. This helps to maintain a more constant temperature distribution throughout the barrel and permits any small bubbles to dissipate before recirculation. Also, any inertial forces resulting from the unequal fuel intake and return rates will be horizontal and have little or no effect on the measured weight.

A considerable amount of heat is added to the fuel while traversing the engine, so a heat exchanger is provided in the fuel return path to prevent a runaway temperature increase. Fuel temperature is not critical, but must be stable during each run. A substantial portion of the test loop, including the engine, heat exchanger, and various connecting hoses, contains fuel that will not be detected by scale weight. Being confined to a constant volume, this fuel will expand or shrink with temperature variations, thereby changing the amount of fuel that would otherwise be left in the barrel and leading to erroneous measurements.

The barrel must be replenished periodically from an external fuel supply, which can only be done during an interval between test runs. The engine continues to operate and consume fuel during this time, so the refill rate must exceed the consumption rate by a factor of two or more in order to fill the barrel within a reasonable length of time. For this reason two supply pumps are used in parallel as shown in Figure 1. Limit switches are provided near both the upper and lower ends of the barrel to automatically control the supply pumps, so the locomotive can be left unattended while idling. The refill lines are deliberately terminated at a point above the fuel surface to preclude any chance of siphoning. Each line is equipped with a pressure-relief check valve to prevent any continuing dribble of fuel after the pumps are stopped.

The General Electric engines lose a small fraction of the circulated fuel through leakage at the injector pumps, typically amounting to one or two percent of the fuel burned. In normal operation, this fuel is collected on each side of the engine in an injector leakage line (sometimes called a "candy cane" because of its shape) and then returned to the fuel tank by gravity. To avoid an unmeasured loss of fuel from the test loop, both leakage lines must be diverted at the engine and extended such that all leakage fuel will be returned to the barrel. As with the refill lines, these should be terminated above the fuel surface to prevent siphoning. Testing should not be started until fuel is seen to drip or flow steadily from both lines, indicating a steady-state condition.

It is important that both gravity return lines be supported throughout their length to minimize sag; otherwise none of the leakage fuel can reach the barrel until depressions in the line have been filled, at which time much of the accumulated fuel may be siphoned into the barrel in a few seconds, leading to irregular test results. Also, an air pocket may form behind the remaining fuel to block continuing flow from the on-board leakage lines, causing the latter to overflow and spill fuel at the engine.

All fuel lines at the scale are supported from an overhead structure with none permitted to contact the barrel. While this

arrangement prevents any random disturbance of the scale reading, a minor effect is introduced due to buoyancy of the submerged suction and return lines. This effect can be exactly determined and will cause the measured fuel consumption to exceed the actual consumption according to the ratio by which the barrel cross-sectional area exceeds that of the fuel surrounding the submerged lines. The error factor will remain constant at a given facility and is easily applied for compensation of the measured weight.

Horsepower Defined

Fuel efficiency of a locomotive is usually specified in terms of its inverse counterpart called specific fuel consumption (SFC), defined as the fuel consumption rate divided by useful horsepower produced. Values are typically quoted in pound per horsepower-hour. At this point, we should stop to consider exactly what is meant by "useful horsepower." As shown in Figure 2, horsepower can take on any of several interpretations depending on the point of definition.

1. Brake horsepower (BHP) is the power delivered by an engine at the end of the crankshaft, exclusive of power lost due to internal friction or used by internal engine accessories, and is the value considered as useful by an engine builder.

2. Traction horsepower (THP) is the mechanical power driving the main generator, consisting of brake horsepower minus the accessory horsepower (AHP). The latter is the power used by various accessory loads, such as the air compressor, fans and blowers, and the 74-volt auxiliary generator. Traction horsepower is the value commonly quoted as the horsepower rating of a locomotive.

3. Net traction horsepower, or simply net horsepower (NHP), is the electrical output of the main generator, consisting of traction horsepower reduced by generator losses. By custom, generator losses include the power used for generator field excitation, even when derived from an external source. Net horsepower is the only one that lends itself to convenient measurement.

4. Rail horsepower (RHP) is the mechanical power delivered at the wheel treads, and consists of the power remaining after subtraction of traction motor and gear losses. While this value is the one most significant to a railroad, it has no application in a static fuel test and will not be considered further in this discussion.

For each value of horsepower there is a corresponding value of SFC, obtained by dividing the fuel rate by the horsepower in question:

BSFC = Brake specific fuel consumption

TSFC = Traction specific fuel consumption

NSFC = Net specific fuel consumption

Conduct of the Test

The engine must be operated under load for a while prior to testing, longer if initially cold, to heat the oil to a stable temperature. Warm-up is most quickly accomplished in throttle-8, so a descending throttle sequence is convenient for testing. A typical test run at the higher throttle positions requires four to five minutes, limited by the need to maintain a constant accessory load without excessive drift in water temperature, and consumes up to 110 pounds of fuel with a 4,000 horsepower engine. Three or more runs in each throttle position are recommended to verify the consistency of measured data. Test runs in the lower throttle positions will require a longer time to use enough fuel for an accurate measurement. To maintain stable operating conditions, the engine must be left undisturbed between consecutive runs at the same throttle position. Therefore, the only event marking the start or end of a run is the recording of clock time and scale weight.

Net horsepower is determined by the volts and amps delivered to the load box, recorded at frequent intervals to capture any fluctuations in either value. Voltage should be measured at a point on board the locomotive, as several volts may be lost to cable resistance. For reasons that will be discussed, the ambient temperature, barometric pressure, and fuel inlet temperature should be recorded during each test run.

The rectified output voltage of a traction alternator consists of an average DC value with superimposed ripple, the amount of which will depend on the generated AC waveform. The ripple component transfers little or no power during normal operation, because the load current is kept largely free of ripple by inductance in the traction motor fields. However, with the resistive load used for static testing, the same ripple waveform will appear in the current, so the average power delivered will slightly exceed that obtained by multiplying the separately averaged volts and amps. The error has been observed to range from 0.1 to 0.3 percent. RMS-indicating meters can be used for direct error-free measurements, or the ripple can be determined separately for the alternator in question and used for adjustment of the average typically measured.

Performance Variations

It is generally known that a diesel engine performs with lower BSFC (higher fuel efficiency) when the combustion intake air is cooler and/or more dense. Consequently, it would be misleading to compare the performance of two engines, or one engine against a recognized standard, under widely different ambient conditions. Since testing must usually be done under prevailing ambient conditions, locomotive manufacturers have provided a chart or formula for each engine model showing the variation of BSFC with air temperature and barometric pressure, by which the observed performance at test site conditions can be "corrected" or adjusted to predict a value for any reasonable set of ambient conditions. Engine BSFC is further dependent on fuel quality, more specifically its heating value, commonly expressed in BTU per pound.

The Association of American Railroads (AAR) has established a set of standard conditions for engine testing, specifying values for those given above and others that might affect the test results:

- 60° F ambient temperature
- 28.86" Hg barometric pressure (1000 ft. altitude)
- 60° F fuel inlet temperature
- 19,350 BTU/lb fuel heating value
- 0.845 fuel specific gravity at 60° F
- 40 MPH track speed

The first three items given above are measured during each test run. As illustrated in Figure 3, each of the two site ambient conditions (air temperature and barometric pressure) is applied to the builder-specified engine characteristics to develop a correction factor for BSFC adjustment. Fuel heating value and specific gravity are both measured in a laboratory environment using specialized instruments, requiring that one or more samples of the test fuel be set aside for this purpose. The correction factor for heating value is simply its measured value divided by the AAR standard. Both specific gravity and fuel inlet temperature are needed to derive a correction factor for fuel density, which does not directly apply to BSFC but can be needed for other refinements.

It might appear strange to specify track speed for a test that is best performed while stationary. This derives from the fact that one parameter necessary to the calculation of brake horsepower from measured data is main generator (or alternator) efficiency, which can vary considerably with load impedance. The specified value of track speed implicitly specifies the generator load impedance for a particular locomotive type. If the test is conducted with a load box resistance equal to the 40 mph value, the same main generator efficiency will apply to both site and AAR standard conditions.

For a six-axle, 4,000 horsepower DC locomotive in throttle-8, load impedance at 40 mps is about 1/3 ohm with EMD and 1/4 ohm with GE locomotives. These values will be noticeably higher on locomotives with four axles and those rated at lower horsepower.

Generic Correction Process

Figure 4 shows a generic flowchart of the process for correcting the site test results to AAR standard conditions. The chart is arranged in two roughly equal parts representing the site and corrected test data. As discussed earlier, site measurements include fuel weight and elapsed time for calculation of fuel rate, and generator volts and amps for calculation of net horsepower (NHP). One must remember that the engine and fuel quality correction factors are defined only for correcting brake horsepower (BHP). To obtain the latter, site NHP is first divided by main generator efficiency (obtained from the locomotive builder for each throttle position) to determine the site THP, to which is added the site accessory horsepower (AHP) to obtain the site BHP. AHP has been defined; methods for calculation will be presented in the next section.

The dashed lines extending from the site fuel rate and BHP to their corrected counterparts represent the process of correction to AAR standard conditions. The individual correction factors for ambient conditions and fuel

quality, although defined only as adjustments for BSFC, are separately applied to the fuel rate or BHP depending on the prevailing method of power control on the locomotive. Fuel rate and BHP are corrected individually because, if the BSFC should deviate from expected results, it might be useful to know how much deviation is attributable to each parameter. Examples for specific situations will be given later.

Once the corrected BHP is determined, the corrected AHP (generally different from site AHP) is subtracted to obtain the corrected THP, which is then multiplied by generator efficiency to obtain corrected NHP. As stated previously, the corrected fuel rate can be divided by each corrected horsepower value to determine the corresponding value of specific fuel consumption.

Accessory Horsepower

Locomotive accessories are usually rotating machines, either driven directly by the engine or by an induction motor which receives power from a companion alternator. In either case, accessory speeds are proportional to the engine RPM. Except for the 74-volt auxiliary generator, accessory machines are intended to deliver air and thus impose a load on the engine proportional to air density. Fan and blower loads are also proportional to the cube of their respective speeds and therefore to the cube of engine speed. The

reciprocating air compressor is a prominent exception to the cube law, having an internal friction load proportional to speed, plus the occasional pumping load component which is proportional to both speed and air density. However, its intermittent load makes the air compressor an unnecessary nuisance if used during the test, so it is typically cut out and an external source of compressed air used if needed.

Many accessories can exhibit more than one operational status, being arranged as multiple similar units separately controlled, or perhaps operable at more than one power level with a given engine speed. In the context of this work it is convenient to think of such multiple units as a single accessory with additional status modes. The "off" status is the lowest available, and applies only to accessories that can be switched off completely (zero horsepower).

On a locomotive having all motor-driven accessories, a three phase wattmeter can be used to measure their combined horsepower at site conditions, in which case the companion alternator efficiency must be known to determine the equivalent mechanical load presented to the engine. The alternative method, usable to all locomotives, is to record the status of each accessory device during each test run for subsequent calculation of its horsepower. With this method it is

important that no accessory change status during the run unless steps are taken to measure the time spent in each status mode.

Figure 5 shows the process for calculating site accessory horsepower (AHP) from the recorded status. Locomotive builders typically make available a reference horsepower for each accessory at every status thereof, valid at the air density corresponding to the AAR standard conditions and an arbitrary base speed (often the throttle-8 speed), and adjusted for motor-driven machines to the equivalent mechanical load on the engine. The appropriate value for each accessory load is selected according to its operation status and adjusted by two correction factors: one for site air density obtained from measured ambient conditions, and the other being the ratio of measured engine speed to the arbitrary base speed, cubed when being applied to fans or blowers. Auxiliary generator current output can be measured and the corresponding horsepower calculated or, as is often done, its nominal minimum value can be stipulated with reasonable accuracy if all heavy 74-volt appliances are turned off during the test. Once determined, the individual AHP values are added to obtain the total site AHP.

Figure 6 illustrates the process used to calculate corrected AHP, which is similar in concept to the process described above, and uses

the same set of reference horsepower values. However, the status to be assigned for each accessory load must be that typical of normal operation at AAR standard conditions. This information must also be acquired from the locomotive builder and for some accessories will change with the throttle position. By definition, the air density correction factor at standard conditions is unity and thus will have no effect on the calculation. The engine speed correction factor is calculated from the specified RPM for the throttle position instead of measured RPM, implying that standard conditions would stipulate a correctly adjusted engine governor. The corrected horsepower load for the auxiliary generator is assumed to be its nominal minimum.

For accessories that frequently change status during operation, such as the radiator fan(s), the effective status at standard conditions must often be represented as a hybrid of two consecutive modes. The proper reference horsepower for such a "fractional" status will be a weighted average determined by the time spent in each mode, and can be found by interpolation.

Specific Examples

Having already examined the engine correction process in general terms, a few specific examples will now be presented. As mentioned earlier, these will differ somewhat as needed to properly represent the method used by the locomotive for power control.

The typical modern GE locomotive is designed to maintain a constant brake horsepower at each powered throttle position, adjusting the fuel rate as needed to accommodate variations in engine performance. This process is shown in Figure 7, wherein the full effect of the ambient and fuel quality correction factors is applied to the fuel rate, and the corrected BHP remains unchanged from its value at site conditions. The process is otherwise identical with the previously described generic process.

Another method used for power control seeks to maintain a constant electrical output, or net horsepower. This method is typical of EMD locomotives with DC traction. By design, therefore, corrected NHP is equal to site NHP as represented in Figure 8. This will also be true for traction horsepower, if the main generator efficiency can be presumed equal at both site and standard conditions. However, as the site and corrected accessory loads will not generally be equal, corrected BHP must be obtained by adding the corrected THP and AHP, the generic process in this case being applied in reverse. Thus the site and corrected BHP will in general be unequal.

With this arrangement the locomotive is obligated to adjust fuel rate not only for engine performance variations, but also to accommodate the change in brake horsepower needed to

compensate for unequal site and corrected accessory loads. To account for this effect, one must compute the ratio of corrected to site BHP, and apply the result to the site fuel rate along with the other correction factors to obtain the corrected fuel rate.

In the non-powered throttle positions, the electrical output will be directly controlled in dynamic braking, or zero in idle. Therefore, the correction process for these positions is very similar to the constant-NHP process described above, with one important difference. In using the correction factors, we have tacitly assumed that brake horsepower and fuel rate are exactly proportional if other factors remain undisturbed. As illustrated in Figure 9, this is essentially correct only at high levels of power. At the low end, the linear relationship is revealed to be offset by a measurable fuel rate at zero BHP. This represents the fuel burned to overcome friction and other loads internal to the engine, and increases with engine speed as expected. Therefore, after correction for engine performance, the fuel rate must be further adjusted by adding or subtracting a value determined from the BHP change and the slope of the corrected linear relationship, to determine the fully corrected fuel rate.

Many older locomotives regulate their power output by a procedure commonly known as "load control," whereby the engine

governor can adjust the electrical load to maintain a constant fuel rack setting, and therefore a constant volumetric fuel rate. Figure 10 shows the correction process to be used with this arrangement. Site fuel rate measurements, which are based on weight, must therefore be adjusted by the fuel density correction factor to reflect the amount burned at standard conditions. This correction factor must also be applied to the brake horsepower, which will change in proportion to the fuel rate, so the BSFC will not falsely appear to depend on fuel density. Correction for ambient conditions and fuel quality is accomplished with the same correction factors used with other control methods, but these are applied inversely to the brake horsepower instead of fuel rate.

Dynamic Braking Issues

A small but measurable amount of electrical horsepower is generated in dynamic braking for traction motor field excitation, which raises the occasionally debated issue of whether to consider this power as a parasitic loss or useful work. The former choice can be supported by the following arguments:

1. The useful work produced in dynamic braking, if any, would be that dissipated in the brake grids.
2. Motor field input can vary widely with a given grid input, depending on several variables.

3. Lacking any standard value, zero field input should be used for evaluation.

Conversely, an equal number of arguments can be presented in favor of including traction motor field excitation as useful work:

1. Motor field input should be considered useful work, being necessary for a useful result.
2. Motor field input depends on train operation, unlike fixed or automatically controlled accessory loads.
3. Lacking any standard value, maximum available field input should be used for evaluation.

The above issue is primarily philosophical and is not likely to be resolved soon in favor of either viewpoint. Adding to the question is the fact that motor field excitation depends on many variables associated with train handling, and little is known from which to determine a representative value for test purposes.

Conclusion

The specific fuel consumption obtained by the foregoing methods can be used to make comparisons or evaluations at a specific throttle position, or the corrected fuel rate can be used for the non-powered positions in which BSFC is almost meaningless and the other two SFC values are infinite. Alternatively, the corrected horsepower values and fuel rates can be weighted by the fraction of

time spent in each throttle position, if known, and individually totaled to obtain an overall SFC for a particular duty cycle. The latter SFC would, of course, need to include any operation at idle and dynamic braking.

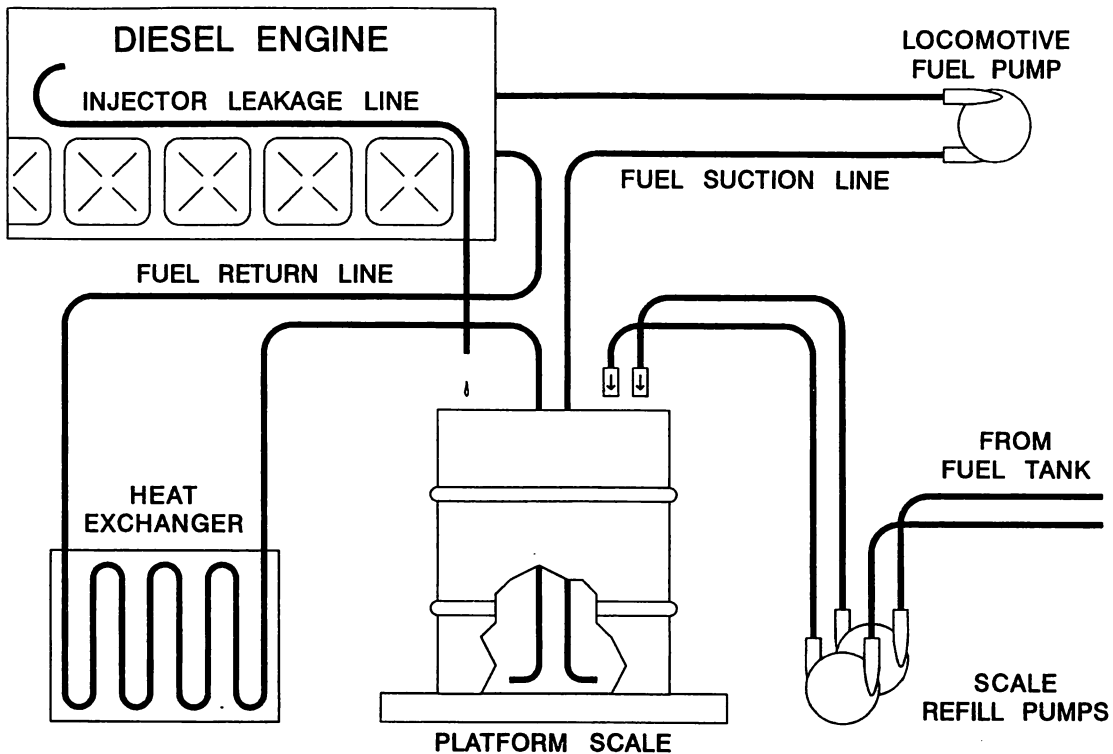


Figure 1. Diagram of Fuel System Test Loop

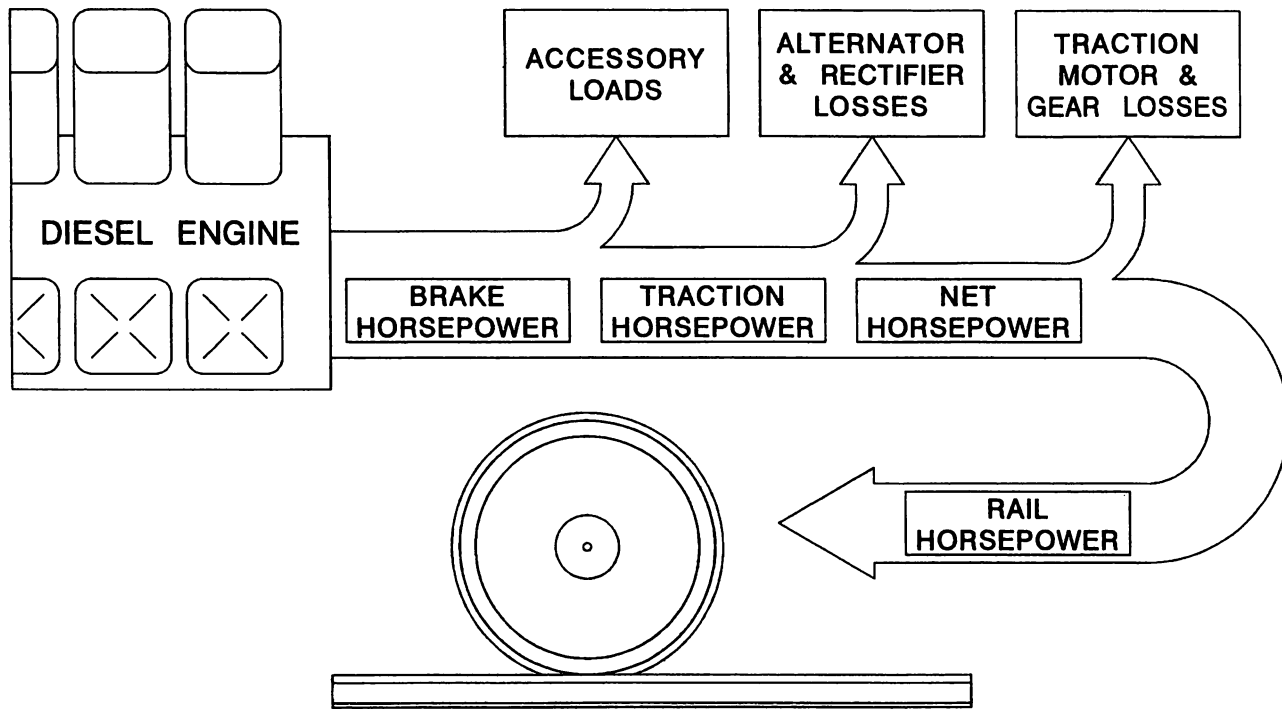


Figure 2. Horsepower Identified at Various Points

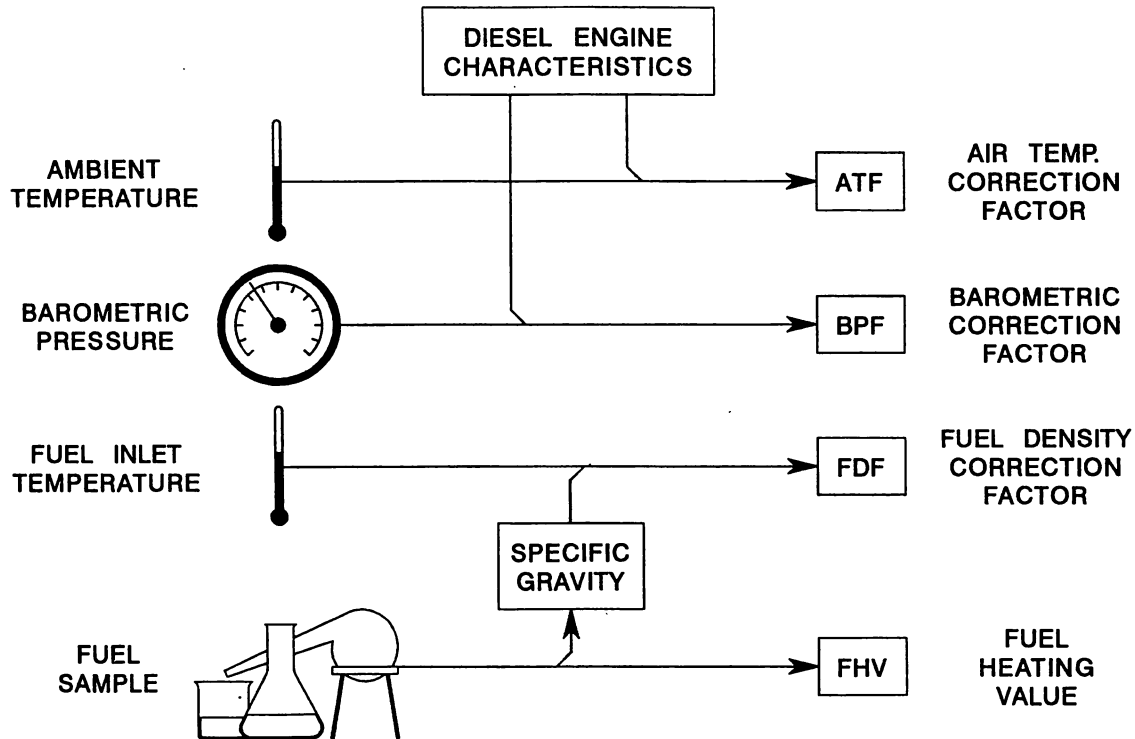


Figure 3. Engine and Fuel Quality Correction Factors

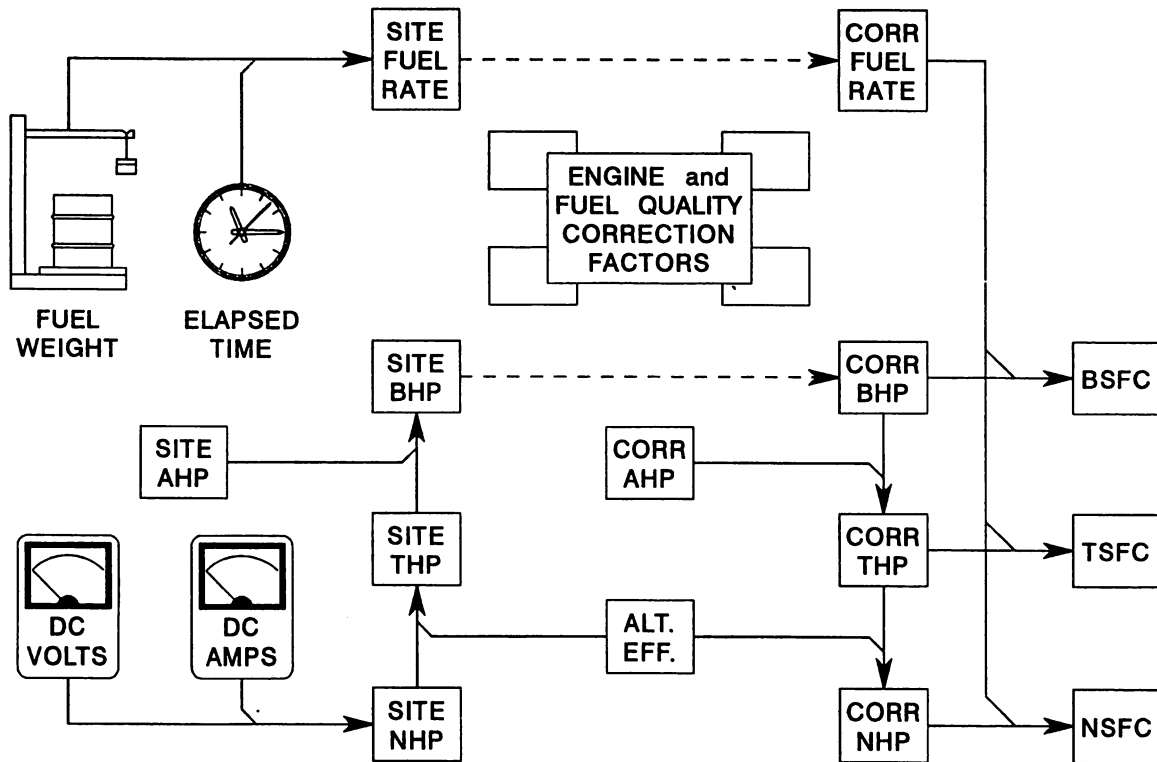


Figure 4. Flowchart for Generic Correction Process

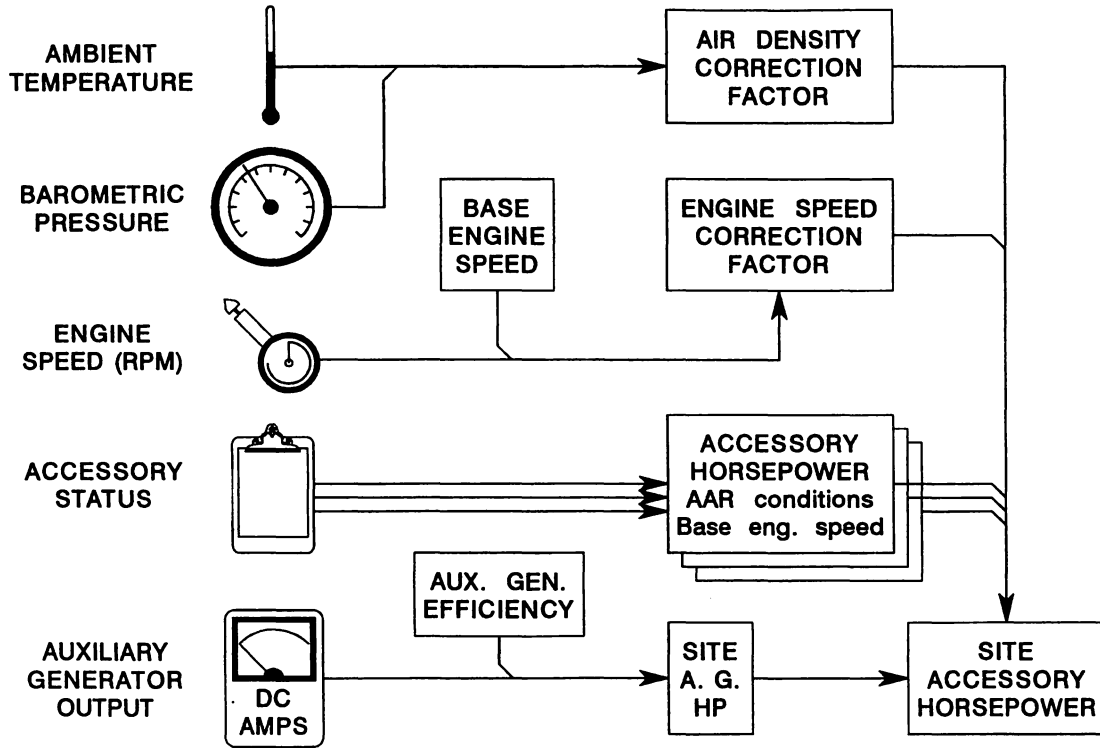


Figure 5. Determination of Site Accessory Horsepower

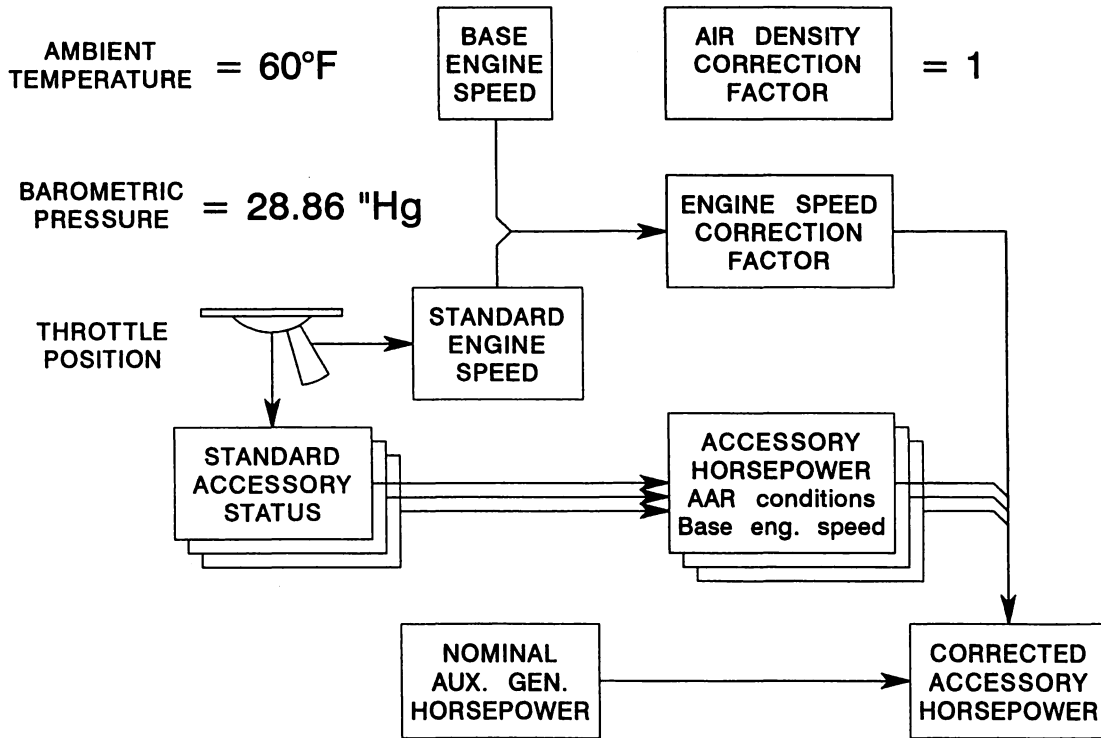


Figure 6. Determination of Corrected Accessory Horsepower

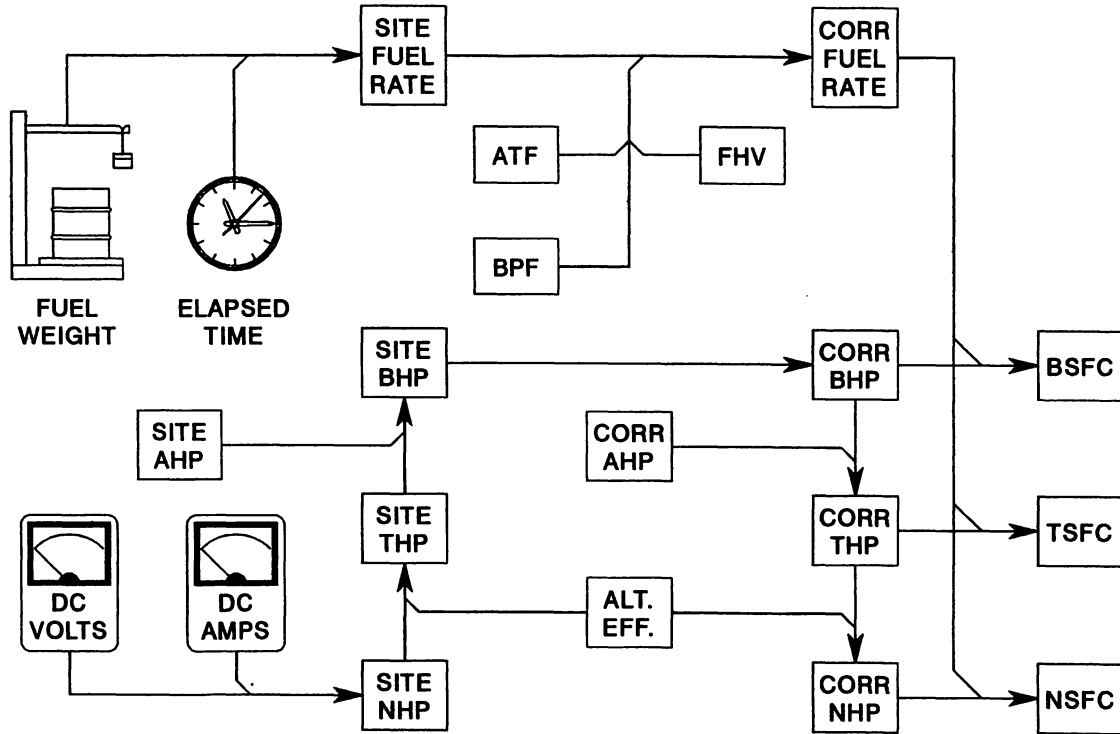


Figure 7. Flowchart for Constant-BHP Correction Process

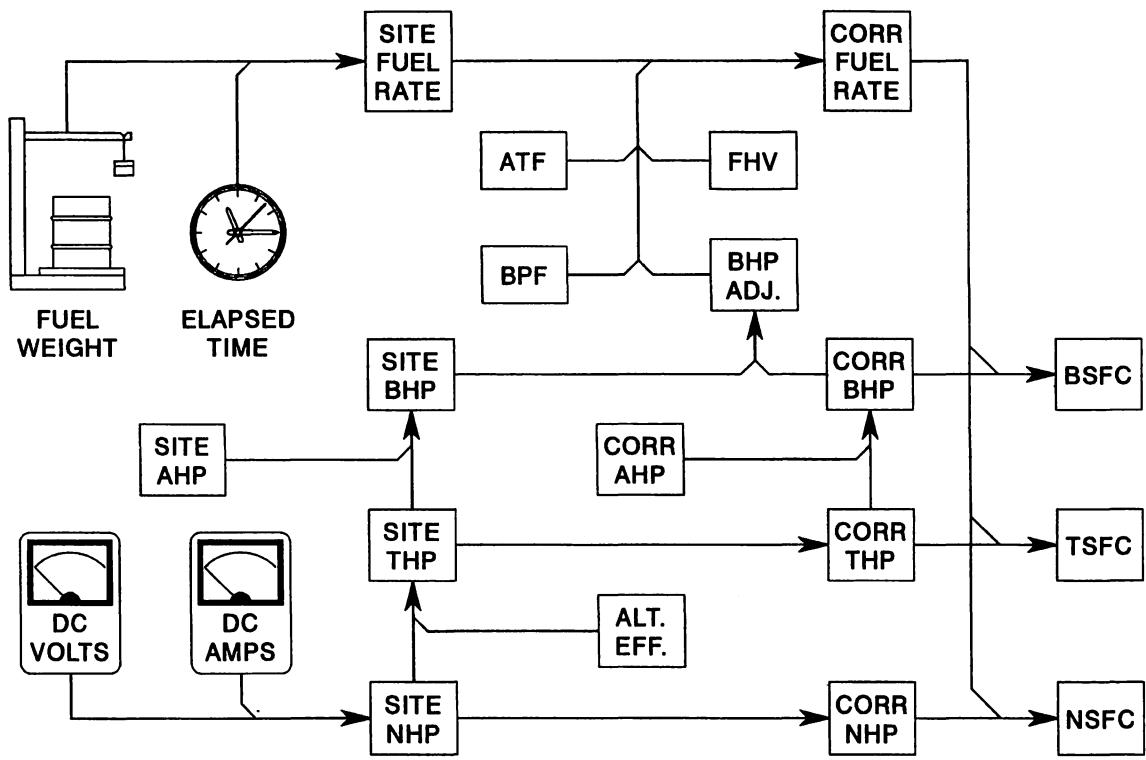


Figure 8. Flowchart for Constant-NHP Correction Process

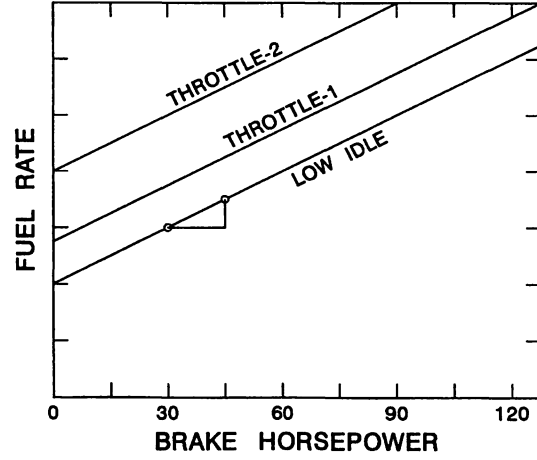
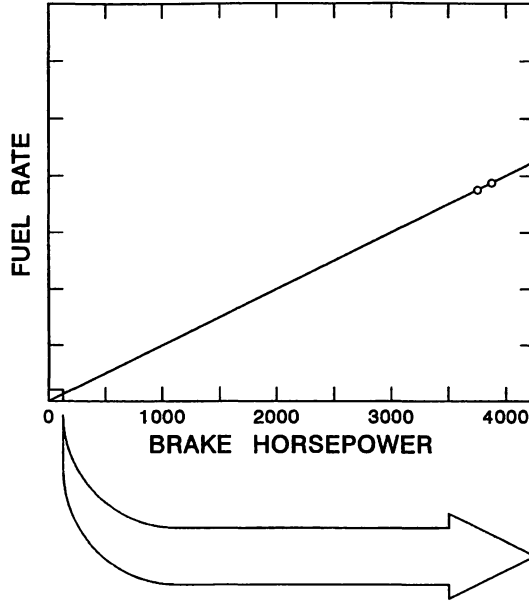


Figure 9. Fuel Rate as Affected by Brake Horsepower

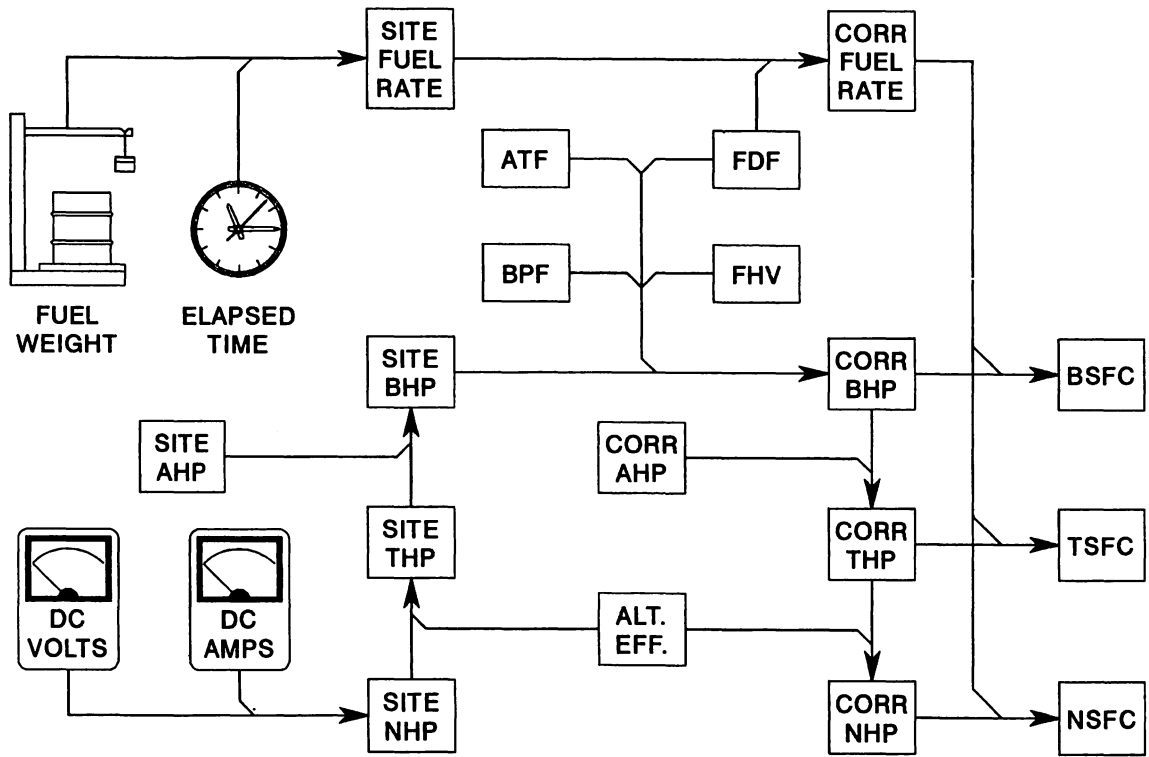


Figure 10. Flowchart for Load Control Correction Process

**REPORT OF THE COMMITTEE
ON DIESEL ELECTRICAL MAINTENANCE**

**TUESDAY, SEPTEMBER 22, 1998
9:00 A.M.**

Chairman
LES WHITE
Electrical Specialist
CN Rwy.
Montreal, PQ
Canada

Vice Chairman
J. YOUNGWIRTH
Supvr. Tech. Service
Electro-Motive
La Grange, IL

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C. Wilkerson	Asst. Mgr. Mech-Maint.	Norfolk Southern	Roanoke, VA

*formerly of Amtrak

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 the Electrical Specialist for the system.

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.

I. LOCOMOTIVE TROUBLESHOOTING ASSISTANT

by Sam Anoo - Union Pacific

The locomotive troubleshooting assistant (LTA) is Union Pacific's strategic initiative to deal with new technology. Under developed and rapidly changing new technology, under-qualified mechanics, high costs required to develop training infrastructure and a vision to move towards predictive technology have resulted in UPRR taking on the challenge of developing an expert system.

LTA is a hybrid case based reasoning and rule based reasoning expert system developed at UP. The system helps novice electricians troubleshoot GE Dash-8/9 and AC4400 locomotive electro-mechanical problems. LTA's case base contains over 400 diagnostic cases for GE locomotives with more cases currently under development, including new cases for EMD's SD60 and SD90 locomotives.

Dialogue-style interface

LTA is a very intuitive dialogue-style interface. Depending on the problem symptoms at hand, the system retrieves relevant cases from its case base of previous solutions and asks the user to answer a few optional questions or to conduct some tests. Based on the user's response, the system recommends appropriate corrective actions. LTA's case-base, compared to rule based and belief

network approaches for this type of problem, is easier to maintain and support.

What is an expert system?

Expert systems (or knowledge-based systems) have been the most successful applications of artificial intelligence during the past two decades. Many Fortune 500 companies are using expert system technologies in their business processes and many have embedded them in their products. Expert system technologies have been used to enable corporations to permanently capture employees' accumulated experience and know-how in knowledge bases as a corporate intellectual asset as well as to provide solutions to complex problems like diagnosis, scheduling, planning and design. These problems are often beyond the realm of conventional algorithmic problem solving, operations research techniques, and procedural programming methods.

How does it work?

Every expert system has a knowledge base and an inference engine module. Depending on the type of expert system, the inference engine applies symbolic pattern matching, logical deduction, statistical induction, probabilistic reasoning, fuzzy logic, etc. to a problem description using its knowledge base. Small chunks of knowledge can be added, deleted and modified without any changes to the inference engine module. The three most successful

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expert system technologies used in the diagnostic domain are rule-based, case-based and belief network expert systems.

In rule-based reasoning (RBR) systems, knowledge is represented in "if-then" types of rules and the inference engine features include symbolic pattern matching, forward and backward chaining. In case-based reasoning (CBR) systems, knowledge is represented in cases and the inference engine applies symbolic pattern matching, fuzzy numerical matching, nearest neighbor similarity matching, and decision tree induction. A diagnostic case describes a problem in terms of symptoms and test combined with a corrective action. Finally, in belief network systems, also known as Bayesian belief networks (BBN) or casual probabilistic networks, knowledge is represented in probabilistic nodes and arcs and the inference engine applies Bayesian conditional probability or Bayes rule. BBN is a specialized influence diagram, which comes from decision analysis - it is a generalization of a decision tree into a decision network.

What are the builders doing?

General Electric has embedded BBN in its new AC6000 locomotive diagnostics - an expert system. The system identifies the most probable cause of locomotive failure and recommends an appropriate corrective action. BBN requires accurate prior failure mode data

and needs frequent updating of the probabilistic network. The other major locomotive builder, Electro-Motive Division, because of competitive reasons, has named its locomotive fault help system, which is a standard procedural hypertext system, EMD Expert. EMD Expert is not an expert system.

What does the LTA do?

The LTA accomplishes the following tasks:

- GE Download & Upload
- Access to Latest EMD Expert & GE Help Text
- Expert & Quick Fixes for -8, -9 & C44AC Faults
- GE Fault Time in Conventional Time
- Summary Analysis of fault log
- Fault restrictions for individual faults
- History & Record of Locomotive Fix and Device Use
- System-wide access to download data

Which units can be diagnosed using the LTA?

- All UP/SP/CNW C44ACs - 761 units
- All UP SD9043ACs - 274 units
- All UP/SP/CNW DASH 9s - 270 units
- All UP/SP/CNW DASH 8s - 345 units

A total of **1650 HHP Units** could be diagnosed using LTA

**What is the future
for expert system?**

It is imperative that all railroads come together in developing a common expert system that could be shared. Maintenance expertise is our business and we should make all efforts to improve it and keep it ours.

Fault: GE Help: QF: Description:		Occur:	Reset:	Loco Speed:	Notch:	Eng Speed:
7419-02	Run	PMSB+ OR PMSB- OR INC3-3.4.7 BAD	98279.75	98279.75	0.0	1
C6D5	Run	Fault Reset While In Level 1	98278.83	98279.43	0.0	1
C6D5	Yes	Load Limited: Load Pot < 80%	98265.30	98270.00	40.0	8
C6D5	Yes	Load Limited: Load Pot < 80%	98106.58	98107.45	10.1	8
C6D5	Yes	Load Limited: Load Pot < 80%	98103.38	98109.71	30.4	8
C6D5	Yes	Load Limited: Load Pot < 80%	98100.63	98101.76	24.6	8
C6D5	Yes	Load Limited: Load Pot < 80%	98097.38	98097.43	24.6	8
C6D5	Yes	Load Limited: Load Pot < 80%	98094.13	98095.62	44.3	8
C6D5	Yes	Load Limited: Load Pot < 80%	98093.16	98093.21	16.1	8
C6D5	Yes	Fault Reset While In Level 1	98087.63	98113.40	24.2	8
C6D5	Yes	Load Limited: Load Pot < 80%	98085.58	98087.63	27.6	4
C6D4	Yes	T/L 8 And 9 Changed While Loaded	97367.61	97378.55	41.0	8
7148-00		T/L 8 And 9 Changed While Loaded	97367.61	97367.61	0.0	1
7148-08		TGSS FAILED	96606.28	96606.21	0.0	1
		TGSS FAILED	96606.83	96606.05	47.6	4
					46.5	4

Summary	History	Details	Print
New Alerts	Alerts	Alerts	Alerts
Selected Log	View Log	Alerts	Alerts

CarePoint - [Search - AC4400 CID]

Description:
CASD Load Limited: Load Pot < 80%

Questions:

Question	Answer [Yes/No]
<input type="checkbox"/> Is the fuel pressure at idle less than 55 psi?	Not Answered
<input type="checkbox"/> Does fuel pressure drop to less than 30 psi in notch 8 load?	Not Answered
<input type="checkbox"/> Does the engine speed respond to throttle command?	Not Answered
<input type="checkbox"/> Do any cylinders not fire during the pop test?	Not Answered
<input type="checkbox"/> Is there voltage at the solenoid of the pump not firing?	Not Answered
<input type="checkbox"/> Please select a fault code for Quick Fix troubleshooting help.	CASD Load Limited: L

Actions:

- 68 Replace the fuel regulator carbide...
- 47 Replace the fuel filter.
- 40 Repair wiring or send to the shop to troubleshoot EFI system...
- 35 Repair Solenoid wiring...
- 36 Check the pump cross head if OK, then replace the pump...

CasePort - (Search - A&K 400 CGO)	Answers (Yes/No)
<p>File Edit Search Query Window Help</p> <p>Description:</p> <p>CASD Load Limited Load Pot < 88%</p>	<p>Not Answered</p> <p>Not Answered</p> <p>Not Answered</p> <p>Not Answered</p> <p>Yes</p> <p>CASD Load Limited: L</p>
<p>Question:</p> <p>Does fuel pressure drop to less than 30 psi in notch B load?...</p> <p>Does the engine speed respond to throttle command?...</p> <p>Do any cylinders not fire during the pop test?...</p> <p>Is there voltage at the solenoid of the pump not firing?...</p> <p>Is the fuel pressure at idle less than 55 psi?...</p> <p>Please select a fuel code for Quick Fix troubleshooting help.</p>	
<p>Elements</p> <p>100 <input type="checkbox"/> Replace the fuel regulator cartridge .</p> <p>41 <input type="checkbox"/> Replace the fuel filter.</p> <p>36 <input type="checkbox"/> Repair wiring or send to the shop to troubleshoot EFI system...</p> <p>33 <input type="checkbox"/> Repair Solenoid wiring...</p> <p>33 <input type="checkbox"/> Check the pump cross head if OK, then replace the pump...</p> <p>30 <input type="checkbox"/></p> <p>30 <input type="checkbox"/></p> <p>30 <input type="checkbox"/></p>	
<p>Back</p>	

II. LOCOMOTIVE ELECTRONIC BRAKE MAINTENANCE

*by Robert J. Reynolds
Canadian Pacific Railroad*

The freight locomotive electronic air brake system is fairly new in the railroad industry. This equipment is manufactured by Westinghouse Air Brake Company (Wabco) and Knorr Brake (New York Air Brake). Both companies began working on their replacement for the old standard 26L pneumatic brake system several years ago. Harris Controls, now known as GE-Harris Railway Electronics, developed an electronic brake sub-system for its Locomotrol II system as early as 1983. Various forms of electronic brake control have been in use for rapid transit applications for decades, but we will focus this paper on freight locomotive equipment.

The Wabco equipment began as the EPIC model 3101 and we tested this equipment on CPR. It was replaced by a more advanced system known as EPIC 3102, of which there are over a thousand units in operation. Wabco has since developed what they call EPIC II to further improve their design by reducing the number of parts in the electronic control system.

The first Knorr Brake equipment is known as the CCB or computer controlled brake. Again there are over one thousand units equipped and we tested one unit on CPR.

Knorr also developed a new model based on the CCB and it is called CCB II. The CCB II has a new pneumatic portion with reduced number of components. GE-Harris and Knorr Brake worked together on the electronic control box that is about a quarter of the size of the one on the original CCB. The control has become a field replaceable unit. The electronic box has capability to add Locomotrol distributed power if that option is required.

This further reduces the need for added function boxes, interconnections, etc. CP will be taking delivery of 81 locomotives complete with distributed power option this year. This distributed power is a new development that has integrated the man-machine function into the locomotive control display screens. We will be performing extensive tests on this equipment as we have done in the past for new distributed power equipment. Tests will include operation of the equipment on the 150 cars brake rack as well as in train system tests.

The locomotive electronic air brake system was designed to be fully compatible with 26L pneumatic brake equipment. A locomotive equipped with electronic controls can either lead or trail 26L equipped units and vice versa.

I have made a comparison of the two systems. The following are the improvements and added features of locomotive electronic brake compared with 26L equipment.

- a. It is a standard product - certain options that differ from standard can be programmed in by software without adding hardware.
- b. The system performs self-diagnostics. The equipment can predict when a fault will occur and flag this information for attention of maintenance personnel before the failure occurs.
- c. It has non operator adjustable independent brake setting.
- d. The system prevents the operator from changing the automatic brake set-up while the locomotive is moving.
- e. The equalizing reservoir pressure is maintained against any leakage.
- f. It has easy replacement of pneumatic modules in minimum time.
- g. It is fully integrated with locomotive builder's on board information display screens.
- h. It performs the air brake control of distributed power without added air brake hardware.
- i. It has future capability of controlling an electronically controlled pneumatic brake operated train. ECP use is gradually expanding and so it

makes sense to have the locomotive brake equipment also control ECP format. Our ECP train will use a separate ECP control console until this integration is performed.

The electronic brake system makes initial installation by the locomotive builders much easier and faster. The equipment typically consists of the following major components:

- a. A pneumatic equipment rack consisting of several main control valves. This looks similar to a 26-LUM rack. The main control valves or portions are:
 - brake pipe control
 - independent brake control
 - brake cylinder control
 - dynamic brake bail-off
 - electronic air pressure transducers
 - air pressure switches
 - other devices such as reducing valves, check valves and reservoirs.
- b. A main electronics enclosure that contains the micro-processor, electrical interfacing components and a power supply. The microcomputer has a fault logger. The logger stores any equipment faults complete with time and date in battery backed memory.
- c. An interface enclosure to connect the system to the locomotive electrical system. In newer locomotives this

interface passes air pressures to the locomotive display screen system. This form of information display eliminates the old pneumatic air gauges. The interface also commands a power knock-down for emergency and penalty brake applications; it inputs the status of train overspeed, cab signal and crew alert status.

- d. The brake controller unit handles for the automatic brake and the independent brake. The positions and actions are the same as on the 26C brake valve. Recently Knorr added a readout on its controller for equalizing reservoir pressure. This was added to overcome a lag time for displaying air pressures on the locomotive integrated display screen.

The amount of pneumatic piping of the system is greatly reduced compared to 26L. Most of the piping is replaced instead by electronic control logic. The only pipe connections to the system are main reservoir, brake pipe, brake cylinder and independent control lines. The various major components are connected together by cables. But even the amount of cabling is reducing as these systems evolve.

The locomotive electronic brake system is just about standard on new locomotives. There are a few thousand in service. We have about 200 such locomotives operating for as long as three years

on Canadian Pacific. Reliability has been very good. We operate through severe winter conditions where airline freeze-ups can occur.

All of our electronic brake equipped units plus many of our 26L units have air dryer systems. We have not had any problem of freeze-up in the pneumatic portion of the electronic brake system. Compressor freeze-ups on newer locomotives have been a problem, but not in the brake system which is piped after the air dryer.

As with any equipment, it must be properly maintained to ensure safe and reliable service. The maintenance of this equipment involves both preventive and corrective maintenance. The basic maintenance philosophy is to fault-isolate the problem component to the lowest replaceable level. The replaceable level is for major components such as a brake pipe pneumatic portion or electronic control box. This is becoming a common approach for most railroads and is particularly suitable for such complex equipment.

Preventive maintenance must be done to keep the equipment operating safely and reliably. Preventive maintenance work includes inspection, servicing, and scheduled maintenance. If a component is removed and replaced the complete system must be tested to ensure proper operation.

The following is a list of scheduled maintenance activities for this equipment:

- a. 30 days: Perform a standing emergency brake test. The test is performed first with the automatic brake valve handle and later with the conductor's emergency brake valve. Each resulting emergency must occur immediately and cause a power knockdown.
- b. Periodic: Once every 90 days it is required to perform tests on the air pressure gauges or display screen pressure readouts.
- c. Annually: Replace filters used on the main reservoir and independent control lines. Lubricate the mechanical fittings in the controller. Inspect the cables connecting the various components, making sure there is no chafing or rubbing on locomotive structures or supports. Inspect terminal boards for secure connections. Then perform a standing functional test including emergency brake test.
- d. 5 years: Perform a COT&S - that is the industry mnemonic for cleaning, oiling, and testing. This includes replacement for all pneumatic portions with factory qualified components. Perform the same work as specified on the annual schedule. The FRA has permitted the five year period for this equipment because it is continuously self-

diagnosing itself. Transport Canada has granted the same interval in Canada.

- e. Ten years: Remove and replace the circuit card that houses the memory battery. This battery is used to retain fault memory whenever the locomotive is shut down.

The philosophy to change out major modules is not applicable with certain earlier systems. On those systems, technicians need to directly troubleshoot and replace electronic circuit boards. One area of concern is the problem of static electricity. The old pneumatic air brake system did not have this problem. The solid state electronics contained in the system such as microprocessor and memory chips can be damaged by static. So care must be followed to protect against this. Employees working directly on the electronic modules must be properly trained and use anti-static devices such as wrist-straps. Anti-static packaging must be used for shipping defective components. Another detail that will prevent damage is to ensure that power is turned off whenever replacing components. This includes cable connections and pneumatic portions that have an electrical connection.

Routine locomotive inspections can be made without any special precautions to the brake system as long as covers are not removed.

High potential testing of the locomotive high voltage system does require special instructions to prevent damage. During hi-pot testing all system cable connections must be disconnected.

Another tool that is used for troubleshooting most electronic equipment today is the laptop PC computer. The PC is connected to the equipment test port, special software is operated and the laptop displays a menu of functions. The repair person can see if there are any current faults, download a history of past faults or view present status in real time. Fault history is a very valuable source of information. Everyone has been faced with a reported road defect that does not exist when the locomotive reaches the repair facility. By having the equipment fault history, such intermittent faults can be traced and corrected. The PC can also monitor various parameters while the equipment is operated. The manual that comes with the system shows in very good detail the action the repair person is to take to either make an adjustment or replace a component. It also gives detail on how to perform a test on the system. The test software is also evolving. I can remember earlier versions that did not have the capability to print out instructions or test results.

In conclusion, the locomotive

electronic air brake system has done a very good job of replacing the old standard pneumatic brake system. It was designed to be more dependable and can be serviced and maintained with less time and effort and at lower cost than previous systems. The future unfolding of ECP brakes and train control systems will utilize the available capacity and capability of electronic brake systems.

Model LM-1 The Locomotive Marker Light

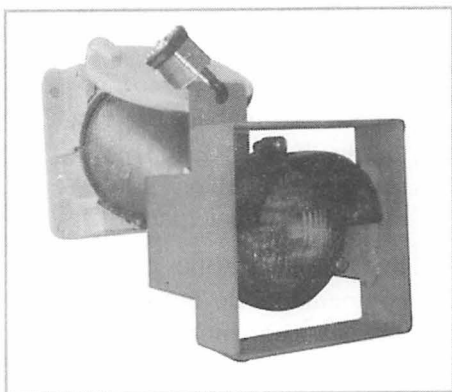
**FRA APPROVED
RED FLASHING LIGHT**

**PLUGS INTO THE
MU RECEPTACLE AND
BEGINS FLASHING
IMMEDIATELY!**

**POWERED BY THE
LOCOMOTIVE'S BATTERIES**

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

USED AT THE REAR OF THE TRAIN:



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

ADVANTAGES

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

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

SPECIFICATIONS:

Light:	High Impact Lexan Housing with Red Lens & Visor. Steel "Surround" Guard.
Bulb:	GE #1141, 18 W 5000 hrs. at 15% duty cycle; 100 candela.
Weight:	10 lbs.
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III. SD70MAC CAPACITOR DISCHARGE PROCEDURE

by Mike Barr - BNSF

The introduction of AC locomotive technology within the past several years has brought with it many changes to the railroad industry. The advantages of the AC locomotive are familiar to most of us:

- With its higher starting torque, the AC traction motor has more "pulling power" than its DC counterpart.
- Because brushes and commutators do not exist in an AC traction motor, traction motor stall burns cannot occur.
- AC traction motors have lower maintenance requirements.
- Without the high current requirements for low speed pulling, much less heat builds up in the AC traction motor, virtually eliminating short time ratings.

However, with these and many other advantages comes the requirement for additional attention to safety when performing certain maintenance and repair tasks on AC locomotives. The Burlington Northern Santa Fe currently operates over 400 EMD SD70MAC locomotives. Due to the type of inverter used on these locomotives, capacitors connect in parallel with the load to provide a

constant voltage supply. Since these capacitors store energy it is possible for dangerously high voltage to be present even after the locomotive is shut down. Voltages may exist in excess of 2700 volts in several places on these locomotives.

These dangers were brought in to sharp focus on the BNSF when a minor incident of injury occurred at our Alliance Diesel Shop in Alliance, Nebraska in March of last year. The Alliance shop has maintenance responsibility for our entire fleet of SD70MAC locomotives.

The injury was to an electrician who was in the process of unhooking one of the capacitors in the traction converter cabinet for removal. Proper procedures had been followed prior to the electrician entering the traction converter cabinet. This included conducting the shorting test through the locomotive's computer as well as probing the locomotive. Both test procedures indicated that zero voltage was present. However since a nut was missing from the bus bar, the capacitor was not tied to the discharge system. As the electrician attempted to remove the grounding strap from the capacitor so that it could be removed and replaced, she received an electric shock and a burn to her hand.

Since proper procedures were followed and injury still resulted, work in this area of the locomotive

was suspended until new, more comprehensive procedures were developed. For the next several weeks both BNSF and EMD personnel worked to develop a fail safe procedure for discharging the SD70MAC locomotive. The video you will see is the result of these efforts and demonstrates the capacitor discharge procedure currently in use on the BNSF.

IV. POWER SAVINGS FOR ELECTRIC LOCOMOTIVES

by Leroy F. Motley, National Passenger Railroad Corporation

Introducing the AEM-7 electric locomotive, Figure 1. The AEM-7 is a 7000 horse power electric locomotive which is capable of reaching speeds up to 125 mph. This speed capability does not come free. On a daily 388-mile trip, a typical AEM-7 dissipates, on an average, 11,242 kilowatt hours of power. Each week, this total power consumption cost Amtrak over \$5500.00 per locomotive.

The AEM-7 receives its power input from an overhead catenary system, which can provide 11 KV/25 Hz, 12.5 KV/60 Hz and 25 KV/60 Hz. This input power is fed to a 1.5 MVA transformer as shown in Figure 2. There are several areas that are fed by the secondary of the transformer. These areas which are responsible for a major portion of the total power consumption are as follows:

- Propulsion circuitry for the four 1500 H.P. GE-780 DC traction motors
- 175 VA 3 ϕ 440 V 60 Hz Auxiliary Power (APL) with 0.8 P.F.
- 500 KW 3 ϕ 480 V 60 Hz Head End Power (HEP) with 0.8 P.F.

There are two ways to reduce the amount of power consumed by an AEM-7 locomotive.

- Shut down non-essential power consuming systems when a locomotive is stationary.
- Improve the 0.8 Power Factor (P.F.) of the propulsion, APL and HEP systems.

Shutting Down Non-essential Power Systems

An AEM-7 locomotive is energized 22 hours per day. Twelve out of the 22 hours, the locomotive is in revenue service. This revenue service puts a great demand on the four 1500 HP traction motors where a great amount of heat is produced. As a result, the motors must be cooled using eight 480 Vac, 8.8 HP blowers. However, when a locomotive is stationary the heat generated is significantly reduced. During this 10 hour time period the four 1500 HP traction motors do not require cooling, eliminating the need for cooling. Amtrak found that shutting down the blowers during the 10 hour time period result in a power cost saving.

Example 1 Blower Shutdown

Testing showed that the eight blowers consumed 71 KWH of power per hour.

The power saved per year would be:

$$52 \text{ locomotives} \times 71 \text{ KWH} \times 10 \text{ Hours} \times 348 \text{ days of operation} \\ = 52 \times 71 \times 10 \times 348$$

$$= 12848160 \text{ KWH per year}$$

$$\text{Yearly Cost saving to Amtrack} \\ 12848160 \text{ KWH} \times \$0.07 = \\ \$899,371.20.$$

Power Factor Improvement

Amtrak was faced with the problem of aging AEM-7 locomotives. We needed to overhaul these locomotives so that they would last an additional 15 years. We had to decide whether to overhaul the AEM-7 with the existing silicon controlled rectifiers (SCR)'s, or upgrade to gate turn on (GTO) insulated gate bipolar transistor (IGBT) technology. Upgrading to GTO/IGBT technology was more expensive initially, but less expensive in the long run. With GTO/IGBT technology there is an advantage of a 0.99 P.F. as opposed to the 0.8 P.F. of the SCR technology.

What is the advantage of a 0.99 P.F. over a 0.8 P.F.? What amount of power does an AEM-7 consume? If we turn our attention to Figure 3, we will see the typical power consumption of a locomotive during a 103-mile trip from Philadelphia to Harrisburg. The total power consumption of the locomotive is 2985 KWH at a 0.8 P.F. The substation, which supplies power to the catenary, would have to supply the power consumed by the locomotive plus the apparent power loss caused by the 0.8 P.F.

Example 2 - Power Saving, 0.99 P.F.

With a 0.8 P.F.

Power supplied by the substation =
 $2985 \text{ KWH} + 2985 \text{ KWH} (1-0.8)$
 $2985 \text{ KWH} + 597 \text{ KWH}$
 $= 3582 \text{ KWH}$

With a 0.99 P.F.

Power provided by the substation=
 $2985 \text{ KWH} + 2985 \text{ KWH} (1-0.99)$
 $2985 \text{ KWH} + 29.85 \text{ KWH}$
 $= 3015 \text{ KWH}$

Power saving for Amtrak = $3582 \text{ KWH} - 3015 \text{ KWH} = 567 \text{ KWH}$

Cost saving for Amtrak = $567 \text{ KWH} \times \$0.07/\text{KWH} = \39.69

An AEM-7 locomotive travels an average of 135,000 miles per year. The following example shows what the cost saving would be with GTO/IGBT technology:

Example 3 - Yearly Saving, 0.99 P.F.

The average power consumption of a locomotive per mile traveled is $2985 \text{ KWH} / 103 \text{ Miles} = 28.98 \text{ KWH/MI}$

That means each AEM-7 consumes on an average

$135 \text{ MI} \times (28.98 \text{ KWH/MI}) = 3912300 \text{ KWH}$

Since there are 52 locomotives in the fleet, the total power consumption for the year

$3912300 \text{ KWH} \times 52 \text{ locomotive} = 203439600 \text{ KWH}$

With a 0.8 P.F.

Power provided by the substation = $203439600 \text{ KWH} (1.20)$
 $= 244127520 \text{ KWH}$

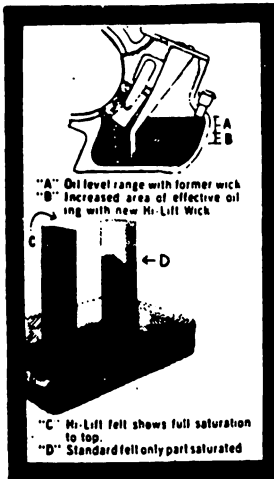
With a 0.99 P.F.

Power provided by the substation = $203439600 \text{ KWH} (1.01)$
 $= 205473996 \text{ KWH}$

Power saving for Amtrak =
 244127520 KWH-205473996
 KWH = 38653524 KWH

Cost saving for Amtrak =
 38653524 KWH x \$0.07/KWH =
 \$2,705,746.68

In conclusion, it is clear that by instituting the above energy saving methods, Amtrak can save over \$3.6 million per year. These methods are the first steps in allowing Amtrak to reduce operating cost in the continuing quest to becoming self-sufficient.



How Miller Hi-Lift Wick Lubricators cut maintenance costs

Here's a locomotive traction motor lubricator that offers 40% greater oil lift and doubled oil capacity.

Upper picture shows increased oiling efficiency provided by Miller Hi-Lift wick lubricator. Lower picture illustrates simple test that proves greater oil-lifting ability of Hi-Lift felt. Hi-Lift felt segment ("C") is completely saturated to top with oil. Standard felt ("D") has unsaturated, white area at top. Both are same size and were placed in tray before oil was added. Details available from your locomotive builder or write direct to:

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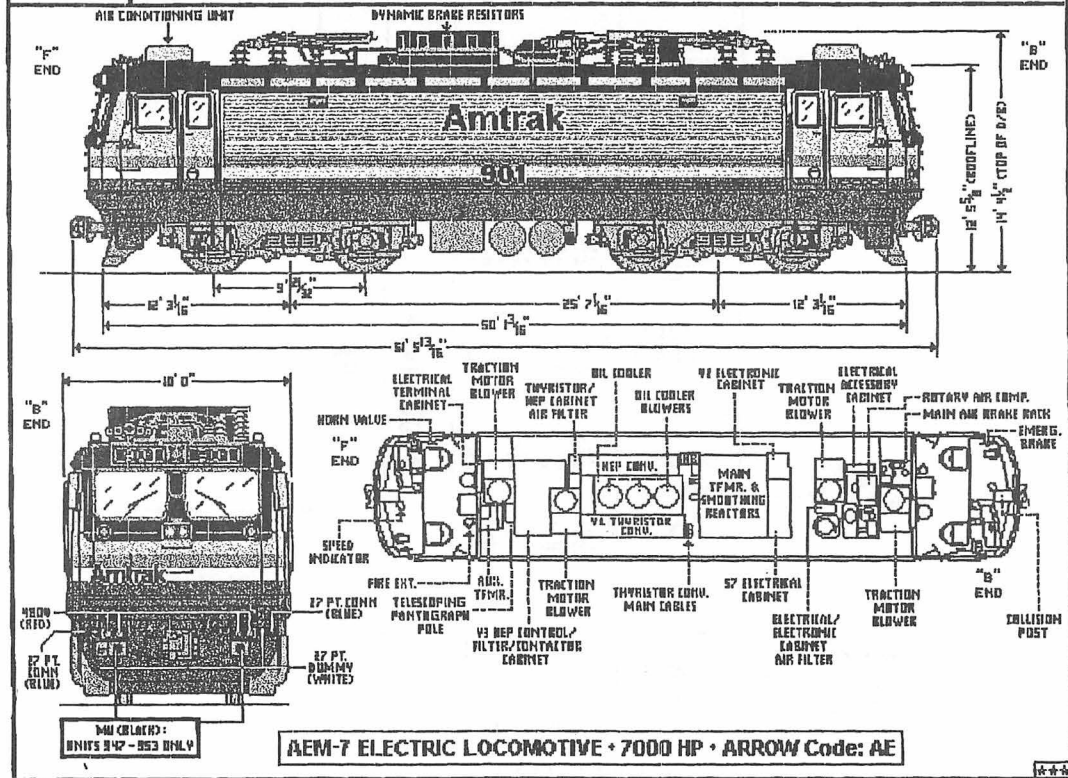


Figure 1

Figure 2

1.5 MVA Transformer

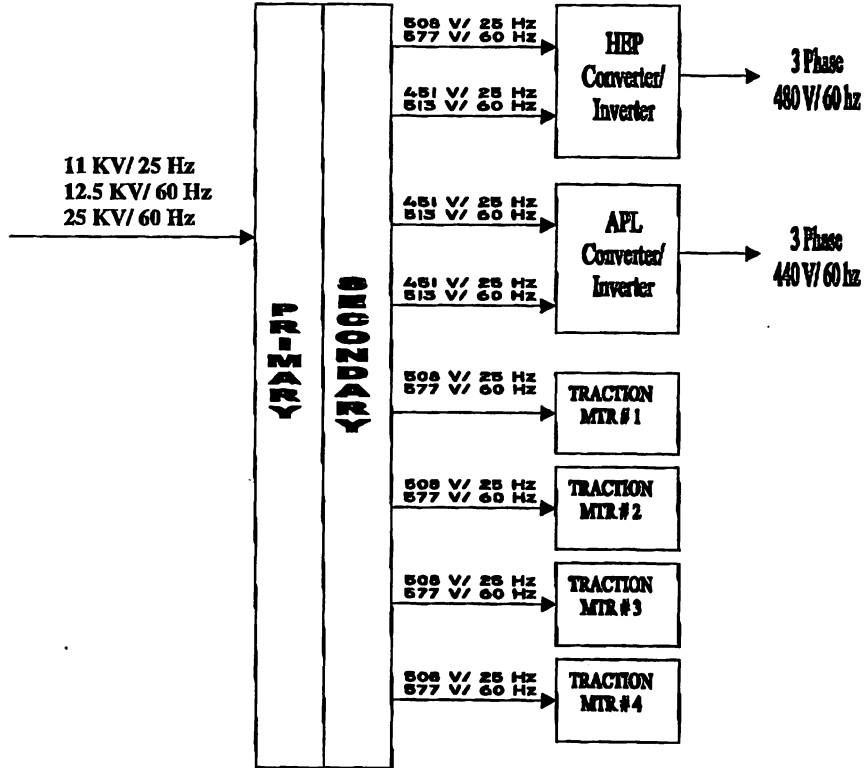
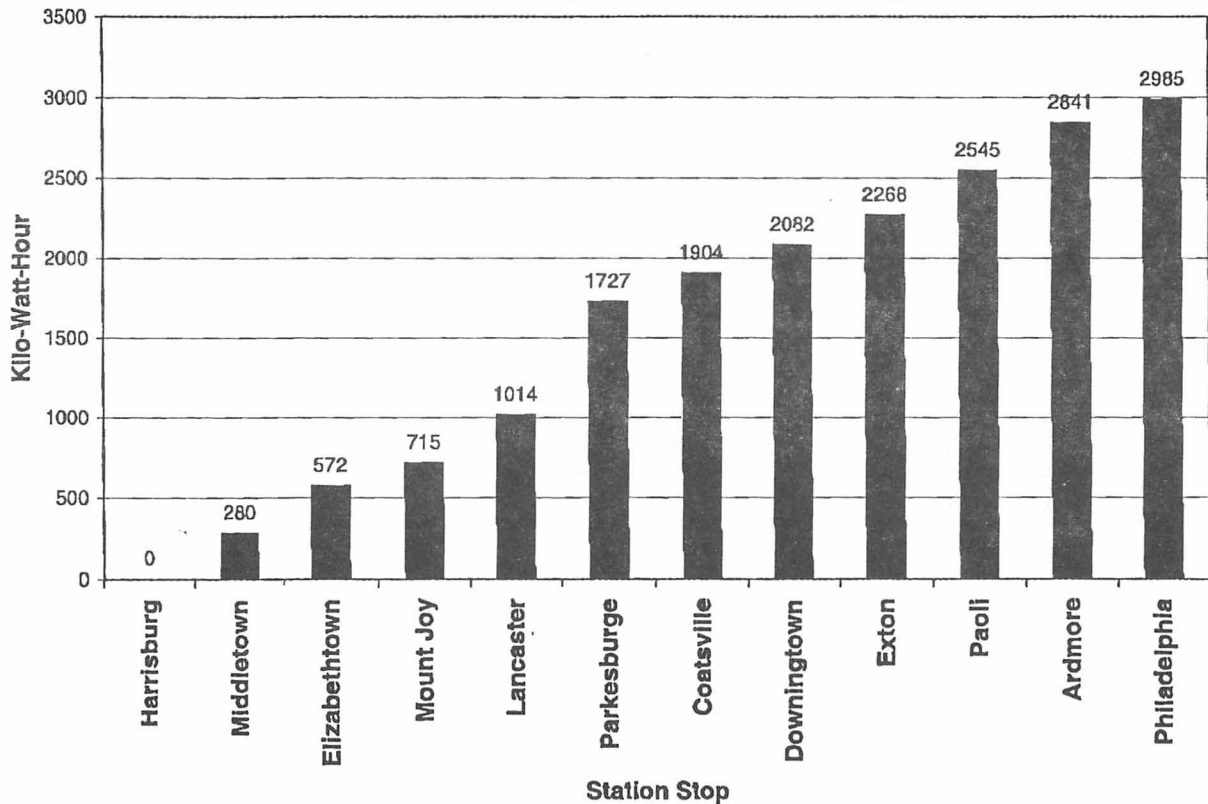


Figure 3

Total Power Consumption Harrisburg to Philadelphia



V. AUTO STOP / START & LAYOVER SYSTEMS

by Les White, CN
John Chessario, GE
and Dan Smith, WATCO

The products in this paper are all designed to reduce fuel consumption through increased shut down cycles. With the current price of fuel, these systems may not have been priorities for most mechanical departments. However, one of last year's presentations quoted the Union Pacific's annual fuel consumption at over 1.3 billion gallons, or \$914 million. Obviously, using those quantities as a base line, small savings in fuel expenditures, such as one half of one percent, could represent savings better used elsewhere. Scaling down this base line for your particular road may still justify a second look based on today's prices.

At this point the Electrical Committee would like to stipulate that this presentation is not intended as an endorsement of one system over another. It is simply a summary approach to the topic. In general, there are three types of systems that allow the locomotive to be shut down for longer periods, therefore reducing fuel consumption.

With an arguable variance in quoted savings which will not be addressed in this forum, fluid heating systems generally make the following assertions:

- A reduction in fuel consumption
- A reduction in engine wear
- A reduction in oil consumption
- A reduction in emissions
- Quicker start up in cold weather
- Some form of protection / alarm system.

We will begin by reviewing a system which combines its own mechanisms and some external support. The Hotstart system uses a remote power source to provide fluid heating for the cooling system alone or the oil system as well. Its pump and heating element array circulate fluids through the prime mover systems to maintain a satisfactory temperature range. An optional battery charger may also be selected.

Upgrades over the years include a change in the diameter of the heating tanks and isolating the oil and water systems. A new oil pump increased the gallon per minute rate and included changing to a Viton seal. A new design flow switch made the previous magnetic plunger configuration obsolete. This eliminated false readings due to contamination. The relocation of the coolant pump assembly allows for more efficient draining. Finally, an upgrade has been made to the alarm system, providing a 5VDC backup.

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The next system we will review is by Microphor. While not actively pursuing this market at present, its LTP system continues to be made available. The LTP consists of a small engine / generator set not requiring an externally supplied power source and uses a combination of heat transfer methods. Locomotive coolant is circulated initially around a heat exchanger on the LTP diesel engine and then an immersion heater in the locomotive retention tank. Power for the immersion element, battery charging and circulating pumps is provided by an internal alternator.

The last systems we will discuss are General Electric's new offering and the Smart Start systems. It should be noted the Q-Tron also has an offering but since it was discussed last year we will quickly review GE and Smart Start.

General Electric will be unveiling its new AutoStart system late this year. AutoStart will be available on new locomotives and as a retrofit package for some earlier models. Based on customer parameters, the AutoStart system will shut down an unused unit and then restart as needed to maintain battery condition and an acceptable water temperature. The system is monitored through the diagnostic information display with system information available on board or through laptop download. Installation is estimated at 24 man-hours.

Smart Start monitors a number

of parameters to initiate shut down. Some of the criteria might be ambient temperature, cooling water temperature, locomotive battery voltage, brake cylinder pressure and uninterrupted idle time and directional change. Once the criteria are met Smart Start will begin its stop sequence. Along reverse lines of logic, should cooling water temperature, battery voltage or brake cylinder pressure fall to a level outside system parameters, and provided Smart Start initiated the shut down, the system will begin the start sequence.

System upgrades over the recent years include more compact hardware, dual colored LED's, a governor assist pump and a relay circuit to delay loading for one minute following start up.

As an example of maintenance considerations which would almost certainly enter into a cost analysis and a system operation, our presentation will include a short film on one of the topic systems.

REPORT OF THE COMMITTEE
ON SHOP EQUIPMENT

TUESDAY, SEPTEMBER 16, 1998
10:30 A.M.



Pre-Convention
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***The Shop Equipment Committee** wishes to thank the Southern & Southwestern Rwy. Assn. for hosting their Pre-Convention Presentation in Jekyll Island, GA on July 17, 1998*

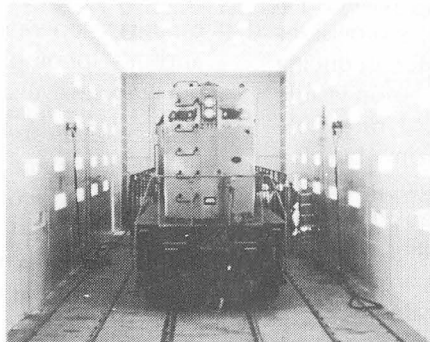
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I. "SMOKE OPACITY TESTING" EMISSION DETECTION EQUIPMENT AND ITS USE

by Michael J. Scaringe, Amtrak and
Darlene Kisko, GE
(Presented at the
1997 Annual Meeting)

In 1990, the United States Congress passed the Clean Air Act. The Act allowed the Environmental Protection Agency (EPA) to expand to state and local governments the authority to prevent and control air pollution at its source. The Clean Air Act (CAA) addressed two sources, stationary sources and mobile sources:

Stationary Sources: paints and various chemicals used in the shop facilities, as well as vapors from fuels and fuel storage facilities, fall into this category. These provisions also set standards for reducing both visible and non-visible particulate matter. Non-visible includes sulfates from burning diesel fuel. The visible pollutants include dust and smoke. Permits are required at facilities where a significant amount of any of these air pollutants is generated.

Mobile Sources: The CAA has specific provisions that deal directly with air pollution from "mobile sources" such as locomotives.

There are also state and local regulations that require attention to the federal requirements. In many cases the local standards are more stringent than the federal requirements. Almost any activity that creates air pollutants is regulated to some degree. The

most common on railroads are dust from unpaved roads, ballast unloading and dressing, rail grinding, and excessive smoke from locomotives.

Companies violating any governmental air quality law or regulations can face the potential of sizable fines and penalties.


Several railroads have taken steps to protect the environment and to help reduce company fines and violations. The Union Pacific Railroad has taken an active role, becoming the leader in conducting smoke tests. UP and South Coast Air Quality Management District (SCAQMD), reached an agreement on conducting smoke tests as part of their periodic maintenance inspections for locomotives operating in California and all locomotives subject to being excessive smokers.

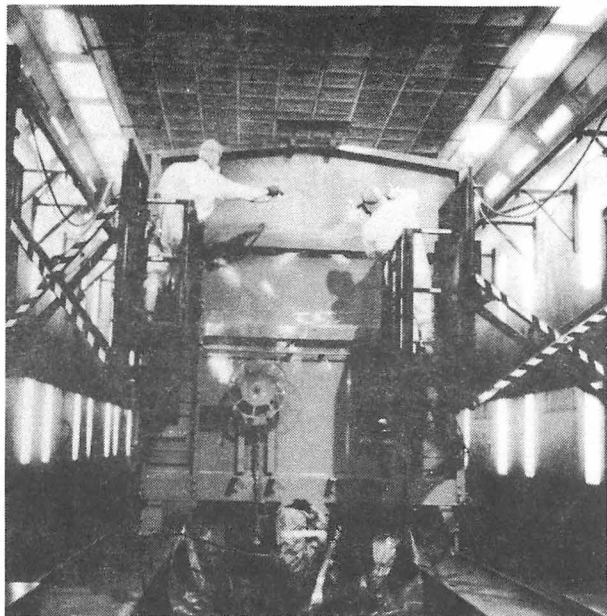
Excessive smoke is not the problem it once was when coal and oil fired locomotives powered the trains. With diesel powered locomotives, emissions can be better controlled and limited. Keeping the railroad's equipment in good working order and operating it in the proper manner can greatly reduce the release of potentially harmful pollutants into the air. A single smoker locomotive can waste thousands of gallons of fuel while darkening the sky with unnecessary emissions. The less smoke that can be seen, the more fuel is being burnt to power the engine. Too much smoke may signal an improperly tuned locomotive.

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Union Pacific has established a comprehensive emissions policy that requires training of employees whose job duties include the repairing of excessive smoking locomotives and the periodic testing of locomotives. This training is divided into three levels:

LEVEL 1 - EV16 or qualified evaluator training

LEVEL 2 - Opacity meter operation training

LEVEL 3 - State certified visible emissions evaluator

Individuals must be certified at level 1 in order to be certified at level 2 and so on.

A "qualified evaluator" has been trained to analyze smoke by looking at an exhaust stack using a opacity gauge, to determine opacity levels.

An "opacity meter operator" has been trained to use a computerized meter to determine opacity levels to the hundredth of a percent.

A "state certified visible emissions evaluator" has been trained to analyze smoke by using measures approved by the EPA, by looking at an exhaust stack. A certified evaluator can determine if the opacity meets acceptable standards.

All three types of training are essential to ensure compliance with the law. We will focus on the necessary equipment required to perform opacity meter testing.

Opacity testing has come a long way over the past several years. In the early years and currently, opacity testing is performed by using a hand held opacity gauge by holding it up to the sky and visually looking at the smoke coming from the locomotive. There was very little documentation, testing between all facilities was not uniform, manual notching had to be performed, and results were not always accurate.

UP has developed both portable and fixed computer generated opacity testing equipment. This equipment will now allow it to perform detailed opacity testing, generate reports with greater accuracy, uniform testing between locomotive repair facilities and the capability of analyzing computer data by using opacity testing as a diagnostic tool.

The portable opacity testing unit consists of several key components:

1. Portable generator
2. Portable lap top computer
3. Sender/receiver "smoke meter" unit
4. Hose reel, for air
5. Hydraulic control box
6. Forklift.

Locomotives subject to annual periodic maintenance, visual smokers, locomotives cited for emitting excessive smoke by the South Coast Air Quality Management District or by Union

Pacific inspectors will require computerized opacity testing to be performed.

When using the portable opacity testing unit:

- Locomotives will be spotted on a service track, hand brake and blue flag protection installed;
- Portable opacity unit moved into position perpendicular to the locomotive;
- Portable generator started and air line connected to main reservoir line on locomotive;
- Portable sending/receiver "smoke meter" unit is raised by employee above the locomotive, and moved into position;
- Portable lap top computer installed in cab to be used during testing;
- Employee performs self load test in accordance to opacity testing software;
- Testing information is saved on lap top and downloaded at a later time.

The advantages of the opacity testing units outweigh the disadvantages.

ADVANTAGES:

1. Portable test unit can be used on most all locomotives in a service track area.
2. Computerized opacity testing, generating and storing electronic test results.

3. Uniform testing between various locomotive repair facilities.

4. Provides documentation and compliance with state and federal regulatory agencies.

5. Provides accurate, more detailed opacity test reports.

6. Provides the capability of analyzing computer data as a diagnostic tool

7. Reduces the risk of EPA violations.

DISADVANTAGES

1. Labor intensive, multiple crafts required.

2. Manual notching causes inaccuracies in test results.

3. During winter months, not all service tracks are accessible.

4. Portable unit requires heavy maintenance.

Over the past twelve months Union Pacific has addressed all of the disadvantages of the portable opacity test unit. It has built a permanent computerized opacity test facility at its Salt Lake City locomotive maintenance facility. This new opacity test facility provides them greater flexibility with having both permanent and portable opacity testing. The new facility allows the procedure to be less labor intensive, provides automatic notching during self load testing, provides quicker release of locomotives and requires less maintenance.

The following key components are included in this new opacity test facility:

1. Permanent building.
2. Air compressor and dryer system.
3. Climate controlled room where automated testing is performed.
4. Computer system with "Windows" based software.
5. Sender/receiver "smoke meter" unit.
6. Sender/receiver unit hydraulic controls.
7. Sender/receiver sun shield.

When using the permanent computerized opacity testing facility,

- Locomotives will be moved onto the service track;
- Spotted under test facility catwalk;
- Positioned so that locomotive exhaust stack is directly under smoke meter;
- Hand brake set and blue flag protection installed;
- Computer system with "Windows" based software is turned on to start opacity testing;
- Employee logs in name, unit number, date, time, reason for test and weather conditions.
- Software ensures the locomotive and smoke meter are properly aligned;

- Smoke meter is zeroed before locomotive is started, to ensure accurate self test
- Warnings appear on screen to ensure proper testing and safety precautions;
- Zeroing of smoke meter is automatic and adjustable;
- Computerized opacity software provides passed/failed screen status;
- Employee performs self load test, from idle to 8th notch in accordance with opacity testing software;
- Upon completion of opacity testing, software screen provides graph of test results and passed/failed status.
- Testing information is saved and printed to provide hard copy for file;
- Windows based software provides easy access to previous smoke meter tests.

Locomotives that fail the smoke meter test, can be diagnosed either by conventional troubleshooting or by analyzing the computer opacity test data. Repairs can be made during or after smoke meter testing and then rechecked before dispatching of locomotive.

The permanent opacity testing facility advantages outweigh the disadvantages.

ADVANTAGES

1. The permanent test facility, can be used on all locomotives in a service track area;

2. Computerized opacity testing, generating and storing electronic test results;
3. Uniform testing between various locomotive repair facilities;
4. Provides documentation and compliance with state and federal regulatory agencies;
5. Provides accurate, more detailed opacity test reports.
6. Provides the capability of analyzing computer data as a diagnostic tool;
7. Less labor intensive;
8. Less maintenance of test equipment;
9. Reduces the risk of EPA violations;
10. Quicker release of locomotives, resulting in greater utilization.

DISADVANTAGES

1. Manual notching causes inaccuracies in test results.
2. Locomotives will need to be moved to service track.

SUMMARY

- 1990 Clean Air Act provides state and local government authority to prevent and control air pollution and targets stationary and mobile sources, paint facilities, chemicals, fuel storage areas and locomotives;
- The Union Pacific Railroad and South Coast Air Quality Management District reached an agreement on conducting smoke test as part of their periodic maintenance inspections for locomotives in California.

- The Union Pacific has established a comprehensive emissions policy that includes training of employees at three different levels;
- Opacity testing has evolved from a hand held opacity card gauge to computerized opacity testing equipment;
- Union Pacific Railroad and Mastek Corporation developed both portable and permanent computerized smoke meters to ensure compliance and uniform testing and documentation.

Special thanks to John Steiner and Rick Graham of Union Pacific Railroad, Salt Lake City maintenance facility for their support of this paper.

We would also like to thank Wayne Goff and Don Tetley of Union Pacific Railroad who were instrumental in the opacity test facility development project. These projects are very beneficial to the railroad industry and we appreciate Union Pacific sharing this with us.

II. HYDRAULIC TENSIONING TOOL AND ITS USE

by Mike Dombrowski, GE
Transportation Systems, Erie, Pa

Safety Alert

Before beginning any procedure, be sure to carefully review the Safety Precautions Section in the Maintenance Instructions.

When working with the GE 7HDL™, 6000 hp diesel engine, several maintenance procedures require the use of specialized hydraulic tensioning tools including a cylinder head stud, a connecting rod stud, and a main bearing stud tensioner. This paper discusses bolt tightening, what tensioning is, how it differs from torquing and stretching, and the correct procedures for tensioning and detensioning the connecting rod and cylinder head bolts of the GE 7HDL engine.

Bolt Tightening

The force that holds the engine components together, *the clamping force*, is created by stretching the bolt, not by merely tightening the nuts alone. In this manner, bolts work like rubber bands. The tension of the fastener, trying to relax back to its original length, is what produces the force that holds the components together. In a bolt, this force is called *the clamping load*.

Torquing

Torquing applies a rotary force to the nut to move it down the

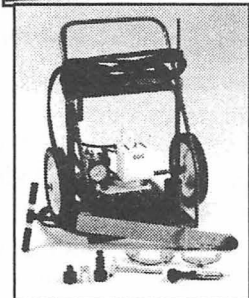
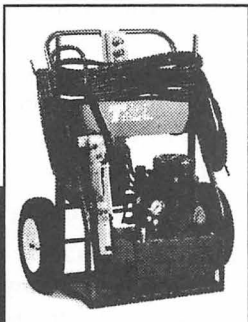
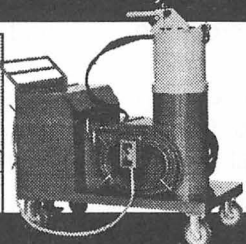
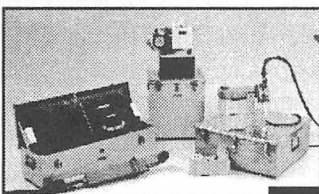
threads of the bolt. Once the nut contacts the surface, it begins to act like a screw jack, forcing the bolt to stretch and creating clamping force. The problem with torquing is the determination of exactly how much clamping force is to be generated. A torque wrench indicates how much force is being applied to the nut, but not how much stretching or clamping load is being generated by torquing. The unknown clamping force value results from most of the torque being absorbed by the friction between the nut and the threads or the mating surface, or by twisting in the bolt.

Stretching or Elongation

Stretching is the tightening method that still depends on torque to stretch the bolt but allows for improved measurement of the actual clamping force that is being produced. This is accomplished by accurately measuring the length of the bolt before torque is applied, then measuring it again after torquing has been completed. Once the amount of stretch has been measured, the amount of clamping force being produced can be estimated. Although stretching provides a more accurate measure of clamping force than torquing, the stretching method does have some shortcomings.

For example, stretching can be very time consuming. It allows only one bolt to be tightened at a time which can lead to uneven clamping and point loading along

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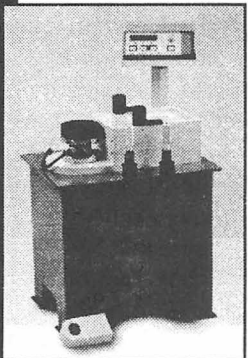
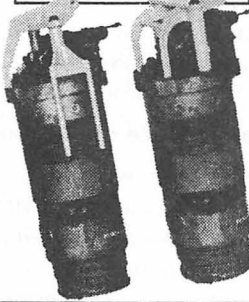
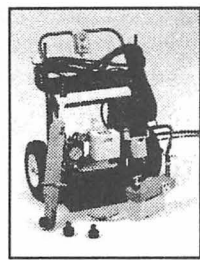
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the gaskets and surfaces that are being joined. Stretching can often require so much torque that the threads may become galled. Additionally, stretching cannot account for variations in bolt shank size which will change the amount of clamping force that is produced. For instance, if a 2-inch diameter bolt and a 1-7/8 inch diameter bolt are stretched an identical distance, the larger of the two will produce more clamping force.

Tensioning

The disadvantages of torquing and stretching sections are solved by tensioning. Hydraulic tensioners do not generate clamping force by applying torque to the nut. Instead, they attach to the end of the bolt or stud and pull on it with a known amount of force. The bolt or stud stretches, producing clamping force. Then, the nut can be moved down the thread until contacting the mating surface to hold the stretched bolt or stud in its new position. *Tensioning* provides an accurate measure of clamping force: it is equal to the known amount of force that was applied to the bolt or stud by the hydraulic tensioner. Additionally, the hydraulic tensioning devices eliminate the problem of thread galling and allow all the bolts or studs on that part of the assembly to be tightened simultaneously with identical amounts of force. This simultaneous and evenly applied force on the bolts or studs eliminates uneven pressure distribution on the parts and gaskets.

GE 7HDL, 6000 HP Engine Connecting Rod and Cylinder Head Tensioning

The cylinder head bolt tensioner is designed to fit the 4 cylinder head bolts while the connecting rod and main bearing stud tensioners are designed to fit those components. Regardless of the specific application, all of these tools contain the same basic elements:

1. a base that rests on the engine component, providing an anchor for the pulling force;
2. a hydraulic cylinder that will thread onto the bolt, then stretch it to its recommended tension; and
3. a cap that mates with the nut and allows the operator to turn it.

Tensioning is accomplished in 2 phases of the 7HDL engine - first, at a lower pressure, then at a higher pressure. The first phase is similar to calibration - a way to make sure that an equal amount of stretch is present in each bolt before the stretching process begins. The second phase is the high-pressure pull. A field maintenance example follows to further define this process.

Field Maintenance Application

In the field, removing a power assembly and replacing it with a new one represents a service procedure requiring the use of hydraulic tensioners. Detensioning of the connecting rod nuts begins the maintenance process.

1. Read the safety precautions before beginning any procedure.
 2. Confirm that the proper tensioner is available (connecting rod hydraulic tensioner) by checking the top of the hydraulic cylinder where the unit's hydraulic area is stamped.
 3. Thread the hydraulic tensioner onto the thread exposed above the nut on both studs and continue until the tensioner bridge bottoms on the face of the connecting rod. At this point it is very important to turn the tensioner back again by 1-1/2 turns to verify that there is enough space between the nut and the tensioner. This keeps the nut and tensioner from becoming jammed together when the bolt is unstretched.
 4. Confirm that both of the hydraulic tool pistons are fully compressed when the shoulder of the pistons are about 1 mm from the top of the housing. If they are not fully compressed, connect the hoses and open the return-to-tank valve on the pump. Compress the pistons by screwing them further onto the stud using a 70 mm flat wrench or 1/2 inch ratchet.
 5. Connect the hydraulic hoses to the pump and tensioners. Close the valve on the hydraulic pump and increase the pressure to the proper value. Then, loosen the hexagon rod nut by 1-1/2 turns. The connecting rods are loosened.
 6. Recompress the piston using a flat wrench or ratchet. Release the hydraulic pressure at the pump, disconnect the hydraulic hoses, and remove the tensioner. The rod cap studs are detensioned and the nuts can be removed from the stud.
 7. Remove the rod cap from the rod and install the stud driver to the stud. Lock the tool in place and remove the rod studs. This power assembly is disconnected from the crankshaft.
- Next, the hydraulic tensioning devices are used during power assembly re-installation (details are in the next maintenance instruction). The following information identifies the procedure:
1. Inspect the nuts and studs for defects or galling.
 2. Use a stud driver to screw the studs into the rod and tighten them to the specified torque value.
 3. Apply a light coat of clean oil or other prescribed lubricant to the threads (Molycote GN paste is not to be used here).
 4. Thread the hydraulic connecting rod stud tensioner

- onto the exposed threads of both studs. Continue threading until the tensioner bridge touches the face of the connection rod. Turn the tensioner back half a turn to ensure there is enough space between the tensioner and the nuts.
5. Verify that the tensioner's pistons are fully compressed. (If the shoulder of each piston is about 1 mm from the top of the housing, the tensioner pistons are fully compressed, if they are not compressed, connect the hoses and open the return-to-tank valve on the pump. Then, compress the pistons by screwing them further onto the stud using a 70 mm flat wrench or 1/2 inch ratchet.)
 6. Tighten the connecting rod nuts first at a lower pressure and then at a higher pressure. (When tensioning begins, it is important to observe the puller. If a yellow line appears, the tensioner is at its maximum allowable stroke. Stop the pump immediately, open the return-to-tank valve on the pump, and restroke the piston by screwing it further onto the stud.) To begin tensioning, close the valve on the hydraulic pump and increase the pressure to the prescribed value. Tighten the connecting rod nut by turning the socket using the adjusting bar noting the position of the hex nut.
 7. For the high-pressure pull, increase the hydraulic pressure again to the specified value. Tighten the hex nut by turning the socket with the adjusting bar. Starting from the position the hex nut was in after wa in after the low-pressure stretch, the higher pressure should allow the nuts to move an additional two flats plus or minus a quarter of a flat. (The extra amount of stretch in the bolt should allow the nut to tighten an additional 120° plus or minus 15°)
 8. When the connecting rod nuts have moved the recommended distance, the operation is complete. At this point,
 - a) release the hydraulic pressure at the pump
 - b) disconnect the hydraulic hoses
 - c) remove the tensioner.

If the nuts did not turn properly, possible causes may include an assembly error, defective hardware, or a problem with the tensioner system. Locate the problem and implement the solution before the engine is started and damage occurs.
 9. After the connecting rod nuts have been tightened to specifications, check the rod end for thrust movement on the crank pin.

Conclusion

The proper use of the hydraulic tensioning tools provides measurement accuracy and eliminates “guess work”. Tensioning offers advantages to improve service efficiency and to increase the reliability and performance of the engines.

Acknowledgements

GE Transportation Systems recognizes and appreciates the contributions of following individuals: Robin Baer, Mike Dombroski, Ed King, Darlene Kisko, Donna Perino, Dan Southworth, and the GETS Training Department.

III. HIGH SPEED PORTABLE ALIGN BORING SERIES

by Adam Aldrin

Introduction

Locomotive engines are punished by long hours and a variety of elements, which can cause their lifespan to fall short. When re-manufacturing these engines, they must go through a series of checks to make sure that the engine block is in a state that is acceptable for re-manufacturing. One of these checks is to determine the location and size of the crankshaft main bearing journals. The focus of this paper is to describe the latest technology in "align boring" after it has been determined that the journals are in the wrong location or are the wrong size.

History

Since the early 1990's engine blocks have required align boring. This process is usually done using a large machine and a bed plate method. These machines are slow and expensive. They generally require more than one operator and take up a large amount of floorspace.

In the 1980's some advancements were attempted through developing portable align boring machines. However these machines proved no faster than their predecessors and were underpowered, resulting in a bottleneck in remanufacturing.

Today

A manufacturing company set out to find a solution to the many problems in this machining operation. Its goals were to reduce the number of man-hours involved in the process and increase the precision of the work. These goals included:

Fast rigid setup

High horsepower cuts

Perfect repeatability

Less than 2 minutes/cut

Eliminate honing & grinding

User friendly.

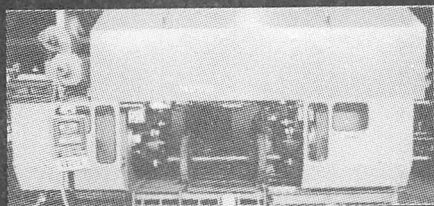
The result is two completely different portable align boring machines. These machines operate at over 1000 surface feet per minute (SFM) resulting in a cut that takes less than 2 minutes. Each machine has its own application, depending on the type and volume of production.

HB1000

The HB1000 is a cost effective portable align boring machine. This machine utilizes hydraulic power combined with electronic control to create a machine that is great for low volume production or remote areas where conditions are less than favorable. The HB1000 utilizes a programmable logic controller (PLC) to make the machine accurate and user friendly. This unit comes with self-lubricating bronze bearings, clamp on boring head, lightweight shafts, and a self-contained drive unit. It can be mounted in less than 5



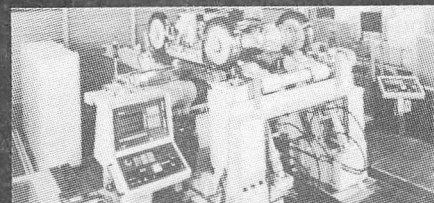
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HA = High Accuracy

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- Capable of surface finishes better than burnishing
- Optionally available drilling & tapping for axle downsizing or new axle manufacturing

HT = High Technology

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minutes and will complete a new cap in 3 cuts. It is not necessary to remove the main bearing caps, which is a big time saver. This machine is also available with an optional facing head for machining thrust bearing surfaces.

SB1000

The SB1000 is a high-speed production oriented machine. It is a computer numerical controlled (CNC) machine that is capable of a .120" cut at over 1000 SFM. The SB1000 incorporates a telescoping shaft that allows the entire engine block to be machined with just one setup. The SB1000 is available with the standard bronze bearings or custom Teflon-coated high-speed roller bearings. This machine connects to the engine block in less than 5 seconds. There is a self contained tool box that has plenty of room for storage. This machine is a must for all production re-manufacturing companies.

Summary

These Align Boring Machines are the wave of the future. They operate with incredible efficiency. They can be as much as 3 times faster than older methods, making them easy to operate and cost effective to own. They take up very little floor space and allow you to take the machine to the engine, not the engine to the machine!

IV. LOCOMOTIVE MOBILE SERVICING

by P.J. Gagne,

St. Lawrence & Hudson Railway

It's been a railway tradition that when locomotives require servicing they are moved to a central fixed servicing site where they can be properly serviced with oil, water, sand, inspected, cleaned and returned to operation. The transportation to and from these service sites is time consuming, costly and reduces locomotive availability. There is also the cost of building or maintaining a fixed service facility.

To reduce the cost of servicing and at the same time gain flexibility, some of the major railways have begun to use tractor-trailers to convey the servicing supplies to the locomotive.

The benefits of this mobile locomotive servicing are several:

Reduced operating costs

- Non revenue trips are eliminated
- The cost of building and maintaining service facilities is reduced or eliminated

Planned Maintenance

- Service to locomotives is more flexible and easier to plan and therefore schedules are likely to be met resulting in improved locomotive utilization.

Customer Service

- Locomotives are in the field longer and it is easier to meet customer needs and schedules.

Maximum Flexibility

- Mobile Servicing can be performed 365 days per year 24 hours per day.
- Any location such as mainline rail yards, customers sites, remote locations or any location where locomotives arrive, depart or tie up can be used.

Mobile servicing is not a new idea as other industries have used it. For example:

Construction

- Contractors fuel and service their heavy equipment at construction sites

Airlines

- Fueling and servicing is performed at the gate. Planes are not moved to a hanger for servicing.

Navies

- Naval vessels are fuelled and supplied at sea by supply ships. They do not have to return to port for servicing.

Air Force

- Planes can be fuelled in the air.

Railroads can use the same philosophy and mold it to their needs. Locomotives only make money when they are hauling cars, not when they are switched out of

trains. At some facilities 80% of arriving locomotives require only service. In one instance 25% of locomotives formerly serviced at a fixed site are now serviced with mobile equipment in the field. This has resulted in cost reductions through reduced movements, reduced fleet size and reduced scheduling.

Also mobile servicing offers complete flexibility, as needs change mobile servicing changes accordingly. Capital outlay is less and the servicing equipment can be as good or better than that at the fixed site. If locomotives can be serviced on site as well or better by mobile equipment in less than an hour it is better than hours or days transporting it to and from a fixed site.

New mobile technology and equipment offer comparable service to fixed sites with the bonus of not having to move the locomotive. Sand and oil can be dispensed in a matter of minutes. For example, certain mobile vehicles can transfer sand into a locomotive at a rate of 500 lbs. per minute or four times faster than gravity hoppers.

Typical Equipment and Supplies

- On board generator for power, lights, heating
- Cooling water
- Lube oil
- Traction sand
- Vacuum pump and tanks for emptying toilets

- Vacuum and tank for cleaning engine sump
- Vacuum for cleaning locomotive cabs etc.
- Misc. supplies, compressor oil, drinking water, cab supplies etc.
- Aerial fall protection platform for roof work
- Storage compartments
- Portable and adjustable lighting
- Dispensing pumps and hoses

As examples, this paper will describe two mobile service operations. One in the USA and one in Canada. Both use mobile servicing as part of their overall servicing strategy.

The US railroad is using mobile vehicles in seven major cities in the eastern US. The vehicles are mainly tractor-trailer units with 48 ft. trailers carrying all supplies and dispensing equipment on board. In one city the use of such was justified by the elimination of a servicing facility located within the inner city. All servicing is now performed on the outskirts of the city saving valuable locomotive travel time that was formerly required to reach the service center. Also the cost of maintaining the facility has been eliminated and the cost of the operating vehicles is considerably less. The yearly saving has approached one million dollars.

In another US location, the vehicle is based in a major rail yard servicing main line power. It also travels to outlying areas to service smaller yards and train departure locations such as intermodal terminals and customer's facilities. 30% of all sand consumed by this railway is supplied at this location by mobile vehicles. Mobile servicing has resulted in locomotives visiting a service or repair facility on average every 43 days thus maintaining a high degree of availability.

In Canada, the vehicle operates a little differently. Its main purpose is fixed assignments and to service locomotives in satellite rail yards, customers facilities and intermodal terminals. This has eliminated the requirement to move locomotives to a central servicing site. Coupled with a repair crew it has eliminated the need to send 500 locomotives to a central servicing location. This has not only reduced travel time and increased locomotive availability, but it has also reduced congestion at the diesel servicing and repairs facility and increased productivity at the shop. Also as with the US railroad the time between shop visits for repairs has increased. With the elimination of transporting locomotives back to a central site and servicing in the field the locomotive availability increased resulting in a reduction of the locomotive fleet size. There had been some earlier mobile servicing operations but they

could not duplicate the potential of these new mobile vehicles. With the new vehicles servicing became scheduled and consistent; 100% servicing was possible, thereby keeping the locomotives working and on their assignments.

The keys to the successful mobile servicing operation are coordination, co-operation, and the use of heavy duty, well made mobile vehicles with large capacity for supplies and efficient dispensing equipment (i.e. sand, oil) and collection equipment operation (i.e. toilet draining).

These vehicles can provide all the supplies and services of fixed facilities. Compared to previous methods of mobile servicing the new method is faster, safer and more consistent, since it guarantees complete servicing. These vehicles operate on a fixed schedule or as part of a service on demand criteria. Large mobile units can reduce the need to have service facilities and supplies in numerous locations. One vehicle can service a large area in one week. For example the Canadian operation serves 15 locations per week within a 100-mile radius of its base site.

Each railway operates its servicing system differently. Some operate on an as need basis and others on a fixed weekly schedule. Mobile servicing becomes complete when combined with mobile fuelling, which is normally done using tanker trucks.

Types of equipment can vary but the best combination presently is the tractor-trailer unit because of its ability to carry both large capacity material storage tanks and the dispensing equipment for the sand oil and water. Railways have tried smaller units but their inability to carry enough material to remain in the field before refilling was a drawback. Also the tractor-trailer combination allows more flexibility in case of mechanical failure with the truck portion. A replacement tractor is always available. Mechanical failure in a single unit truck puts the entire servicing unit out of business. These vehicles can typically carry up to 12 tons of sand and 500 gallons of water and lube oil.

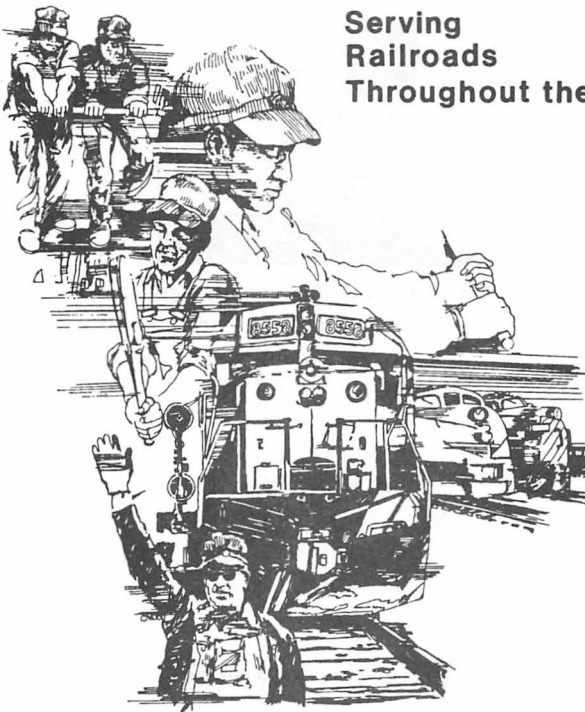
Mobile servicing leads to increased flexibility, greater locomotive availability and lower servicing costs. It has dividends for the entire railway particularly , the Mechanical, Operations and Transportation functions. But to realize its full benefits all these departments must work together in planning and coordinating the mobile servicing system.





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**REPORT OF THE COMMITTEE
ON DIESEL MECHANICAL MAINTENANCE**

**WEDNESDAY, SEPTEMBER 23, 1998
9:15 A.M.**



T. H. VOLKMANN, Chairman

Mgr.-Loco. Facility - Engine Components
Union Pacific
North Little Rock, AR

Vice Chairman

J. HOLLEY

Mgr.-Process Mapping
CSX Transportation
Jacksonville, FL

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PERSONAL HISTORY

Tad H. Volkmann

Tad H. Volkmann, chairman of the LMOA committee on Diesel Mechanical Maintenance, was born January 31, 1957, in Chicago, Illinois. He was raised in Naperville, Illinois, where he acquired an early interest in railroads from his grandfather.

Tad received an associate degree in drafting and mechanical design from Morrison Institute of Technology in 1978, and a Bachelor of Science Degree in manufacturing engineering from Milwaukee School of Engineering in 1980. He graduated with honors from both institutions, and taught classes in numerical controlled machining and robotics as a teaching assistant at M.S.O.E.

Tad began his career at Chicago and North Western in 1980 as a management trainee in the motive power department. He was promoted to assistant diesel supervisor in 1981, and to general foreman at Marshalltown, Iowa, in 1983. Tad was appointed shop manager at Marshalltown in 1987, where he oversaw a period of growth that resulted in the doubling of maintenance activities and workforce.

Tad was promoted to superintendent motive power-GE locomotives in 1994, with responsibility for the maintenance and performance of CNW's fleet of General Electric locomotives.

When CNW was merged into the Union Pacific Railroad in 1995, Tad moved to Salt Lake City, Utah, as senior manager of UP's Salt Lake Diesel Facility. Tad has been most recently appointed manager locomotive facility-engine components, at Union Pacific's Jenks Locomotive Shop in North Little Rock, Arkansas. Tad is responsible for the remanufacturing and performance of diesel engines and locomotive mechanical components system wide.

Tad lives in Conway, Arkansas, with his wife Sue and three children. His hobbies include fishing, boating, backpacking, and rabid support of the Chicago Bears football team.

I. LMOA BEST PRACTICES SERIES: GM ENGINE CRANKCASE PRESSURE TROUBLESHOOTING

by John Sadler - CN

GM locomotive engines are built with an aspiration system to ventilate and draw potentially explosive vapors from the engine crankcase. The pressure in the crankcase for a normal running engine is negative relative to the atmosphere. When this pressure rises to a set level above atmosphere, indicating an abnormally and potentially dangerous engine condition, a protective device shuts down the engine. This is indicated by the crankcase portion of the engine protection device tripping.

Following an engine shutdown caused by the engine pressure detector being actuated, do not open any handhole or top deck covers to make an inspection until the engine has been stopped and allowed to cool for at least 2 hours. Do not attempt to restart the engine until proper engine inspections have been complete.

Depending on the type of failure or the finding of obvious defects during the inspections, the complete troubleshooting procedure may not be required.

Crankcase pressure problems are created by either the flow of air into the crankcase being too high, meaning the crankcase is not

sealed adequately allowing air to leak in, or the evacuation system is not performing adequately to create a vacuum. The following procedures cover both potential problems.

After deemed safe to work, make the following engine static checks.

- 1) Check the excessive oil level in the crankcase. Excessive oil can result in the front gear train splashing oil into the detector, leading to a false trip.
- 2) Check that the eductor tube and aspiration system is in place and inspect externally. The eduction system is necessary to develop a vacuum.
- 3) Perform a top deck inspection looking for the following conditions that could lead to air leaks into the crankcase:
 - a) Leaks at the top deck cover seals or head frame gasket.
 - b) Loose or broken crab bolts.
 - c) Improperly seated power assemblies.
 - d) Missing crab stud retainer plate bolts.
 - e) Cracks on the cylinder relief valve welds.
 - f) Cracked cylinder head retainer or retainer welds.

- 4) Perform a complete air box inspection looking for:
 - a) Cracked, broken, scuffed or overheated pistons. This can allow combustion or air box gases into the crankcase resulting in crankcase pressure.
 - b) Excessively worn liners or piston rings based on a visual check.
 - c) Missing pan to case bolts or dowels.
 - d) Cracked or defective weld on the top deck drain line.
- 5) Perform a crankcase inspection looking for:
 - a) Overheated bearing caps or connecting rod bearings that could have resulted in a crankcase explosion.
 - b) Missing p-pipes that result in a piston failure
 - c) Cracked or defective weld on the air box drain line.
 - d) Wrist pin bearing failure. Feel sides of wrist pin.

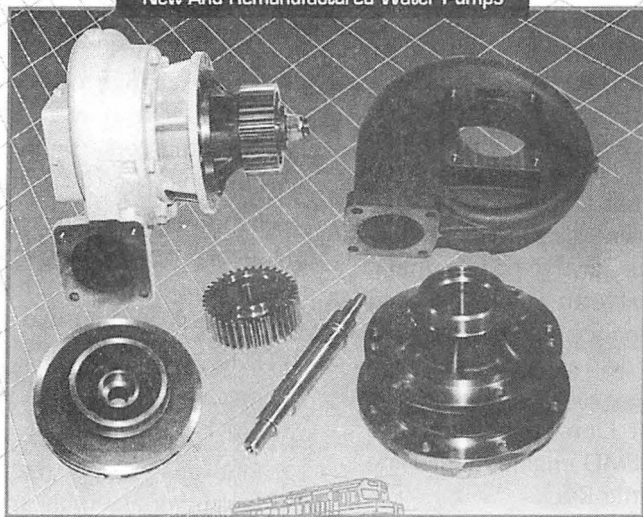
After checking all the previous items and making any corrections, perform the following running checks:
- 6) With the engine idling, make a running inspection of the top deck, looking for any defects identified by excessive smoke from leaking combustion gases.
 - a) Loose injector
 - b) Cracked head lifting holes.
 - c) Cracked head retainer or retainer weld.
 - d) Leak at the crab stud retainer plate bolt.
 - e) Excessive smoke in the lube oil strainer housing indicating a cracked piston.
- 7) After the engine reaches normal operating temperature, apply a manometer and check the crankcase pressure while in notch 8 load.
 - a) If a maximum pressure of negative 1 inch is present in notch 8 load, and the engine crankcase protector does not trip, this completes troubleshooting.
 - b) If the engine crankcase protector trips with negative crankcase pressure:
 - i) Check for an improperly applied lube oil relief valve. If discharged inboard instead of outboard, false trips can occur.
 - ii) Check that the main lube oil and piston cooling pump discharge pipe O-rings are in place. Leaks in this area can cause false trips of the EPD.
 - iii) If nothing else is found at this stage, renew the protection device and repeat this test.

- 8) If negative crankcase pressure cannot be achieved while loading, perform the following:
- a) Dismantle and inspect the eductor and lube oil separator looking for plugging or being improperly orificed.
 - b) Check for lower liner seals missing or bad. This can be achieved by flooding the air box with water.
 - c) Perform a cylinder compression test.

In most cases, following this complete procedure will lead to the solution of a crankcase overpressure problem.

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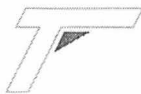


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II. UNION PACIFIC'S NEW EMD DIESEL ENGINE REBUILD LINE AT DOWNING B. JENKS LOCOMOTIVE FACILITY NORTH LITTLE ROCK, ARKANSAS

by Tad Volkmann, UP

Background

When Union Pacific and Southern Pacific merged in 1996, both railroads possessed EMD diesel engine rebuild lines at their respective backshop facilities in North Little Rock, AR and Denver, CO. An intensive merger study indicated that it would best serve the combined railroad to primarily concentrate EMD heavy maintenance at North Little Rock and GE maintenance in Denver, so a strategic decision was made to discontinue EMD engine rebuild activities at Denver in favor of a combined EMD engine rebuild line at North Little Rock.

The Existing Denver Engine Rebuild Line

Denver's Burnham Locomotive Shop has a straight line engine build concept that had been designed from a clean sheet of paper in 1991 concurrent with Southern Pacific's decision to cease engine rebuilding in Sacramento, CA, and concentrate nearly all locomotive backshop activities, including EMD engine rebuilding, at Denver. The primary designer of this engine line was Dennis Magures, who was general foreman in the Burnham Shop at the time. The Denver engine line

was designed for an ultimate production capacity of 355 engines per year at a staffing of 68 craftsmen, spread over three shifts on a seven day per week basis.

Denver Engine Line Design Criteria

- Straight line engine qualification and assembly
- Off-site vendor warehouse - just in time material support
- Unit exchange of engine wear components (power assemblies, turbochargers, pumps, governors, injectors, etc.)
- In-house qualification and reconditioning of durable engine components (crankshafts, camshafts, gears, housings, layshafts)
- Extensive block welding machining repair to minimize block UTEX expense
- Innovative "stab pit" concept for power assembly application
- Modular final build stations for assembly of engine ends and middles with self contained care system.

The Denver engine line was well thought out, planned, and laid out. Although it never was staffed for the ultimate designed production capacity, the Denver line did achieve a regular production of 250 engines per year utilizing 42 craftsmen on a five day per week schedule (one engine produced per each working day). Actual productivity equated to six engines rebuilt per each craftsman, per year.

The Existing North Little Rock engine rebuild line

The Jenks engine line was originally set up when Downing B. Jenks Shop was opened in 1984, and evolved in a sometimes organized manner as the years passed and production needs increased. By UP/SP merger time in 1996, the existing line was a contained sprawl that occupied parts of two different crane bays. The existing line had both positive and negative features.

Positive Features:

- Excellent power assembly application stabbing system utilizing Proceco turning fixtures and staffed with two men per station.

This system actually took 1-3/4 man hours less than the impressive Denver engine line "stab pit" concept to apply an engine set of power assemblies.

- Good "high production" crankcase repair philosophy.

The Jenks philosophy was to purposely limit the amount of process time and man hours spent on repair and line boring of crankcases and oil pans, in order to maximize production capability. Extensive crankcase repair and machining jobs were kicked out of the process line and outsourced to vendors who could effect the repairs in a more economical manner.

- Experienced, productive workforce.

The "ace-in-the-hole" of the existing Jenks engine line was an experienced and productive force of 41 craftsman, who consistently overcame poor layout and crane coverage to produce one complete engine per two-shift working day. Unfortunately, the production was achieved with the workforce having to "swim upstream" against the existing engine line's limitations.

Negative Features:

- Awkward engine assembly flow.

Engine assembly was conducted in two separate, side-by-side crane bays. Partially assembled engines had to be "handed over" between bays on a balky, unreliable air pallet in order to complete the assembly process.

- Inadequate crane coverage

Crane coverage was horribly inadequate. Two power assembly application "stabbing stations" had to share just one single leg gantry crane. Four final build stations shared two single leg gantry cranes. Craftsmen spent a significant part of their work days waiting for a crane.

- Disorganized material ordering and delivery system.

The existing engine line material system relied on the engine line supervisor and material expeditor to figure out each day what material would be needed that

day; then generate a material requisition and transmit or walk the requisition over to the supply department. Although the Union Pacific had a future material planning feature in its project computer system that ordered appropriate quantities of material for specific projects, this computer system did not help the engine line plan for material needs into the future nor did it assist in actually ordering the parts from the supply warehouse. As a result, the existing engine line material system was reactive in nature and entailed a great deal of managing by exception.

The EMD Diesel Engine Line Project Team

After initial in-depth studies of the existing Denver and North Little Rock EMD engine rebuild operations, it was time to combine the best features of both lines into the best overall high volume engine line possible, within budgetary constraints. Union Pacific's newly appointed Manager Locomotive Facility-Engine Tad Volkmann formed a project team consisting of engine line craftsmen, supervisors, and managers from both Denver and North Little Rock to tackle this task. Consultants to the team were Jack Jolley, General Director - Rebuild Operations; and Dennis Magures, Director - Rebuild Operations, Denver Burnham Shop. The project team commenced work in April 1997 and first set the goals that they would strive to achieve in the new engine line design:

The Projects Team's Goals

- Maximize safety in the physical layout and work flow
- Design production capacity to remanufacture 500 EMD engines annually
- Achieve 50% synergy savings through:
 - 1) straight line engine assembly process flow
 - 2) increased crane availability
 - 3) limiting process time spent on crankcase repair
 - 4) improve material planning, ordering, and deliver.
- New engine line must be up and running by September 15, 1997, when 20 transferred Denver line employees arrive to work at NLR.

The Project Team's Design Process

The project team studied all positive and negative aspects of both existing engine lines, and conducted critical path process flow analysis of each line. Starting with a blank sheet of paper, the team started mapping various physical layouts, sifting the proposed layouts against the required process flow to achieve a maximum production capability of 2 finished diesel engines per working day, and an engine process dwell time of five and one half days. Five different physical layout proposals were prepared and distributed to all craftsmen working at both Denver and North

Little Rock engine lines for their comments, ideas, and suggestions. After gathering feedback from all engine line employees, the team members met on May 29 and 30, 1997, along with team consultant and Denver engine line designer Dennis Magures, to adapt a finalized physical layout for the new Jenks engine line. The team went through a formal decision making process, and by the end of a sometimes agonizing and contentious session, emerged with the final design.

The New North Little Rock Jenks EMD Engine Line Design

Overview

The new engine is designed with all engine assembly operations performed in one bay, with engines oriented in a linear manner at all work stations. Engine strip remains in the adjacent bay, along with crankcase qualification and welding operations, due to space limitations and excessive cost that would be incurred in moving an existing large Proceco engine block cleaning machine. In-house crankcase welding and repair has been limited to 16 process hours for both process flow and economic reasons.

Qualified/repaired crankcases now move from the qualification bay to the assembly bay on a simple rubber tired dolly, pulled by a forklift truck. Crane availability has been increased by 300%. The material planning, ordering and delivery process has been vastly improved by integrating the first

application of Union Pacific's new bill of material driven production planning system computer program into the engine line design. The engine line supervisor or material expeditor are now able to look at material availability and future-order material for scheduled production needs up to 21 days into the future. Actual material delivery is accomplished to 10 different consignee locations along the engine line, with material delivered no more than eight hours before anticipated usage.

Engine Strip

Although the engine strip area was not moved from its location in the old Jenks engine line, the room was extended 10 feet to the south to accommodate an additional coffin type engine block washing machine. The necessity for parallel cleaning of two engine blocks was indicated by critical path process flow analysis.

Block Qualification and Welding

These operations are now located just south of the engine strip area, and adjacent to the engine assembly bay. Three qualification/welding stations are supported by compact turning fixtures relocated from Denver.

Contaminated air evacuation and welding flash protection systems have been vastly improved over the previous engine line. As mentioned before, maximum allowable process time for crankcase welding repair has been set at 16 linear process hours.

Crankcase Line Bore

The line bore station is now located at the north end of the engine assembly bay. The old Jenks line bore machine has been replaced with a new machine jointly developed by Union Pacific line bore machinists and Advanced Engineering Industries of Plymouth, Mich. The new line bore machine is a portable, single head design that features whole crankcase reach ability on one set-up, cutting feeds and speed more than double the old machine's capability, and touch probe set-up technology. Line boring process time is also held to a maximum of 16 hours to conform to the critical path. The crankshaft is applied to this work station after line bore is finished. A new 10 ton single leg gantry crane services this area.

Power Assembly Stabbing

The power assembly, camshaft, and head frame application operations are done at two stabbing stations located in the engine assembly bay just south of the line bore work station. The original Jenks method of stabbing has been retained, utilizing two Proceco turning fixtures. Each stabbing station has its own three ton single leg gantry crane.

Engine Final Build

Engine ends and exhaust decks are assembled in three final build stations that were relocated from Denver, and final assembly operations mirror the former Denver engine line's best practice.

Each final build station is equipped with power ramps and a self-contained "jungle gym" dual overhead crane system.

Implementation of the New Engine Line

As soon as the design concept was finalized, the engine line project team set out immediately to unlock capital funds allocated to the project, plan a phased implementation that would not disrupt normal engine production, order both capital and O.E. equipment and accomplish necessary utility and concrete work.

Planning, preparation, and implementation work commenced according to schedule, culminating in a flurry of equipment moving and installation activity the weekend of September 13-14, 1997. By September 22nd, when the transferred craftsmen from the Denver engine line arrived at North Little Rock Jenks Shop to work, only the crankcase qualification and welding area was not complete. On September 25th, the Union Pacific board of directors toured the new North Little Rock Jenks EMD diesel engine rebuild line.

Results of New EMD Diesel Engine Rebuild Line at North Little Rock Jenks Shop

Seventeen Denver engine line employees transferred to the Jenks engine line on September 22, 1997. After a two week orientation to Jenks Shop, they joined the 41 existing engine line employees,

increasing the work force by 41%. The engine line work force was redistributed into a three shift per day, five day per week operation. The new engine line went through a period of adjustment and tuning, culminating in a concentrated test the week of December 8, 1997 to confirm that the operation could generate the engine rebuild throughput to keep pace with an ambitious 1998 overhaul plan envisioned at that time, which included 439 EMD locomotives.

Actual Synergy Savings

- 1) Old Denver engine line

5 rebuilt engines/week

42 engine line workers

x 50 working weeks/yr

= 5.95 engines/man/year

- 2) Old NLR Jenks engine line

5 rebuilt engines/week

41 engine line workers

x 50 working weeks/yr

= 6.10 engines/man/year

- 3) New NLR Jenks engine line

10 rebuilt engines/week

58 engine line workers

x 50 working weeks/yr

= 8.62 engines/man/year

SYNERGY SAVINGS - 41.3%

Estimated Ultimate Production Potential

Based upon experience to date, and an ultimate design staffing of 76 engine line employees, it is estimated that the ultimate production potential of the new North Little Rock Jenks EMD diesel engine rebuild line is over 600 engines per year.

One of the most important lessons learned in the engine line project was the value of a cross functional team of subject matter experts, supported by active feedback from all of those employees who would be affected by the project. Close communication and constant follow up were absolutely key to the success of the project. Special thanks is due the former Southern Pacific Denver engine line employees, who despite facing relocation and disruption of their lives, willingly gave their active input and support to the project from the very beginning.

We will now view a brief video presentation featuring the new engine line.

III. GE TURBO REBUILD PROCEDURES

By Ed Burrier, Norfolk Southern

A. General Procedure for Disassembly of GE Engine Turbochargers

References: GE Backshop Manual Vol. III and Norfolk Southern Quality Assurance Manual.

1. Inspection

a) Prior to disassembly, make a preliminary inspection. Record the conditions found, as they may affect the extent and nature of the work required. A thorough inspection often will show conditions that existed on the engine from which the turbocharger was removed and which should be reported and corrected.

- 1) Record the serial number of the turbocharger assembly
- 2) Examine the turbocharger for missing or broken parts.
- 3) Examine the turbine inlet assembly for signs of overheating (excessive high pre-turbine temperatures).

b) Thorough inspection should be continued through the entire repair and overhaul process.

2. Disassembly

a) Secure the turbocharger in the servicing fixture provided.

Position the turbocharger with the compressor end up.

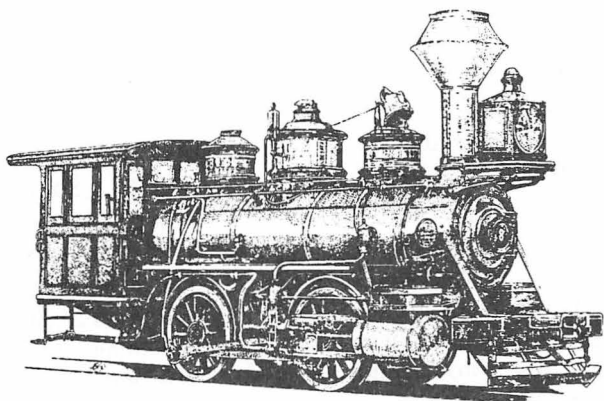
b) Remove the bolts and lockwashers which secure the blower inlet to the blower casing. Install three 1/2" - 13 bolts provided in the blower inlet and jack the blower inlet from its fit in the blower casing. Let inlet clear, being careful not to bump and damage the compressor wheel.

c) Remove the bolts and lockwashers which secure the blower casing to the turbine casing. Lift blower casing and diffuser clear of the turbocharger assembly and bolt the blower casing to the stand provided for its trip to the aluminum wash.

d) Position the turbocharger with the turbine end up.

1) On older designed turbochargers with the scalloped inlet flange, remove the lockwashers, bolts and heat treated washers which secure the turbine inlet assembly and keys to the turbine casing. Install four 1/2" - 13 bolts in the holes provided in the inlet lange and jack the inlet flange from its fit on the turbine casing.

2) On recent designed turbochargers with round inlet flange, remove the lock wire, bolts and keys which secure the turbine inlet



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clamp ring to the turbine casing. Install four 1/2"-13 bolts in the holes provided in the inlet flange and jack the inlet flange from its fit on the turbine casing.

e) Lift out the turbine inlet assembly. Place it on a bench and assemble as follows:

- 1) Remove and discard bolts and nuts which secure the retainer to the nose piece. Remove the retainer and nose piece.
- 2) Remove and discard bolts and nuts which secure the shroud to the inlet flange. Remove the shroud and nozzle ring.

f) Position the turbocharger in its normal position (feet down). Disassemble and remove the rotor assembly in the following manner.

- 1) Use one wrench applied to the flats near the end of the rotor stud to secure the stud from turning. Simultaneously use a second wrench to loosen and remove the rotor locknut.
- 2) Remove the turbine disk assembly together with the stud as a sub-assembly. First install a protective cap, Part No. 147x2077, on the compressor end of the stud. Then lightly tap the end of the cap to force the disk from its doweled and rabbled fit to the rotor shaft.

CAUTION: Take precautions to prevent disc assembly from falling and becoming damaged as it is disengaged from the shaft.

3) Install three 5/16"-18 screws in holes provided in the cap and jack the cap from its fit between the shaft and compressor wheel sleeve.

NOTE: Some models require the use of three 1/4"-20 screws for jacking the cap loose. Apply torque to all jacking screws in small increments to prevent cocking the cap during removal. Cocking the cap may deform the tapered segments of the cap.

4) Apply puller, Part No. 147x2227, and pull the compressor wheel assembly together with the key from its fit on the shaft.

NOTE: On early production turbochargers secure the puller to the compressor wheel sleeve with 3/8"-16 bolts; on current production turbochargers use 3/8" - 20 bolts.

5) Remove the lockwires and capscrews which secure the blower end seal to the turbine casing. Install three 1/4"-20 screws in holes provided in the seal and jack the seal from its fit in the turbine casing.

- 6) Remove the thrust collar from the rotor shaft.
- 7) Remove the lockwires and capscrews which secure the turbine end seal to the turbine casing. Use a pry bar and gently work around the seal circumference to pry the seal from its fit in the turbine casing or use jack screws on later models.
- 8) Remove the rotor shaft from the turbine casing.

NOTE: Rotor assembly components should be temporarily reassembled for shipment to the dynamic balancing unit, protective wooden box provided.

- 9) Remove the bearings from their fit in the turbine casing.

NOTE: Turbine casing seals and bearings should be scrapped.

- 10) Remove the side clean out covers and clean out flange covers.

- 11) Component parts should be cleaned as follows:

- a) Turbine casing to Proceco washer.
- b) Turbine inlet assembly and blower inlet to Proceco washer and then to glass bead machine.
- c) Aluminum diffuser (blower) to aluminum washer.

B. General Procedure for Rebuilding of GE Engine Turbochargers

References: GE backshop manual Vol. III, and Norfolk Southern Quality Assurance Manual

- a) After checking for cracks around the four mounting bolt holes in the feet, secure the turbine casing in the servicing fixture.
- b) All component parts upon return from cleaning should be inspected for cracks or flaws that may develop on surfaces during normal operation. Especially susceptible are the parts exposed to numerous thermal cracks.
 - 1) Turbine casing; tap exhaust stack and turbine inlet assembly mounting holes. Remove all old seal/gasket from mounting face. Blow out the oil passages with compressed air.
 - 2) Blower casing; remove all old sealant from the faces and be sure they are free of nicks and cracks.
 - 3) Blower diffuser should be handled with care to avoid damage to the vanes and flat mounting surfaces roughness. Reject diffuser when vanes are cracked or damaged or when the throat opening between vanes exceeds an average of 1.240".

- 4) No cracks permitted in later design inlet flange. Remove burrs, nicks and upset metal from rabbet fits.
 - 5) Check shroud for cracks and foreign object damage. Radial cracks outward from mounting holes are acceptable; no other cracks are allowed.
- c) Install new rotor shaft bearing as follows:
- 1) Clean and examine both bearing seats in the turbine casing. The bores and seats must be free of dirt, burns, nicks and picked up metal. Bores must be 2.9382" - 2.9375".
 - 2) Clean the new bearings with a soft cloth or paper towel. Examine the new bearings and ensure they are free of nicks, scratches or other defects.
 - 3) Super cool the new bearings to -102°F and quickly install them in their respective bores. Make certain the dowels engages in the dowel groove.
- WARNING:** To prevent personal injury, wear protective gloves when handling the super cooled bearings.
- 4) After bearings reach turbine casing temperature; check to ensure the back faces of the bearings are in complete contact with the faces of the turbine casing; a 0.0015" thickness gauge should not enter between these surfaces at any point around the circumference.
- 5) Now that bearings have reached turbine casing temperature, measure bores with inside micrometers (three measuring points) and record on worksheet under comments.
- 6) Lubricate bearing surfaces with film of oil.
- d) The dynamically balanced rotor must be disassembled as follows; being careful to mark the thrust collar with the line corresponding to the shaft keyway, so that dynamic balance can be maintained during the assembly process.
- 1) Remove stud locknut and use jacking screws to remove cap. If cap is equipped with permanent magnets, make certain magnets are secure and like poles are in the same direction.
 - 2) Use puller to remove wheel assembly.
 - 3) Remove thrust collar-mark for reassembly.
 - 4) Separate shaft from disc assembly by using two pry bars.

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- 5) Measure shaft diameter corresponding to each bearing bore to determine bearing clearance to be recorded on worksheet.
 - 6) Check the "stud to turbine assembly" torque for the correct 60 ft. lb. value. Apply torque at 7/8" flats on the rotor stud using the stud torque application tool.
 - e) Apply a bead of high temperature sealant to the blower end seal mounting face of the turbine casing. Position the thrust collar in the blower end seal and assemble with new bolts coated with anti-seize compound. Tighten the bolts with 5-8 ft. lb. of torque and lockwire pairs of bolt heads in a tightening direction.
 - f) Insert the rotor shaft through the bearings being careful to align the keyway with the thrust collar mark.
 - g) Apply the bead of high temperature sealant to the turbine end seal mounting face in the turbine casing. Assemble the turbine seal and secure with capscrews coated with anti-seize compound. Tighten capscrews with 5-8 ft.lb of torque and lockwire pairs of bolt heads in a tightening direction.
 - h) Check that thrust collar mark is still aligned with shaft keyway, assemble compressor wheel and align keyways by installing key. Tap key into place until it stops at the groove in the sleeve. This is necessary to retain rotor balance.
 - i) Assemble the turbine disc assembly into the rotor shaft making sure the offset dowel holes are aligned. Bolt pusher bar fixture on turbine end of casing and tighten pusher bolt to hold turbine disc assembly against end of shaft.
 - j) Apply rotor cap to engage cap keyway with the key. Apply locknut into the rotor stud. Back off the pusher bolt from the disc assembly. Apply stud holding tool on flats at end of rotor stud and position stud tool handle against servicing fixture so it will prevent stud from turning clockwise. Retighten the pusher bolt. Tighten the rotor stud locknut to 100 ft.lb. of torque; loosen and retighten to 80 ft. lb. of torque. Remove the pusher bar fixture and the stud holding tool.
- CAUTION:** The compressor wheel must not turn while tightening the locknut to avoid loosening the stud in the turbine disc.

- k) Rotate the rotor assembly to ensure it turns freely, then measure and record the rotor assembly end play which should be 0.012" - 0.024". Move all rotor end play toward the blower end, then measure the clearance between the turbine disc and turbine seal, which should be 0.020:-0.049".
- l) Sub-assemble the turbine inlet assembly as follows:
- 1) Assemble nose piece, the nozzle ring and the retainer. Secure the six new bolts and locknuts. Apply liquid non-flavored milk of magnesia to bolt threads before assembly. Tighten bolts and nuts to 25-30 ft. lb. of torque; loosen and retorqued to 16-20 ft. lb. of torque. Check the integrity of this sub assembly relative to the nozzle ring. There should be no axial or circumferential movement of the nose piece.
 - 2) With the inlet flange placed on its exhaust manifold face, assemble the subassembly with the nozzle ring, locating lug position in the keyway in the flange.
- NOTE:** Tighten retainer and shroud bolts and nuts using a 1/2"-12 point socket or combination wrench on the nuts and a 7/16"-12 point deep socket or combination wrench on bolt heads. Use sockets with torque wrench.
- 3) Assemble the shroud in place and secure it with eight new bolts and locknuts. Apply liquid, non-flavored milk of magnesia to bolt threads before assembly. Tighten bolts and nuts to 12-16 ft. lb. of torque.
- m) Assemble the turbine inlet assembly to the turbo as follows:
- 1) For older turbine inlet assemblies with scalloped inlet flange, loosely bolt four locating keys to the turbine end of the turbine casing after applying high temperature anti-seize thread compound to the bolt threads and washer faces. Using two guide pins, Part No. 147x2073, in turbine casing bolt holes, position the turbine inlet assembly in the turbine casing, aligning four keys in the slots. Secure with bolts and new hardened flat washers. Apply high temperature anti-seize compound to all threads of tapered holes, bolts and to the washer face of bolt heads before assembly. Torque turbine inlet assemble bolts to 35-40 ft. lb. Torque locating bolts to 20-25 ft. lb. Lockwise pairs of bolt heads in a tightening direction.

- n) Working down the exhaust pipe discharge opening of the turbine casing and using thickness gauges, measure the clearance between the turbine bucket tips and the shroud bore at four locations, bottom, top and each side. Record measurements on work sheets.
- o) If the diffuser has not been rejected for any defects and remains installed in the blower casing, then check the torque on the six flat head screws and confirm they are within the 6-9 ft. lb value. Stake screws by prick punching to force different metal into each end of each screw slot.
- p) If the diffuser has been rejected, sub-assemble the blower casing and diffuser in the following manner:
- 1) Apply a light coating of Molykote 321 lubricant to the mounting face of the diffuser and to the face of each vane.
 - 2) Install the diffuser and six flat head screws. To center the diffuser in the blower casing, tighten the screws in a crisscross pattern in small increments up to the final torque of 6-9 ft. lb.
 - 3) Stake screws by prick punching to force diffuser metal into each end of each screw slot.
- q) Apply a thin coat of Permatex No. 2 or RTV sealant to the blower casing mounting face on the turbine casing.
- r) Assemble the blower casing diffuser subassembly taking care not to damage the tips of the compressor wheel and secure with bolts and lockwashers. Tighten bolts in a crisscross pattern in increments up to the final torque of 55 ft. lb.
- s) Carefully install the blower inlet to avoid damaging the compressor wheel. Secure the bolts and lockwashers tightened to 40-50 ft. lb. of torque.
- t) With the turbocharger in an upright (normal) position, check that the rotor turns freely, then measure the radial clearance between the compressor wheel and blower inlet at a distance of 1/4"-3/8" in from the face of the wheel. Check at four locations, top and bottom and both sides.
- u) Apply pipe plugs to all open pipe tapped holes. Apply fiber board covers to all air, exhaust, water and oil openings prior to sending to the paint booth.

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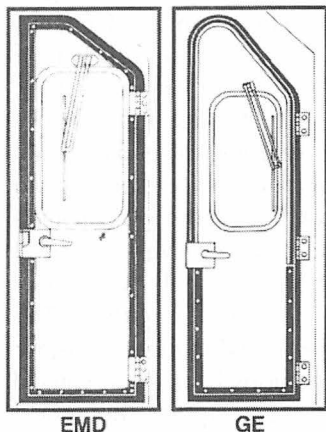
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IV. MECHANICAL IMPACT OF LOCOMOTIVE EMISSIONS REGULATIONS

by Jack Kuhns, Durox Company

As everyone is probably aware, the next challenge facing our industry collectively is meeting EPA mandated emission standards. These standards, signed into law earlier this year, represent a significant hurdle we all must clear in order to continue to grow as an industry and as individual corporations.

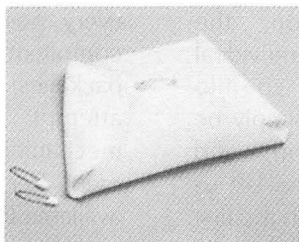
To put a perspective on these standards, we may have personally been affected by EPA standards with our own vehicles by having to comply with annual E-checks necessary for license renewal. If the test was less than satisfactory, we then had to face the financial dilemma of trying to keep a not-so-new but otherwise serviceable vehicle on the street, or replacing it with a new one or invest in the old one. This is exactly what our industry must decide. The guidelines by which we will make these decisions have been spelled out clearly (?) in the short document titled Emission Standards for Locomotives and Locomotive Engines. This 81 page document is quite comprehensive.....

For the purpose of this brief paper we will only be focusing on the tiered level of emissions standards and how they will effect the mechanical components we deal with on a daily basis. Specifically, we will only detail the

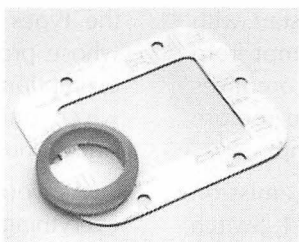
first level or Tier "0". As of this writing, details of specific components and kits that will be mentioned shortly have not been made available from the industry's vendors. It is hoped that at the annual meeting more specific details can be reported. This report will continue in the future as new levels of compliance come due and new technology is made available.

It should be mentioned that a system has been put in place that will allow for fleet averaging and banking of credits for those units or fleets of units that meet or fall below the standard of their type, and the trading or selling of credits between remanufacturers and builders. The application of this aspect of the requirements is to be determined on a fleet by fleet basis, by each individual company. This part of the ruling document allows individual railroads to work with either the original equipment manufacturers or with aftermarket suppliers to establish fleet averages. These averages will be based on tested or certified "kits" or "components" that are applied to specific locomotive types that bring the type into compliance with the tiered levels of emissions.

There is also a system in place that will put a total dollar cap on the investment that must be made to each type of locomotive in the attempt to bring it into compliance, based on the cost spread over the projected service life of the locomotive.



STOPS LEAKS.



STOPS LEAKS.

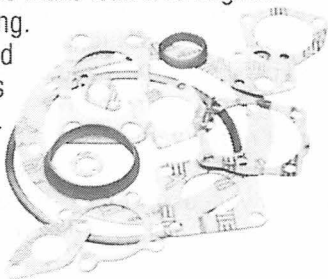
NO DROPS. NO DRIPS. NO DRIBBLES.

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Our exclusive Swellex™ gaskets and Durogard seals will stop all oil leaks from diesel locomotives. No drops.

No drips. No dribbles. The cost is minor. The savings are major. The proof is convincing. **And part of our world is cleaner.**



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DUROX
COMPANY

This is admittedly a very simple overview/interpretation of the EPA emission standards as they apply to our industry and leaves out numerous details that may have a pronounced affect on the decisions made by the individual rail companies, but to go into much greater detail will simply be subjective interpretation and would spawn long debate. Let us now attempt to focus in on the first level or "Tier 0" and how that will effect our current equipment.

It might be easier to start with what locomotive are exempt from these standards. Any locomotives that were manufactured before January 1, 1973 are exempt.

There will be two emission levels as shown in Figure 1. Switch engines will be held to a lower standard than line-haul locomotives. It should be noted that switch units will be defined as units having 2300 horsepower or less.

The first classification will be for those locomotives produced after 1973 and before 1990. Those units must meet Tier "0" emission levels at their first rebuild after January 1, 2000. A rebuild is defined as when all the power assemblies have been replaced with new or remanufactured. This of course leaves the owner/operator with the aforementioned dilemma of extensive retrofit of an approved system that will bring the older unit into compliance, or replacement with a unit that has already been brought into compliance through

rebuild and offered for sale, or purchasing a unit that is newly manufactured to the higher standards. For the purpose of this paper, again, we cannot cover every possibility because of the complexity of the total fleet packages; therefore, we will only attempt to report on the mechanical options available to meet Tier "O" that are currently available to the industry.

We will start with the GE units. See Figure 2, 3 and 4, which list the types that are exempt, those whose production dates span the exemption cut-off date, and those which only have been produced since January 1, 1973.

As you can see from the list everything through and including the U33B will be exempt. There are several types that have production runs of manufacture prior to the cut off date of exemption but continue through January 1, 1973. These include the U23B, U33C, U36B, U36C and the B30-7.

All the other models starting with the U18B and down the list, will have to comply. The options at this time for the GE units will be to retrofit a split cooling package. This includes new radiators with increased capacity as well as matching intercoolers that will reduce the induction temperatures. This must also be matched with electronic fuel injection (EFI). This will be necessary because either one

alone will not be able to certify the engine. The cams will have to be changed with the EFI, as well as the nozzles and most of the components of the fuel system including filter housings and associated hardware. There may be the need to match the turbo to the engine as well.

These modifications would probably be accomplished in the backshop rebuild program as the extent of the modifications would require enough downtime that a complete overhaul would probably be considered. At the time of this writing a complete bill of materials has not been generated. This is due in part because a "kit" has yet to be certified that is universal. Another factor concerning older model 7FDL engines is that the block castings of certain production runs are not heavy enough in the area of the cam and cam bearing areas to take the higher forces present in the operation on the EFI injection pumps. A breakdown of the serial numbers and respective horsepower ratings will follow this text.

For EMD locomotives the breakdowns by model types in relation to the production runs are shown in Figure 5 through 10. As with the GE units there are a number of units whose production runs span the cutoff date. There are also quite a few models still currently in service across the industry that are exempt.

For the EMD locomotives the options are similar to those for the GE units, in that attention must be given to the aftercoolers and the fuel delivery system. EFI must be used in conjunction with a four pass aftercooler. On certain units this may have to be accompanied with a 4° retard in injection timing. Reported testing to date has shown that with the above modifications the 710 series turbocharged units should reach Tier "0" requirements. This will come with an approximate fuel penalty of 3%. Testing has not been completed as of this writing but preliminary tests show that the 645 turbocharged engines in the SD40-2 and GP40-2 might be able to meet the Tier "0" level with an improved fuel injector and the timing retard. The SD50 series might have a difficult time without a reduction in the horsepower rating as this engine was optimized for fuel economy and has a resulting higher NO_x rating proportionally. Testing on the GP40 and SD40 has not been documented. The switch engine fleet comprising of all the rest of the active units under 2300 horsepower will probably be able to meet their standards with newer technology power assemblies and fuel injectors.

The Tier "0" standards apply to all locomotives produced between January 1, 1973 and through the 2001 model year. They must meet the standards at their first rebuild beyond January 1, 2002. These

standards also apply to locomotives manufactured after January 1, 1990, but they must meet Tier "0" at their first rebuild after January 1, 2001. There are other provisions for 1994 and newer locomotives that are equipped with a certified kit, as well as provisions for new production locomotives. As stated above, the specifics of the impact of the mechanical components has yet to be completely defined and a continuing analysis of the regulations without details of the designs or changes to those components would be beyond the scope of the paper.

In review, the components that will have the most attention drawn to them from our mechanical departments budgets will be: new and new-design fuel injectors and nozzles including new and remanufactured governors and EFI systems replacing governors in some systems; cooling systems, including new as well as new-design aftercoolers and radiators and associated cooling system components such as cooling fans and their operating parameters; new and new-design power assemblies, including new-design combustion chamber and piston crown technology; new and new-design turbochargers that are matched to the new engine operating parameters; and new and new-design electrical control and circuitry including new load and main generator excitation curves to help with the particulate matter side of the regulations.

In summary as our industry evolves through mergers and acquisitions the way we make decisions concerning the management of our locomotive fleets will also have to evolve. The value or perceived value of locomotives may be now based on a whole new set of criteria. Our work forces must now be trained in a whole new set of skills involving locomotive maintenance and troubleshooting as well as the actual testing and monitoring of locomotive emissions. In closing, our fleet management and purchasing decisions will be even more than now dictated by total life cycle costs of locomotives and their components.

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Tier "0" Emission Levels For Line-Haul Locomotives

- HC₂ = 1.00
- CO = 5.00
- NO_x = 9.50
- PM = 0.60

Tier "0" Locomotive Emissions For Switch Duty

- HC₂ = 2.10
- CO = 8.00
- NO_x = 14.00
- PM = 0.72

Figure 1

GE Locomotives That Are Exempt

- | | |
|---------|--------|
| → UM20B | → U25B |
| → U25C | → U30C |
| → U50D | → U30B |
| → U28B | → U28C |
| → U28CG | → U50C |
| → U30CG | → U33B |
| → U23C | |

Figure 2

GE Locomotives Whose Production Runs Span the Cutoff Date

- | | |
|--------|---------|
| → U23B | 1968-77 |
| → U33C | 1968-75 |
| → U36B | 1970-76 |
| → U36C | 1971-75 |

Figure 3

GE Locomotives By Type That Must Comply

- | | |
|------------------|--------------|
| → C30-7 | → Super 7C30 |
| → B23-7 | → B32-8 |
| → C36-7 | → B36-7 |
| → AC6000 | → -9-44CW |
| → C39-8 | → AC4400 |
| → -8 40C | → B39-8 |
| → AC Convertible | |

Figure 4

EMD Locomotives That Are Exempt

→ GP7&9&18	→ GP&SD35
→ SD7&9&18	→ GP&SD38
→ GP20	→ GP&SD40
→ SD24	→ SD45
→ GP30	

Figure 5

EMD Locomotives Whose Production Runs Span the Cutoff Date

→ SD45-2	1972-75
→ GP38-2	1972-85
→ SD38-2	1972-79
→ SD40-2	1972-86
→ GP40-2	1972-86

Figure 6

EMD Locomotives By Type That Must Comply

→ GP38-2	→ SD80
→ GP15T	→ SD90
→ GP15-1	→ GP60
→ SD60	→ GP50
→ SD50	
→ SD70	

Figure 7

**EMD Switcher Locomotives
That Are Exempt**

→ SW1200

Figure 8

**EMD Switcher Locomotives
That Must Comply**

- MP15
- MP15AC
- MP15T

Figure 9

**EMD Switcher Locomotives
Whose Production Runs
Span Cutoff Date**

→ SW1500

1966-74

Figure 10

GE Diesel Engine Blocks and Maximum Rated Horsepower
These numbers are located in the left front mounting foot.

12 Cylinder

Block Serial Number	Max. H.P.	Start Mfg.	Comments
41R992027H1 to H4	2500	1963	First Double Wall
41R992027H1 to H4 must have "H" or "K" in the S/N or case date code	3000	1967	Double Wall
41R992027H5 and Higher	3150	July 1969	Heavy double wall near oil header, with rib on inboard boss of cylinder hold down bolt
41R992162H2	2250	June 1970	Cast date only one made for Conrail single wall
41R992162H4 to H14 even "H" numbers	2500	July 1974	Single wall
41R99216H16	3000	April 1975	Two horizontal internal edges single wall
41R99258H2 to H9	3200	May 1975	Present pattern sloping internal crankcase upper edge current production single wall

16 Cylinder

Block Serial Number	Max. H.P.	Start Mfg.	Comments
Cooper-Bessemer to FVDL-9-A	2500	1960 & 61	15 frames cast
41R992162 H1 & H3	2500	Jan. 1970	S/N E7004010, 12, 13, 14, 18 for application at this rating only
Cooper-Bessemer FVDL-9-J	3300	Cast Dates prior to 7-3-69	
41R992003H1 to H5	3300		Double Wall
41R992009H1 to H5 with "K" or "H" in cast date & S/N May also be stamped 41R992135 for Erie machined castings	3600		Double Wall
41R992009H7	3600		

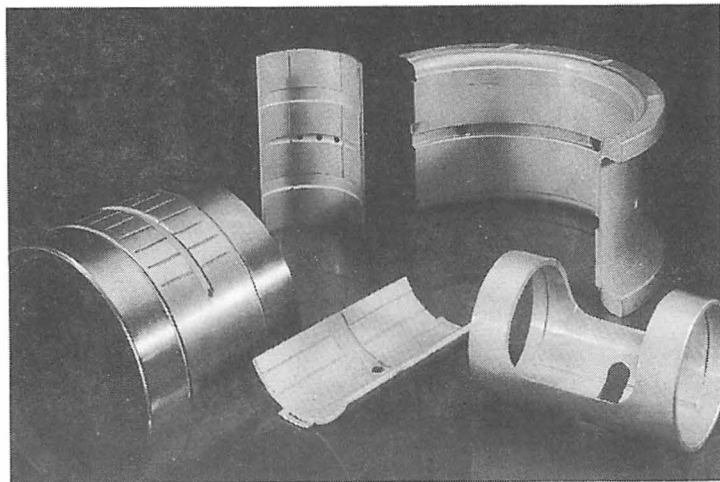
Block Serial Number	Max. H.P.	Start Mfg.	Comments
41R992162H5 and Greater O "H" numbers	3600	Aug. 1970	Castings have a 1/4 inch radius relieved area around the upper bearing nut seat, single wall.
41R992003H6 and Greater May also be stamped 41R992135 for Erie machined castings.	3900	July 1969	Long ribs running in vertical direction as extensions of the cyl. bolt boss at lube oil header double wall
41R992258 All odd "H" numbers	3900	Sept. 1974	Current production, single wall
41R992525H1 to H3	3900		

Figure 11

“Discover The Locomotive Engine Bearing Specialist”

Railways worldwide are using MIBA Bearings in their EMD, G.E. and ALCO Engines. They depend on MIBA for continuous research and development and for MIBA's manufacturing quality assurance systems to provide the added service life that the railways want for their engines.

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The following paper on Engine Bearing Developments was presented by John Sadler of the CN at last year's convention but did not make it to print in time for publication in 1997 Proceedings; therefore, it is included in this year's publication

V. LOCOMOTIVE ENGINE BEARING DEVELOPMENTS

Prepared by John Sadler - CN

Selection of locomotive bearing materials involves a series of compromises that ultimately leads to a finite bearing life. Compatibility, fatigue strength, wear resistance, imbedability, and conformability are all desirable characteristics of a bearing. There is no single material that possesses all of these qualities to a desirable extent, so the qualities are created in bearings by using different alloys, composites, and laminates. A soft running surface has good compatibility, conformability and imbedability, i.e. babbitt, but has poor wear resistance and fatigue strength. Increasing the fatigue strength and wear resistance is accompanied by a compromise in the property of compatibility which can lead to scuffing and seizure.

The following outlines different types of locomotive engine bearings and sets out some of the engine conditions that affect bearing life.

Trimetal Bearing

Trimetal bearings are the current standard being used in most locomotive engines. This bearing has a steel backing with a cooper-tin-lead bronze cast onto it. On top of this bronze layer, a soft overlay (.001" to .002") is electrodeposited.

In the standard trimetal bearing, a nickel bonding layer is electrodeposited on the bronze

layer prior to the application of the overlay to prevent tin migration. Tin has a tendency to migrate out of the overlay into the bronze, softening the overlay with time.

GM has made changes to this standard technique by eliminating the nickel bond layer and increasing the overlay to .004". Their purpose is to make the bearing more conformable to block line bore distortions and offer better protection from corrosive occurrences and extraordinary events. It's bond method utilizes the standard diffusion of metals combined with a mechanical technique to improve the bond strength and reduce occurrences of overlay flaking. This technique also eliminates the hard nickel barrier that does not provide an acceptable bearing surface when the overlay has worn through.

In the standard trimetal bearing, the overlay is soft, offers high conformability at running in, and provides good emergency running conditions. However, as this overlay wears, the bronze will eventually be exposed. The bronze is designed to run as a bearing surface when exposed, but offers less protection from emergency running conditions or extraordinary events.

Generally, the trimetal bearing has good tribological properties at the beginning (good conformability and emergency running conditions). However, these properties deteriorate as the overlay is lost in the primary load zones.

Rillenlager Bearing

This bearing was designed to improve the wear resistance of the overlay and to achieve longer service life. As in the trimetal bearing, a steel backing is covered by a bearing lining material. Tiny grooves are cut in the lining material at well defined intervals and an overlay is electrodeposited onto this surface. The bearing is then bored exposing lining material ridges (approx. 25%) and overlay grooves (approx. 75%).

A particular design using an Alzn lining and an overlay with increased copper and tin content is being tested in railroad engines. The manufacturer states that the bearings will last about four times longer than conventional trimetal bearings in railroad engines due to a low wear rate, low disturbance risk and greater corrosion resistance. The ridges of lining material support the electroplated overlay, in theory reducing the wear of the overlay and at the same time maintaining important tribological characteristics. To what extent each property is maintained will determine the success of this design.

The nickel barrier used to prevent tin migration is less of an issue on the Rillenlager, as a large area of nickel does not become exposed at the same time.

Sputtered Bearing

A bearing designed for high load carrying capability is the sputtered bearing. Originally designed for heavy duty engines with high bearing loads, the overlay is sputtered (vapor

deposited) onto a lining material in the vacuum. The result is a very fine grained structure which is harder than the standard overlay but has a higher fatigue strength.

Although a lower wear rate is expected, conformability and imbedability are compromised. The manufacturer states, however, that this hasn't been a deficiency, and its experience has shown good tribological properties in many production engines. The bearing has yet to be tested in North American railway engines.

Bearing Environment

Recent developments in locomotive engines have resulted in changes to the environment in which the bearings live. Previous locomotives had relatively high oil consumption, which led to lubricating oil being continuously "sweetened". Because of the contributions to emissions that this causes, engines are being designed that minimize oil use. Therefore without frequent oil changes, the net result is poorer lubricating characteristics of the oil. Also, changes in combustion for the purpose of reducing emissions can result in increased soot in the oil.

Firing pressures have increased in the push for improved fuel consumption, necessitating high fatigue strength materials for bearings.

Although bearing manufacturing techniques and design are improving, good prelubrication procedures, filtration, oil analysis, and avoiding critical oil temperatures are paramount in reducing bearing failures.

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
SEVENTEEN YEAR INDEX**

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 SEVENTEEN YEAR INDEX

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 SEVENTEEN YEAR INDEX

1997

1. Wheel Truing as Preventive Maintenance
2. Conrail-Selkirk Diesel Terminal Wastewater Treatment Facility Recent Environmental 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 SEVENTEEN YEAR INDEX

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
FIFTEEN YEAR INDEX**

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 Caterpillar 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 SEVENTEEN YEAR INDEX

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 Multi-grade 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.

1982

1. Energy Conserving Lube Oils.
2. Alternative Fuels Update.
3. Availability of Medium and High Viscosity Index Railroad Oils.
4. Journal Box Oil and Aniline Point.
5. Traction Motor Gear Lubricant Update.
6. Traction Motor Gear Case Seals.

1981

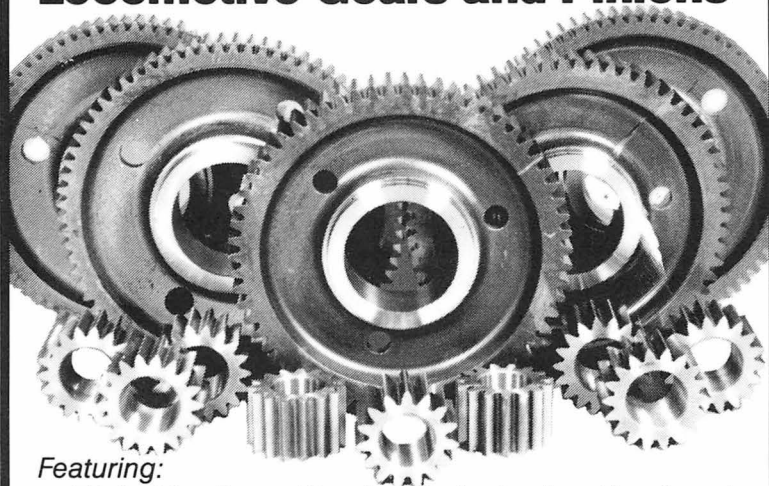
1. Effects of Using Alternate Fuels on Existing Diesel Engines.
2. Update on Cold Weather Procedures for Fuels.
3. New Techniques in Lube Oil Analysis.
4. Traction Motor Gear Lubrication.
5. Multi-Viscosity Oils as an Energy Conservation Technique.

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