LMOA

Locomotive Maintenance Officers Association

Proceedings of the 52nd Annual Meeting

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TECHNICAL PAPERS

Joint Opening Session
Monday, September 17, 1990

CHAIRMAN BATTISTA: Ladies and Gentlemen, this is indeed an honour for me to introduce our principal speaker **Mr. John H. D. Sturgess.** Born in London, England, Mr. Sturgess joined Canadian National's Engineering department in Edmonton in 1958.

In 1963, he was transferred to the Research and Development Department in Montreal and occupied various positions, eventually becoming Manager, Engineering Economics. In 1970, he moved to Vancouver as Assistant Manager, responsible for the railway's operations in British Columbia and in January 1972, he returned to Edmonton to become Regional Manager Marketing, with responsibility for freight marketing activities in CN's Mountain Region.

On September 1, 1979, Mr. Sturgess returned to Montreal as Assistant Vice President, Pricing, with responsibility for directing CN Rail's system-wide freight pricing activities. On January 1, 1980, he was appointed Vice President, Marketing, CN Rail, Montreal, with responsibility for CN Rail's marketing and sales activities in Canada and abroad and in May 1985, he was appointed Senior Vice-President, Marketing.

In August 1985, Mr. Sturgess transferred to Toronto to become Vice-President for the Great Lakes Region, with responsibility for Canadian National Railway's operations in Ontario. On February 1, 1987, he returned to Montreal as Senior Vice-President, CN Rail, and was appointed Senior Vice-President and Chief Operating Officer in July 1987.

Mr. Sturgess is married and has four children.

It is with great pleasure that I turn the podium over to **Mr. John H. D. Sturgess.**

A Decade of Challenge and Change

Keynote Speech By
John Sturgess
Senior Vice President and
Chief Operating Officer
To The
Coordinated Mechanical Association
Atlanta, Georgia
17 September 1990

I'm pleased and honored to have been invited to give the keynote address to the Coordinated Mechanical Associations here in Atlanta.

This joint session is recognized throughout the North American railway industry as one of the most important gatherings of mechanical and operating officers, as well as purchasing officers and representatives of our supply industry. It provides you with an opportunity to exchange information and discuss ideas that are of value to you and your employers.

You, more than any others, are the people who translate your companies' policies and directions into reliable and cost-effective transportation services that must earn their fair share of traffic in a highly competitive marketplace.

It is appropriate, therefore, as we enter a new decade and look forward to the beginning of a new century, that we examine some of the changes we can expect in rail transportation over the next 10 years, and anticipate how they are likely to affect railway operations and costs.

When I was preparing for this meeting, I came across the fact that Atlanta was founded just over a century and a half ago around the terminus of a state-owned railway, and that its original name was, simply, Terminus.

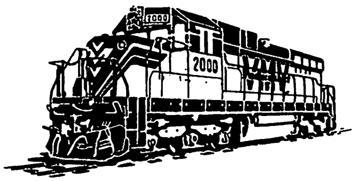
Over the years, Atlanta has prospered because of its relationship with the railway industry, and it has become such an important transportation centre that it is known today as the Gateway to the South.

I am sure that all you railroaders gathered here today in this historic railway city will agree that railways have been a foundation stone in the development of the United States and Canada.

It is our responsibility to ensure that they also play a vital role in the growth and prosperity of our two great nations in the future. The task facing us over the next decade is to modernize and improve the railway infrastructure that gives the North American economy, its backbone of steel, so that it can meet the demands of the 21st century.

The greatest challenge North American railways face in this decade is heavy and increasing competition from the trucking industry and carriers operating on subsidized waterways.

Operating in the northern part of the continent, where waterways freeze up for a significant period



every year, Canadian railroaders see trucking as the major threat.

During our lifetime, we have seen extensive highway networks built at public expense, primarily to serve an increasing number of automobile travellers. But this network has given the trucking industry the rights-of-way it needs to compete for virtually every ton of freight we carry, without having to make any significant capital investment of its own.

All truckers have to do is provide their own vehicles and terminals, and pay a contribution to highway maintenance that, in many cases, is only nominal.

Burdened as we are with the entire cost of our rights-of-way, including paying taxes on them, we in the railway industry have to fight back to retain and expand our traffic volumes.

But we still are not earning the return on investment that is vital for our survival as a dynamic industry. Making that turnaround will not be an easy contest. But it is a contest that we must and can win.

We have a number of valuable assets that we must exploit to their fullest to secure the future of railroading.

The first of these assets is our rail network, and the inherent efficiency of steel wheels rolling on steel rail. No one can match us when it comes to moving large volumes of freight overland with the least expenditure of non-renewable resources, and the greatest economy when all costs are taken fully into account.

A second asset that is ours to exploit is the new technology that scientific advances are making available to us. The nature of our operations — trains moving over a guided right-of-way — puts us in a better position than some of our competitors to make creative use of computer and other technology and increase the efficiency and safety of our operations. It is up to us — the railways and the railway supply industry — to take the fullest advantage possible of that position.

The third asset we possess is the fact that we operate the safest and most environmentally friendly mode of transportation for dangerous and other commodities. The public is becoming increasingly concerned over the potential hazards of dangerous goods in transit, something that is an unavoidable part of our modern industrialized society.

Our dedicated rights-of-way, our traffic control systems, our improved equipment, and our integrated operations allow us to offer shippers the safest mode of transportation available.

But we have to work hard to establish our safety record, and maintain it.

We also have to educate the public on the fact that rail transportation, because of its fuel efficiency, produces fewer emissions per ton-mile than other modes, and that rail lines are in many ways less damaging to the environment than highways carrying equivalent volumes of freight.

Our fourth asset is railway people. Railroading is a mature industry with a rich heritage of professional expertise and pragmatic, hands-on experience.

It is up to us to ensure that this experience and expertise are used in the most effective ways possible, and that we share these benefits with the rising generation of railroaders who will succeed us.

I have spoken of assets, so it is only fair that I mention liabilities as well. And after my opening comments, I may shock you when I say that one of our liabilities stems directly from the long history we celebrate.

History is an asset when it is viewed as a proud bridge to the past. But it is a liability if it becomes a barrier to the future.

History as a liability is most obvious in the burden of regulation that has grown up around railroading — a burden our more recently established competitors do not have to bear.

We see it in the minds of those who would restrict us with further legislation and regulation beacuse they hold outdated concepts about our industry and its role.

But we are less ready to admit that our long history and traditions can be a liability when it comes to changing our own attitudes and habits to meet a more challenging and competitive world.

Unwillingness to accept fundamental change means clinging to outdated perceptions and inefficient methods instead of adapting to new technology and techniques to make our operations more efficient and cost-effective.

Most of all, our history can be a liability if it perpetuates attitudes towards customers that hark back to the days when railways had a virtual monopoly in land transportation.

We cannot expect customers to adapt their shipping patterns and practices to meet our convenience and traditional ways of operating. It is up to us to adapt to their needs.

If there is any simple prescription for the success and survival of the railway industry in the 1990s it is this: The customer must come first, because if we don't have customers, we don't have a railway industry.

This means we have to channel all our resources to offering our customers the most reliable, flexible, cost-effective and safe services we can possibly provide. That's the only way we can hold on to existing traffic, and win back some of the market share we've lost to competitors. We have to give customers what they need in terms of equipment and scheduling, because if we don't, others will.

Let me give you a few examples of what we are doing at Canadian National as we face the toughest challenges in our careers. I'm not suggesting that what we're doing is far in advance of everyone else, or should be a model for the North American rail industry. Far from it.

I simply want to describe one railway's answers to the current challenges just to illustrate the implications these initiatives have for people in operations, in motive power and car equipment, and in purchasing.

As I said a few minutes ago, one of our great assets is the efficiency of the steel wheel on the steel rail. To exploit this asset fully, CN is focusing renewed attention on bulk commodities.

Over the past few years, we have invested millions of dollars in upgrading our main lines with heavier rail and concrete ties to handle heavier, longer trains with larger cars to maximize the productivity of our lines. The idea is to keep our freight rates for these commodities out of the reach of truck competition. We work with major shippers to develop the right equipment and plan our scheduling to meet their requirements.

Margins are generally low in bulk commodity industries, and in a large country like Canada, even small differences in freight costs can mean all the difference between a mining company meeting foreign competition and retaining markets, or having to close down.

This means keeping our costs as low as possible if we want to retain and expand the business, and making sure the schedules we agree to are met.

We will be continuing in this decade to gear our track, our equipment fleet, and our operations for the more efficient movement of bulk commodities.

Another step we are taking to enhance the efficiency, safety and on-time performance of rail operations is investing in Advanced Train Control Systems.

As a pilot project on a 190-mile stretch of track in northern British Comumbia, we are installing a data communications network to link computers on moving locomotives to fixed wayside points and a central dispatch office. Through in-track transponders, we will know the exact location of our trains, thus contributing significantly to safer and more effective train operations. ATCS will enable us to monitor the operating health of our locomotives on a real-time basis from centralized locations, detect potential failures in advance, and schedule maintenance precisely when it is needed.

ATCS has an important customer dimension as well through its on-board reporting system. In these days of fierce competition, many manufacturers and processors work on the 'just-in-time' concept of production to keep costly inventories to a minimum.

This means that our lines are really part of their assembly lines, and they count on scheduling the movement of their shipments over it much more precisely than in the past. If we don't meet their targets, they may have to hold production and lose sales — and that's not the way for us to please customers and hold on to their traffic.

The need for more reliable and predictable service also means that our yard operations have to be much more efficient. There has to be a greater emphasis than ever on keeping the traffic moving on time through yards and on main and branch lines.

I spoke earlier about the growing competition we face from the trucking industry. But this competition also gives us an opportunity to expand intermodal operations.

We have to acknowledge that trucks can be much more flexible than freight trains when it comes to picking up and delivering at the customer's plant or warehouse.

But there's nothing to stop us from using our inherent efficiency to go after the long haul of that truck traffic with intermodal services. CN is going into double-stacking, and making the necessary improvements in clearances along our right-of-way to generate more of this business, as many other railways have already done.

But again, the key to getting this business is keeping operating costs low, and maintaining reliability of performance.

So far I have talked about freight, but we cannot forget the railways have always been a provider of passenger services, directly and indirectly, and will continue to be in the future. Many traditional concepts about rail passenger transporation — both our own and other people's — will have to adapt to the reality of transportation economics.

In today's highly competitive transportation environment, it is completely unrealistic to expect railways to provide passenger services other than on a wholesale basis; that is, we will rent our rights-of-way, and other organizations will retail the services. This has been recognized largely in your country by the formation of Amtrak, and in ours by VIA Rail Canada.

These steps are a recognition of the fact that in view of the competition from automobiles, buses and airlines that have their rights-of-way heavily subsidized, rail passenger services should not be expected to finance themselves entirely out of ticket sales. This subsidy required cannot come from railways, so it has to be provided directly or indirectly by those who benefit from rail passenger services in terms of savings in highway and airport costs, and improvements in the environment that come from reducing automobile traffic.

We have had some success in working with the Government of Ontario to provide rail commuter service in the Greater Toronto Area, an area of some 3,000 square miles housing more than four million people around Canada's largest city.

We operate the trains. The Government of Ontario sets the fares and compensates us for our operating costs, including a fair margin of profit for us.

The success of the GO train concept from our point of view is that from the start it was recognized that those who benefited from improved rail commuter services, and not the railways, should bear the cost burden of providing the service.

I believe that increasing concern over air pollution, highway maintenance and replacement costs, and congestion on highways and at airports means that there is a brighter future for rail passenger services in North America in the long term.

But I also believe it means the acceptance of new and unorthodox approaches if we are to be successful.

For example, in our country, the transcontinental train has lost its role as a basic means of passenger transportation. But there may be opportunities to market it as an unbeatable way to see the scenic beauties of our land.

We have only to look at what happened to the ocean-going passenger liner. Two decades ago, liners were being scrapped as high-capacity and economical jet aircraft brought down air fares and took over the passenger business.

Now they are being refurbished and new ones are being built to serve the highly popular cruise ship market. That's what happens when old attitudes and perceptions are changed.

If I were to predict the shape of CN's rail network by the end of this decade, I would say that we would have smaller, highly productive trunk lines linking intermodal hubs. There would be continuing opportunities for short-line connectors, and branch lines to serve resource areas.

But our branch line network will have to be extensively pruned to reflect the resource needs and traffic patterns of today, rather than the ones that existed at the beginning of this century, when many of these branch lines were built.

Clearly, we need national transportation policies that allow railways to achieve their full potential to serve the economy.

Railways can make a major contribution towards solving such public policy problems as highway and airport congestion, skyrocketing road maintenance costs as the highway network deteriorates, air pollution caused primarily by automobiles, depletion of non-renewable resources such as petroleum, and hazards associated with the movement of dangerous goods. But national transportation policies must allow us to make this contribution.

In the past, it seems, our competitors did a better job than we did of gaining the ear and the confidence of legislators. Again, this is an area in which we have to live down the legacy of our past, when railways were attributed — unfairly — with a "public be damned!" attitude.

We know what we want legislators to do in terms of transportation policies that will ensure the future of our industry, and our task is to go out there and tell them. I am sure we can motivate everyone interested in our great industry to support us in these efforts.

But what do we have to do within our own industry — in operations, in motive power and car equipment, in purchasing and, yes, in the railway supply industry, to secure our future in the '90s and build for the 21st century?

What does all this mean to the delegates attending this gathering of the Coordinated Mechanical Associations?

As I indicated, we have to be ready to abandon old attitudes and approaches that can handicap us in a much more competitive world. Our first concern, in all aspects of our operations, must be greater attention to reducing costs. Every dollar we spend has to come from some customer, somewhere. Every dollar we save gives us an increased competitive edge.

I know that all of you have faced the challenge of doing more with less, of having to cut budgets and, even more painful, reduce staff. This process has to continue if we are to survive. It may mean that instead of cutting back on traditional ways of doing things, we should look at completely new approaches that will achieve our objectives in different ways.

We have to look to new technology to take over even more of our traditional tasks, and we have to be ready to learn new skills and adapt to more up-to-date methods of management.

We have to adopt and communicate a new sense of customer awareness in every aspect of our operations. Every shipment and every car is vital to a customer, and we run the risk of losing that customer if we delay or misdirect it.

That's why we're adopting such techniques as in-consist maintenance, so that the freight can be kept rolling to meet our commitment to the customer. I call that building in quality — and the main quality we can offer our customers is reliability and cost-effectiveness.

At Canadian National we have launched a program to reduce the incidence of bad-order loads. As chief operating officer, I am concerned about the number of cars that have to be bad-ordered in transit, causing delays and additional expense. Surely we should be able to provide customers with cars that will run three or four thousand miles without having to be bad-ordered en route.

As individuals, we wouldn't tolerate that type of performance from Hertz or Avis, and a freight car is much less complex than an automobile. I am sure that the mechanical people meeting here can come up with solutions to that sort of operating problem.

Another key element in our survival is safety. We have to ensure that our operations are as safe as we can make them. We cannot afford the cost of neglecting safety in terms of human suffering, environmental damage, or the impact on the bottom line.

At this point, you probably feel like asking me: What's most important? Cutting costs? Serving the customer? Promoting safe operations?

The answer is: All of the above. In today's world, few managers have the luxury of having to achieve only one objective. We have to achieve all three, and effectively balancing the sometimes conflicting demands of these objectives is what differentiates good managers from the rest.

That's one reason I'm pleased to be here today at a convention where railway people are meeting to improve their skills and knowledge.

I believe that in meeting the challenges of the '90s, railways will have to work together more closely to find joint solutions to common problems. The main competition we now face is not from each other, but from other transportation modes.

So far, I have been speaking mainly to railway delegates, but I also have a word for the suppliers who are so ably represented here today. My message is that our future is your future. If you don't have railways, then who needs to supply them? And that's why you need to change traditional attitudes and approaches as much as we do.

The quality of the transportation services we sell depends very much on the quality of the goods and services you supply us, which means we should be working together on quality assurance processes.

And the prices we pay for your products must take into account the highly competitive market in which we have to earn our living. In other words, we need a supply industry that is just as innovative, competitive and price-conscious as that enjoyed by truckers.

The "just-in-time" scheduling approach our customers use to reduce inventory costs is equally important to us when it comes to railway supplies. At CN, we call it Materials Requirement Planning, and you'll be hearing more about it.

We're looking to the supply industry to be pioneers in innovation. Surprise us. Show us new ways by which we can achieve better results at lower cost if we use your products and ideas. I can assure you, we are an attentive audience, and willing buyers of the right products at affordable prices.

In closing, I would suggest that we in the railway industry should take our inspiration from this remarkable city.

Atlanta was once burned to the ground, but it rose from its ashes to become the great transportation, financial and industrial centre it is today, and a key player in the prosperous new Sun Belt.

I am not suggesting that the inroads of the trucking industry have been as devastating to our industry as General Sherman's siege was to Atlanta.

But I believe the optimism and energy of the people of this city offer us a model as we enter an uncertain and challenging decade.

They faced much more daunting problems realistically, and overcame them. You can do the same in various sessions you attend during this convention, and in the decade that lies ahead.

President Battista: Mr. Sturgess, on behalf of the Coordinated Railroad Officers we thank you for an excellent and inspiring presentation.

In appreciation for taking time from your busy schedule to come here today we would like to present to you a plaque to commemorate this special occasion.

Many thanks from all of us.

Mr.Sturgess: Thank you Armand and members.

Chairman Battista: Thank you ladies and gentlemen for attending our opening session this morning. At this time, we will adjourn to our individual meetings and carry on with the business of the conference. Thank you.

MONDAY, SEPTEMBER 17, 1990
LMOA

Address of
President Paul F. Hoerath

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

A special welcome is extended to LMOA members, RSA members, railroad mechanical officers and guests.

As many of you know, the six technical committees of LMOA are hosted by various railroads and railroad organizations at pre-convention presentations of their technical papers. These presentations are important steps in final preparation for this annual convention. Practice makes perfect! These pre-convention presentations give our technical committees an opportunity to reach members and guests who are unable to attend the annual convention. The pre-convention presentations for 1990 were held as follows:

Diesel Mechanical Committee
Chicago Railroad Mechanical Assn. (Chicago, IL)

New Developments Committee
Southern & Southwestern Rwy. Assn. (Huntington, WV)

Shop Equipment Committee
Southwestern Railway Club (Omaha, NE)

Fuel & Lubricants Committee
Norfolk Southern Corporation (Roanoke, VA)

Diesel Material Committee
Consolidated Rail Corporation (Altoona, PA)

Diesel Electrical Committee
Canadian National/Canadian Pacific (Montreal, PQ, Canada)

Many thanks to these railway clubs and railroads for hosting these pre-convention presentations.

Most of the Presidents' addresses over the past few years have all discussed "Change". It is a magic word that keeps coming up!

Change — in the railroad's physical make-up.
- —Mergers
- —Combinations
- —Tracks sold or abandoned
- —Elimination of railroad shops and service facilities.

Change — in railroad personnel in the mechanical departments. (and others)
- —Cutbacks and reductions
- —Combining positions - job responsibilities, duties, etc.
- —Elimination of personnel through early buy outs, retirements, etc.

Change — the need for more reliable locomotives.
- —Less repairs - less often
- —Less servicing
- —Computers tell what is wrong and tells how to fix it.

Change — in the competitive environment.
- —Railroads steadily losing in percentage of total freight moved to trucking industry
- —Some loss of freight moved to airline industry
- —Some loss of freight moved (to a lesser degree) to barges and pipelines.

Change — the requirement to serve the customer better than the trucks. After all the steel wheel on steel rail is:

—less expensive
—fast
—convenient
—flexible
—reliable
—safe
—and can provide quality service.

But, we of the railroad industry must cooperate. That includes:
—Railroads with other railroads
—Suppliers with railroads and
—Railroads with suppliers.

In order for us to gain our share of the freight marketplace, LMOA stands ready and willing to do our part in helping railroads to be more successful:

—to lower costs by solving problems when they occur - sharing knowledge among our members;

—to lower costs by preventing problems from occurring - alerting other members of troubles to watch out for, what works, what doesn't work, what hasn't been tried.

LMOA is cooperation that works!

Thank you

TUESDAY, SEPTEMBER 18, 1990
LMOA

Acceptance Speech
By Donald D. Hudgens

First of all, I would like to thank you, Paul Hoerath for faithfully serving out your term as president of LMOA even though you have retired from active railroad employment. Thank you for your years of service and valuable contributions to LMOA through your committee membership, chairmanship, and various officer ranks through president. All of us here today wish you a long, healthy, happy and prosperous retirement.

Secondly, I am deeply honored to be offered, and I accept, the office of president of the Locomotive Maintenance Officers Association.

A number of years ago I read an amusing article in *Industrial Research & Development* magazine that questioned the business of railroads. The author quoted another author who stated that the railroads thought of themselves as being in the railroad business rather than the transportation business. The author of the article I was reading then went on, himself, to question the business of railroads and his conclusion was that railroads were not in the transportation or railroad business, but that they were in the civil engineering and construction business...and always have been.

The railroads have, he went on, always prided themselves on their ability to span abysses with magnificent bridges, to bore through mountains with great tunnels, and hang track on precipitious mountain slopes. When reaching their terminus, they reached back to the edifices of antiquity and built temples to the gods of engineering for terminals. He went on to say that railroads were still preoccupied with running a railroad from an engineering rather than a service standpoint. This article was written in 1983, and I think we may, after more than 150 years of existence, be questioning our function ourselves.

Our industry, as we all know, has been undergoing accelerated changes since deregulation some ten years ago. We have seen railroad mergers reduce the number of major railroads. We have seen reorganization reduce the number of people. We have seen reductions in the number of locomotives owned by the nation's railroads and yet we continue to haul more. We are becoming more efficient and I hope our nation recognizes and appreciates our efficiency, particularly in light of the recent developments in the Middle East.

I believe the railroads *are* thinking more of themselves as being in the transportation business. We are becoming responsive to our customers and their needs. Deregulation has forced us to become businessmen...We can no longer increase the price of our service across the board to cover wildly escalating costs brought about by empire builders. We must spend our dollars wisely to ensure that we serve our customers by providing a cost effective service or we will not remain in business. We will, in fact, not deserve to be in business.

We, in the locomotive maintenance end of the business, are charged with that portion of the operation which deals directly with the reliability/availability of our locomotive fleet. If we cannot ensure that our locomotives are able to get from Point A to Point B without failing, then we are failing in our charge... and our customers are not served.

To what extent should railroads be involved in locomotive maintenance? We certainly must at least be responsible for the basics: to ensure that all fluids are on the mark; ensure that locomotives are fueled; ensure that brakes are operating properly; ensure that lights are operable; ensure that we are in compliance with FRA regulations — generally, just the most basic service track stuff. This is where we are probably most vulnerable to criticism from our customers...We cannot afford to have a million dollar piece of machinery *RUN OUT OF FUEL*.

Beyond the basics, how far into locomotive maintenance should we go? Locomotive remanufacturing... component rebuilding...rebuilding wrecks...component replacement... are these functions, *should* these functions, be any more or less a part of a railroad than running trains, or maintaining track structure, cars, or communication networks, or having personnel, accounting, auditing, financial, or administrative functions?

I believe that railroads should be directly involved in most aspects of locomotive and locomotive component rebuilding. We certainly should not be involved in forging wheels and crankshafts, fabricating crankcases, and formulating paint, but I think we are perfectly capable of selecting suitable components which best suit our individual needs and assembling them in our own shops into a reliable finished product. We have on occasion improved on the original product because we are more familiar with our particular needs than the original builder.

I know there are those in our companies who can think of reasons why we should not be in this end of the business. These people are in the financial and accounting end (the ones who ask what answer you want to see, then show it to you) and their reasons are dollars. I must admit that their "reasons" can be persuasive to upper management, but I submit that their "reasons" can also be short-sighted. I believe we should not and must not lose the ability to do our own rework in-house or we will be at the mercy of those who do it. I believe heavy repairs and component rebuilding should remain integral parts of a well managed vertically integrated railroad company.

Admittedly, jurisdictional disputes among our shopcraft people can have a strong negative impact on our overall costs; and these disputes weigh heavily in management's current decisions to do or not to do. I think we must agree that many of these work rules were reached because of some heavy handed methods of management, but as we approach the 21st century, it is time we come to understandings that will enable us to continue to function harmoniously and efficiently together or we will not be in this business at all.

I know railroad locomotive departments have excellent, capable people because I have worked with many of them over my career at Union Pacific, and I have met and come to know mnay more through my affiliation with the Locomotive Maintenance Officers Association.

I believe than anyone here who has been actively involved in this organization for any period of time fully understands and deeply appreciates the valuable professional relationships and warm personal friendships nurtured through this organization. I am sure we have all used contacts made through this organization to help us better serve the companies which employ us. All industries have their professional or trade associations which serve similar purposes; whether they be butchers, bakers, or candlestick makers, and they serve their industries as our association serves our industry.

Article II of our organization's constitution and bylaws states that "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 employees, 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."

I think the LMOA helps all of us in this business by providing a forum, a sounding board, the personal contacts to aid us in doing our jobs better. I am sure each chief mechanical officer realizes that with the "negative employment growth" of his department, he can use all of the help he can get.

Some 3,000 years ago Moses said to Pharaoh "let my people go". Today I say to the railroads' chief mechanical officers, "let your people grow", by getting them involved in LMOA technical committees. Those people will broaden their network of resources, which will aid them in their jobs. The contacts made in this organization are mutually advantageous for all of us in this industry.

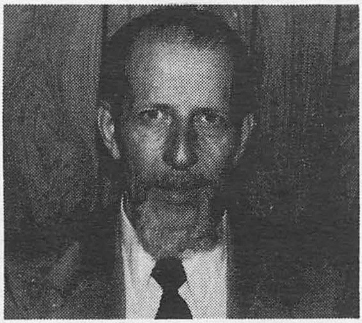
We can all help one another to do a better job for our employers through out membership in the LMOA.

Again, I am honored to be offered and I accept the office of president of LMOA.

Chairman Bill Brown, Burlington Northern, left, presenting LMOA General Desk Set to outgoing President, Paul E. Hoerath, Conrail. Past President, Darrell Walker, Norfolk Southern, witnesses presentation ceremony.

Past President, Dave Goehring, Amtrak, second from right, presents Past President's Pin to outgoing President, Paul F. Hoerath, Conrail, in the presence of Past Presidents Don Ward, far left, and Dale Propp, far right, both of Burlington Northern

OUR OFFICERS



President
PAUL F. HOERATH
Sr. Mechanical Engr.-Shops
Consolidated Rail Corp.
Altoona, PA 16603

	Advertisers	Associate	Active	Total
1939	0	27	60	87
1940	34	48	162	244
1941	38	48	210	296
1946	103	187	676	963
1947	101	284	937	1321
1948	113	295	1183	1591
1949	134	595	1789	2521
1950	123	595	2101	2822
1951	125	626	2912	3663
1952	135	510	2747	3392
1953	118	597	3288	4003
1954	118	545	2943	3606
1955	81	434	3235	3750
1956	110	419	3257	3786
1957	100	423	2678	3201
1958	82	350	2320	2752
1959	90	387	2395	2872
1960	98	393	2302	2793
1961	101	348	2201	2650
1962	118	316	2291	2725
1964	138	273	2345	2756
1965	155	289	2372	2816
1966	163	464	2368	2995
1967	180	408	2327	2915
1968	200	321	2575	3096
1969	192	335	2173	2700
1970	184	345	1929	2458
1971	140	283	1621	2044
1972	132	343	1777	2252
1973	108	345	1563	2016
1974	124	384	1735	2243
1975	103	326	1579	2008
1976	109	314	1610	2033
1977	114	317	1508	1939
1978	125	363	1367	1855
1979	120	391	1251	1762
1980	112	405	1200	1717
1981	114	445	1143	1702
1982	102	440	1261	1803
1983	92	386	1025	1503
1984	95	400	1116	1611
1985	90	386	1006	1482
1986	90	320	702	1112
1987	75	221	615	911
1988	79	226	420	725
1989	70	225	415	710

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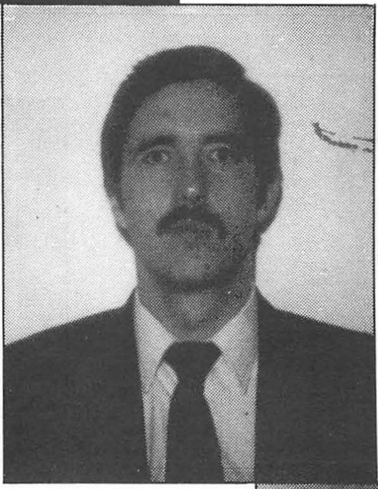

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Southern Pacific Transp. Co.
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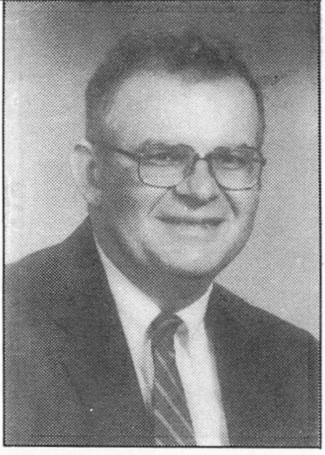

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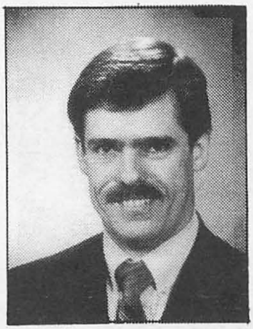

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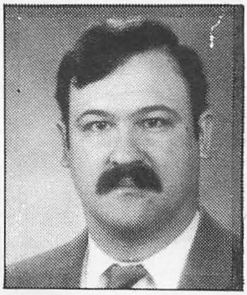

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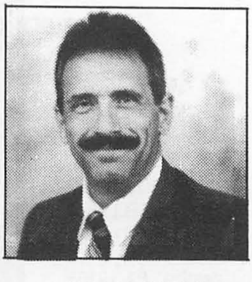

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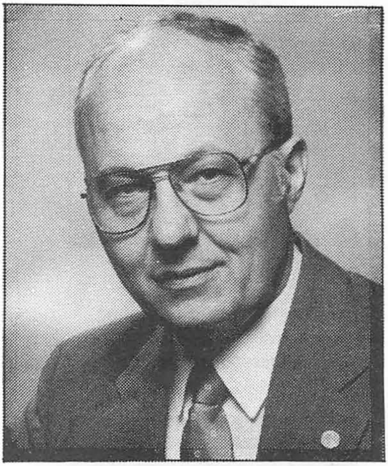

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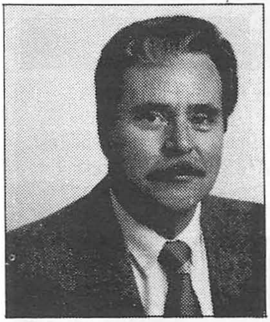

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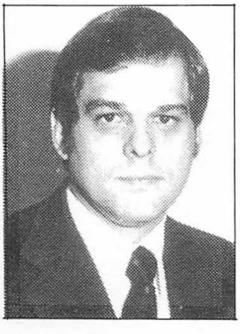

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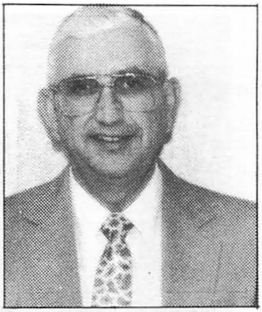

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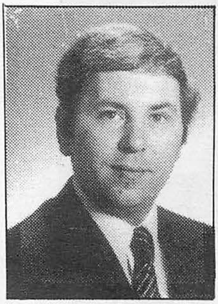

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System Shops
Union Pacific Railroad
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SUPPORT STAFF

T. C. SHEDD
Editorial Director
Modern Railroads
20 N. Wacker Drive
Chicago, IL 60606

— PHOTOS NOT AVAILABLE —

E. L. BAUER
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1983— F. D. BRUNER, Retired Asst. Chief Mechanical Officer-R. & D., Union Pacific Railroad, 10012 Emmet, Omaha, NE 68134

1984— R. R. HOLMES, Retired Director Chemical Labs and Environment, Union Pacific Railroad, 688 J. E. George Blvd., Omaha, NE 68132

1985— D. M. WALKER, Asst. Shop Manager, Norfolk Southern Corporation, 793 Windsor St., Atlanta, GA 30315

1986— D. H. PROPP, Dir.-Loco. Opns., Burlington Northern Railroad, 373 Inverness Drive South, Englewood, CO 80112

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C. N. WIGGINS, Retired Vice-President and Asst to President, Louisville & Nashville R.R., Louisville, KY

LMOA officers in attendance at 1990 Annual Technical Conference in Atlanta, GA. (Left to right): Jack Kuhns, CXS, retired; Allen Keller, Amtrak; Don Hudgens (newly elected President), BN; Bill Brown, Burlington Northern; Paul Hoerath, Conrail; Don Ward, Burlington Northern; Dale Propp, Burlington Northern; Darrell Walker, Norfolk Southern; Dave Goehring, Amtrak.

D. W. MAYBERRY
Vice President-Mechanical
Norfolk Southern Corporation
Roanoke, VA

LMOA wishes to express its thanks to the Norfolk Southern Corporation for hosting Pre-Convention the Pre-Convention Presentation in Roanoke, VA.

Our Fuel & Lube Committee was well received in what we trust was a mutually beneficial experience.

Our thanks to Mr. Mayberry and others responsible for and participating in the program.

REPORT OF THE COMMITTEE ON FUEL AND LUBRICANTS

Monday, September 17, 1990 9:30 A.M.

Pre-Convention Presentation NS

May 15, 1990
Airport Marriott
Roanoke, VA

GLEN A. PETERS, Chairman
Manager-Locomotive and Environmental Testing, ATSF
Topeka, KS

VICE CHAIRMAN
R. R. Lodowski, Manager-Environmental Operations, Conrail, Selkirk, NY

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R. D. Schmisseur	Asst. Manager Testing	C&NW	Chicago, IL
T. L. Schaefer	Director-Fuel Mgmt.	BN	St. Paul, MN
J. Thompson	Senior Research Engineer	Amoco	Naperville, IL
C. W. Tincher	Product Manager	Lyondell	Houston, TX

PERSONAL HISTORY

Glen A. Peters

Glen was born and raised in Smith County, KS. Following high school, he studied refrigeration at Stevenson's Trade School in Kansas City, served in the U.S. Army in Europe, attended Garden City, KS Jr. College and graduated from Washburn University of Topeka.

In June 1963, Glen joined the Santa Fe Railway in Topeka as a test engineer in the Test department. In 1973 he was promoted to spectrograph laboratory supervisor in Barstow, CA. In 1981, he was promoted to his present position of manager of locomotive and environmental testing.

Glen and his wife Barbara have five adult children and four grandchildren. His hobbies include genealogy and automobile restoration.

I. THE RESPONSIBILITY OF RAILROADS AND FACILITY MANAGERS IN THE HANDLING AND DISPOSAL OF HAZARDOUS MATERIALS

During the past years the nation has grown increasingly aware of the effects of waste disposal. The result has been an ever growing number of regulations governing their storage, handling, disposal and responsibility. We will attempt to give a brief review of what is happening now in terms of regulations, programs, costs, and the future outlook.

In 1976 Congress passed the Resource Conservation & Recovery Act (RCRA) to address the growing environmental problem of hazardous and non-hazardous solid waste. RCRA governs generators, transporters, and storage and disposal facilities.

Hazardous waste includes certain listed waste and any material which exhibits one or more defined characteristics. These are ignitability, reactivity, corrosivity, and toxicity.

Ignitability is the characteristic in which a waste is capable of causing a fire through friction, absorption of moisture, or spontaneous chemical changes, and when ignited burns so vigorously and persistently that it is a hazard.

Corrosivity refers to a pH level of the material less than or equal to 2 or equal to or greater than 12.5 (where water, as neutral, has a pH of 7), or when the material corrodes steel at a specified rate.

Reactivity is the extent to which the waste is normally unstable or readily undergoes violent changes without deterioration or when mixed with water generates a toxic gas, vapors or fumes, or reacts violently with water.

Toxicity refers to the maximum concentration of a number of metals or compounds; any waste which exceeds these concentrations threatens human or animal life or health and is considered toxic under RCRA. The concentrations are expressed in mg/liter. New regulations on the required test procedures will substantially increase the number of materials considered as hazardous.

In addition, certain wastes are considered acutely hazardous wastes and are classified as being from specific or non-specific sources. For example, a waste of methylene chloride is considered an acutely hazardous waste from a non-specific source. Wastewater sludge from the production of zinc yellow paint is deemed acutely hazardous material from a specific source.

RCRA governs how hazardous and non-hazardous waste is to be transported and sets forth requirements on manifests, landfills, incinerators, chemical treatment plants, waste piles and groundwater monitoring. RCRA requires facilities which handle hazardous waste in quantities reportable fo the federal government to establish and maintain emergency plans in case of accident, to coordinate these plans with local public safety organizations (police, fire, ambulance), and to provide training for personnel who work with hazardous waste. RCRA regulates wastes from cradle to grave.

RCRA requires a hazardous waste manifest to be filled out by a facility which generates hazardous wastes which are to be transported to a facility that disposes of the wastes. This manifest identifies the waste by shipping name, hazard classification and any identification number by which the waste may be identified; name and address of the generator, name and address of the transporter, name and address of the disposal facility, EPA identification number

for the shipment, number and type of containers, weight of the material, and any other relevant information.

RCRA outlines how the manifests are to be maintained and filed and who receives the manifests. RCRA also requires facilities to maintain operating records, analytical reports, monitoring tests and other records pertaining to storage or disposal of waste. Shippers and TS&D (treatment, storage and disposal) facilities are required to be licensed and have an EPA Identification Number.

Records that include the above information in the manifests must be retained for a minimum of three years. Penalties for incomplete files such as unsigned or missing documents can range up to $25,000/day-incident for a habitual offender. Also unmarked drums found on the property can result in penalties of $300.00 to $1,000.00 each. As you can see proper record keeping is a must and this is the final responsibility of the facility manager.

The storage of waste containers is regulated by the length of time, labeling, proper areas and containers, spill prevention and notification including an emergency plan. Again proper record keeping and labeling become the important factors since storage time is governed by the type of waste and quantity produced and can range from immediate disposal to a maximum of 89 days. If these times are exceeded then the generator becomes a storage facility and must obtain an EPA permit to avoid penalties. States are now regulating these storage time intervals, so local guidelines should be checked and adhered to.

The disposal method is governed by the type of hazardous waste involved. Some can be shipped to an approved landfill or incinerated, but others cannot and require storage or special processing. Proof of the type of disposal methods used must be part of the manifest and signed by the disposal facility.

The Environmental Protection Agency (EPA) established programs a few years ago aimed at developing waste minimization efforts and creating what is identified as the Superfund responsibilities and also what is called the Community Right to Know Act. It is required that MSD sheets and lists of all hazardous materials be furnished to local emergency planning and fire departments, etc. for material that exceeds a minimum threshold level for reporting. The waste minimization is geared to the generators to reduce their hazardous waste production by 50 to 75% over the coming years. We will see under the programs developed how Amtrak and others are trying to accomplish this.

Superfund is a polite way of saying that if more than one company is involved at a waste site, then the guy with the money is responsible for any necessary clean up (what is commonly known as "deep pockets" rule). In other words each railroad is liable for the cost of cleaning up any contamination caused by its waste products. Presently there is no time limit on this responsibility. A storage facility could be closed for any number of years and if a problem occurs (leaking hazardous material) the paper trail will lead the EPA back to the generator of that waste who then is responsible for the clean up. If more than one generator is involved, the clean up cost is divided by the amount of waste stored there by each party, but again the one that has the money is the one who will pay.

OSHA regulations — also called the right to know — have been established to protect the workers from potentially hazardous material. All employees are entitled to be aware of what chemicals they are dealing with and must be trained in the proper handling methods, use of

protective devices, and cleanup. For this requirement the railroads must maintain a complete record of material safety data sheets (MSDS) on all products used in their facility. Employees may have access to these records during their work shift and in emergencies, which can mean 24 hours a day, 7 days a week.

Let us look at some programs and procedures Amtrak has developed to accommodate the regulations developed by RCRA, EPA and DOT. First, Amtrak facilities have environmental and safety managers whose duties include the monitoring of the manifesting of **all** wastes that leave the property, making sure that every copy is signed and returned within the proper time intervals. These duties also include proper record storage and development of emergency treatment procedures. As most of us have learned, these programs are of such a scope that they require the efforts of a devoted department to handle their complexities.

At Amtrak's facilities proper storage areas have been set up for drums, larger tanks etc. to eliminate the possibility of going behind a building someday and finding a pile of so called empty containers that have been sitting there for years (Amtrak has been cleaning up its sites).

Record keeping is monitored by Amtrak's environmental and safety group to ensure that all files are accurate and complete. This also includes the establishment of procedures for the correct handling and labeling of all containers, and performing the proper analysis of wastes when required. Amtrak's policy is to keep complete records on all wastes whether or not they are classified as hazardous, since we cannot predict the future and many establishments will not handle disposals without those records. Anything not identified will automatically be considered hazardous.

The big push within Amtrak at present is to establish waste minimization procedures. As part of this program Amtrak is constantly reviewing the chemicals used for different processes. Whenever possible the process will be changed to eliminate the hazardous waste or reduce the amounts if satisfactory results can be obtained. Reclaiming and recycling of the material also eliminates waste, but not using it in the first place is the best method to reduce the hazardous waste disposal problem.

Amtrak has also installed water treatment facilities at several of its shops including the Wilmington Del. and Beech Grove, Ind. back shops which utilize dissolved air floatation systems. Wastes from the Proceco washers, shop floor, and any oil or grease from the shop pits is collected in a deep well and the solids collected are then pumped to the oil skimmer. This process separates the waste into sludge and oil. The waste water itself is processed through the facility where the pH level is monitored and adjusted to 7.5 pH if necessary.

The capacity of Amtrak's Wilmington water treatment system is around 50,000 gallons per day. Normal usage is in the 25,000 gallons range per day. Quantities of this magnitude qualify the shop as a class A facility requiring the actual operator of the treatment system to hold a class I operator's permit.

Bulk usage of material reduces the number of containers, storage problems and cleanup associated with drum usage. Where possible Amtrak will be using liqua bins of approximately 350 to 420 gallon capacity. The containers are designed for chemicals used in moderate amounts. For high usage products, larger bulk storage tanks are used. Liqua bins were designed to replace the mountains of unsightly, difficult-to-dispose-of 55 gallon drums that were littering our sites. Suppliers of the chemicals are more willing to deliver and fill these tanks or replace them with filled tanks than they are to take empty drums.

Concerning the right to know and material safety data sheets (MSDS) catalog, Amtrak has developed a unique program, where all the exact images of the original MSD sheets are kept on the main computer enabling all the facilities around the country to have access to the computer day or night to obtain the latest information. The networking system for this information can handle up to eight calls at the same time requesting the identical data. The program was necessary because of the difficulties involved in keeping everybody's MSD book up-to-date and the numerous locations spread out around the country. This requires that people capable of accessing the system be available during the working shifts.

Amtrak has also established hazardous communication training programs where all new employees are instructed in the proper care and use of chemicals involved in their jobs. This also includes any transferees who have changed jobs and require additional training. As many as 10,000 to 12,000 employees have been through this program.

As you can see, the programs are extensive and this is an ever rising cost. Amtrak, which has two good size facilities, Wilmington and Beech Grove, spends over $2,000,000 on waste disposal annually for the Amtrak system.

Fines and potential liabilities can also present an enormous cost to the railroads and the facility managers. Failure to comply with RCRA requirements can result in civil and criminal penalties of up to $50,000 for each day of violation and imprisonment of up to five years. A defendant who knowingly endangers another can get up to a $1 million fine. It is known that the regulatory agencies are focusing on the highest level manager involved in violations to the laws. In the railroad's case the final responsibility rests with the facility manager. Defenses of "I didn't know", or "wasn't aware" or "they told me to do it" are no longer acceptable.

What we can expect for the future is an ever increasing flow of new regulations as we become more aware of our environment. For example, engine lube oil may be RCRA listed as hazardous material and some states already have made this regulation. Everything we can do now to fully abide to the present laws will help in adjusting to the more stringent future regulations.

In conclusion, it can only be recommended that we be truthful in our record keeping, establish the necessary programs to reduce our wastes, handle our disposal in the proper manner, and train our personnel. By doing this, our environment will be protected for now and in the future and problems will be eliminated for both our companies and ourselves.

II.
UPDATE ON DIESEL FUEL REGULATIONS

The composition of diesel fuel for the domestic on-highway market is changing significantly as we enter the 1990s. Precisely how this will affect the railroad industry is not known at this time, but it could have major implications.

The composition of diesel fuel is a significant factor in reducing diesel particulate emissions. The sulfur level and some of the aromatic compounds were identified in the early 1980s as having primary effects on particulate emissions. More recent research sponsored by the Coordinating Research Council has verified the sulfur effect but has shown that particualte emissions respond weakly to both aromatics content and cetane number. HC and CO emissions, however, respond quite strongly to cetane number, decreasing as cetane number is increased, but are not responsive to aromatics content.

In response to the request from the heavy-duty diesel manufacturers, the American Petroleum Institute (API), National Petroleum Refiners Association (NPRA), and the Engine Manufacturers Association (EMA) agreed in 1988 to reduce the on-highway diesel fuel sulfur level from its current 0.5% maximum level to 0.05% maximum. (Fig. 1). The agreed-upon date for this reduction is October 1, 1993. It will result in the U.S. average fuel sulfur and level dropping from 0.27% to less than 0.05%.

This single fuel modification will significantly reduce particulate emissions and will allow the engine manufacturers to meet the 0.10 gram/bhp-hr limit with a smaller dependence on exhaust after-treatment devices (i.e., catalysts or particulate traps). As part of the industry agreement, the minimum cetane index will be set at 40 cetane to prevent any further significant increases in aromatics levels in the fuel. This specification change will not significantly affect the U.S. average cetane number, which is expected to remain at the same level (approximately 45 cetane) as it has been through the mid-1980s.

In August 1990, the EPA issued its diesel fuel regulations, setting the maximum sulfur level at 0.05 mass percent, the minimum cetane index at 40, and the maximum aromatic content at 35 volume percent (Fig. 2). In addition, the EPA will allow the engine manufacturers to use 0.1% sulfur fuel in the certification of 1991-1993 engines which are required to meet the 0.25 grams/bhp-hr particulate limit. A small refiner exemption is expected to be part of the Rule. To trace the fuel source, the EPA has proposed that the off-highway and small refiner fuels be dyed, whereas the low-sulfur fuel will remain clear.

In California, the California Air Resources Board (CARB) has developed its own diesel fuel regulations which apply to both the on-highway as well as off-road motor vehicles. To date, railroad locomotive fuels remain exempt from this regulation. The fuel sulfur regulations for the five county South Coast control area were put in place in 1985 and limit the fuel sulfur level to 0.05% maximum. The statewide regulations will take effect on October 1, 1993 and will control both the fuel sulfur level (0.05% max) as well as aromatics. The aromatics levels will vary by producer size, with large refineries restricted to 10% average and small refineries limited to a 20% average.* This is substantially below the current diesel fuel aromatics level of approximately 30%. California refiners must submit their compliance plans to CARB by July 1, 1990 (Fig. 3).

CARB has included in its regulation a provision for refiners to produce a less costly fuel as an alternative to meeting the 10% aromatics limit. To take advantage of this provision, the refiner must run a transient emission test program comparing the proposed alternate fuel to a 10% aromatics reference fuel (Fig. 4). The test results must demonstrate:

* Large refineries produce greater than 50,000 barrels per day diesel fuel (per refinery).

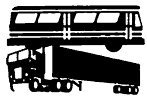
1. Equivalent NO_x,
2. Equivalent particulates (limited credit for secondary sulfate reductions), and
3. Equivalent soluble organic fraction (SOF).

In addition to reducing engine particulate emissions, the new fuels will also have some positive effects on engine maintenance and durability. The lower sulfur levels will reduce engine oil total base number (TBN) depletion and minimize corrosive wear. This could allow oil drain intervals to be extended and/or may signal the introduction of a new generation of lower TBN oils. The low aromatic fuels in California will reduce soot loading of lubricants in older engines, which will reduce the problems associated with high soot levels (oil thickening, filter plugging, accelerated abrasive wear). They may, however, cause increased wear of some high-pressure rotary-type fuel injection systems used in small, high-speed diesel engines due to their poor lubricity characteristics (Fig. 5). The effects in railroad engine injection pumps and injectors have not been determined at this time.

What will the new fuels cost? It is estimated that California refineries will require a $1 billion investment to meet the new diesel fuel regulations. This will result in an average cost increase of 11 to 28 cents per gallon. The effect on the rack price (1989 average 60 cents per gallon) will be an increase of 18% to 47% if the entire average cost is passed along (Fig. 6). An additional complicating factor for California is the government's announced intention to phase out diesel engines in favor of those fueled with methanol. This may discourage some refiners from making the required investment in the facilities to produce the necessary new diesel fuels.

The quest for reduced engine emissions is impacting engine manufacturers, the oil industry and the transportation industry, including the railroads. While not directly affecting railroad fuel composition to date, these modified fuels will probably in the future find their way into the railroad industry, an industry which consumes approximately 6% of the total #2 oil sold in the United States. As October 1993 approaches, some refineries will only manufacture low-sulfur fuel which may cause the supply of high-sulfur fuel to tighten. This could cause prices to escalate. Before the close of the decade, low-sulfur diesel fuel for railroad applications may be required as a result of legislative and regulatory actions.

API, NPRA & EMA Agreement - Highway Diesel Fuel Modification

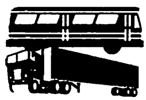


Sulfur, Wt. %	
Current U.S. Avg.	0.27
Oct. 1, 1993, Maximum	0.05
Cetane Index	
1983-1987 U.S. Avg.	45
1983-1988 U.S. Min.	27
Oct. 1, 1993, Minimum	40

API - American Petroleum Institute
NPRA - National Petroleum Refiners Association
EMA - Engine Manufacturers Association

Fig. 1

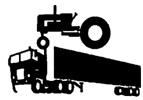
Status of EPA Diesel Regulation



- EPA Final Rule Issued August 21, 1990
- Regulatory Provisions Effective October 1, 1993
  - Applies to On-Highway Diesel Only
  - 0.05 wt.% Sulfur Max.
  - 40 Cetane Index Min. or 35 Vol. % Max. Aromatics
  - Small Refiners Provisions

Fig. 2

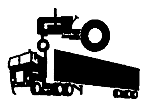
CARB Vehicular Diesel Fuel Regulation



- Applies to both off-road and on-road motor vehicles
- South Coast Control Area
  - Effective now
  - 0.05% sulfur maximum
  - Los Angeles, Orange, Riverside, San Bernardino & Ventura Counties
- Statewide
  - Effective Oct. 1, 1993
  - 0.05% sulfur maximum
  - Aromatics average: 10% large refiners
    20% small refiners
  - Potential for alternative diesel fuels instead of 10% aromatics
  - Refiners must submit compliance plans by July 1, 1990

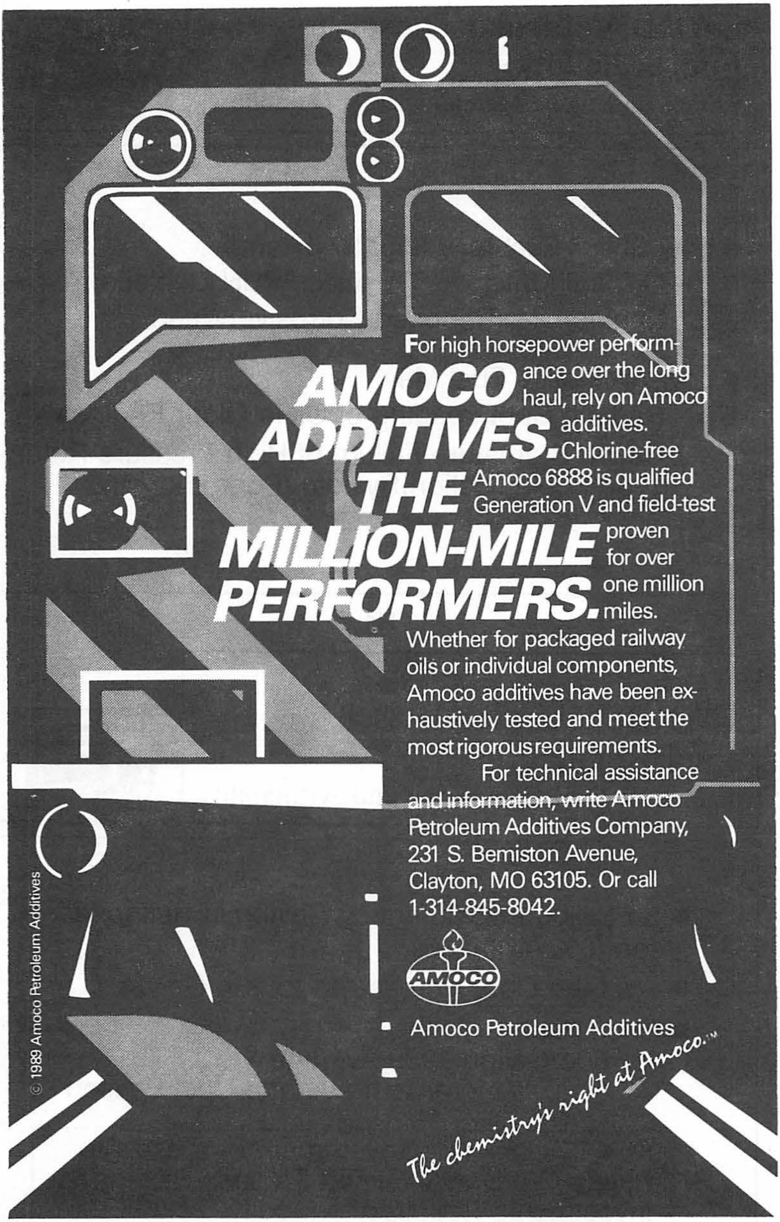
Fig. 3

CARB Vehicular Diesel Alternative Provision



- Potential Option To Produce Less Costly Fuels
- Requires Transient Emissions Testing Of Alternative Fuel And 10% Aromatics Reference Fuel
- Test Results Must Demonstrate
  - Equivalent NOx
  - Equivalent PM (Limited Credit for Secondary Sulfate Reductions)
  - Equivalent Soluble Organic Fraction (SOF)

Fig. 4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For high horsepower performance over the long haul, rely on Amoco additives. Chlorine-free Amoco 6888 is qualified Generation V and field-test proven for over one million miles.
Whether for packaged railway oils or individual components, Amoco additives have been exhaustively tested and meet the most rigorous requirements.
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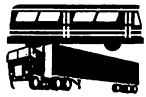
CARB Vehicular Diesel Fuel Regulation

Effects on Engine Maintenance & Durability

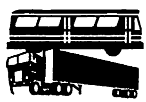


- Low Sulfur Fuel May Slightly Extend
  - Oil Drain Intervals (Reduced TBN Depletion)
  - Engine Life (Reduced Corrosive Wear)
- Low Aromatics Fuel May
  - Reduce Soot Loading of Oil in Older Engines
  - Cause Premature Failure of High Pressure Rotary Type Fuel Injection System (Poor Lubricity)

Fig. 5

CARB Vehicular Diesel Fuel Regulation

Effect on Fuel Cost, Price and Availability



- $1 Billion Investment by California Refineries for 10% Aromatics
- Average Cost Increase 11 to 28¢/Gallon
- Rack Price
  60¢/Gallon 1989 Average
  18-47% Increase if Average Cost Passed on

KEY ISSUE: Will Government Proposals to Phase Out Diesel Fueled Engines Discourage Investments Required to Modify Diesel Fuel?

Fig. 6

III. DIESEL EXHAUST AND WORKER EXPOSURE

Diesel fuel regulations are the result of concern over the environmental impact of diesel exhaust. This discussion addresses another diesel exhaust issue: worker exposure. Why should you be interested in the subject of worker exposure to diesel exhaust? Well, for one thing, the National Institute for Occupational Safety and Health, also known as NIOSH, has declared diesel exhaust a "potential occupational carcinogen". We will elaborate on the regulatory definition of that term later.

We will provide a brief overview of exhaust composition and pertinent components, the effects and regulatory status of these components, monitoring methods and some results of monitoring. Information from NIOSH will be summarized and various regulatory and investigative initiatives will be discussed. Finally, control technologies and recommendations will be reviewed. Excluding the summary of monitoring results, this discussion is a collection of information from other publications and is presented to share that information with you.

Diesel exhaust consists of various inorganic gases, organic compounds and particulates. The inorganic gases which can have deleterious health effects include carbon monoxide, oxides of nitrogen, oxides of sulfur and carbon dioxide. Organics present include formaldehyde, other aldehydes, acrolein, and polynuclear aromatic hydrocarbons, often referred to as PAHs or PNAs. Most of the particulate matter present is soot, which is carbon particulate onto which many organics are absorbed, including polynuclear aromatic hydrocarbons.

How would you know what levels of these components are present in the working environment? Someone with the proper training and equipment can sample the air. The simplest sampling equipment consists of detector tubes and a pump. Detector tubes are glass tubes filled with reagents which change color when they react with a specified component. Before sampling the air, the ends of the tube are broken and the tube is inserted in the pump. A metered piston or bellows pump pulls a known volume of air through the detector tube at a controlled rate. The length of stain or color change in the tube is proportional to the concentration of the component in the air. Detector tubes measure concentration over a short time period.

To monitor for a full shift, a sampling pump with a detector tube or other collection device is used. In many cases, the collection device is sent to a laboratory for analysis.

Once you know what the level of exposure is, how do you know if someone is being overexposed to diesel exhaust? This is a difficult question which is still under study. For many individual exhaust components, the Occupational and Health Administration, OSHA, has established regulatory limits for workplace exposure. However, for railroads, applicable Federal Railroad Administration, FRA, regulations preempt OSHA regulations. For example, FRA regulates exposure to exhaust gases as follows (49 CFR 229.43(a)): Products of combustion shall be released entirely outside the cab and other compartments. Exhaust stacks shall be of sufficient height or other means provided to prevent entry of products of combustion into the cab or other compartments under usual operating conditions. In actual practice, FRA inspectors have reported that they use

OSHA limits as guidelines in determining compliance with the FRA regulations.

Other guidlines exist such as the American Conference of Governmental Industrial Hygienists (ACGIH) recommended exposure limits. Many ACGIH limits were adopted by OSHA when OSHA updated many old limits and established many new standards, effective September 1, 1989.

FRA has often sampled the air for exhaust gases in locomotive cabs. It reports that out of the numerous trips monitored, there were only a few occasions when any measurable levels of contaminants were found, and then only for a short time.

Some railroads have also monitored the air, particularly in locomotive cabs, to determine if there is any exposure at or above established limits. One railroad reports receiving numerous complaints about fumes and eye irritation in high-horsepower 4-cycle locomotives. In response to complaints, sampling was performed by FRA inspectors. Most results were below the detection limit of the detector tubes. In a small percentage of samples, traces of nitrogen dioxide were detected, but far below any OSHA limits. This railroad performed more extensive monitoring on its own with essentially the same results. The locomotive models and train runs with the greatest frequency of complaints were sampled. On occasion, traces of exhaust components were detected in the cab, but never close to any established limits. Still, the railroad reports that heavy fume smell and eye irritation were not encountered on any of the runs sampled.

Another railorad has tested locomotive cab air on 20 to 30 runs. The results were all significantly below OSHA limits. It also tested the air quality in a locomotive shop, simulating a worst case condition by running five to ten locomotives simultaneously with the shop doors down. In that particular case, the results were approximately equal to the OSHA limit for nitrogen dioxide.

A third railroad performed some semi-controlled tests in a tunnel. Conditions ranging from normal to worst-case emergencies were simulated. These tests focussed more on worst-case short-term exposures than on routine occupational exposure. In these tunnel tests, it was determined that carbon monoxide and nitrogen dioxide were the contaminants of greatest concern. These two compounds were also determined to be good markers for overall exhaust exposure; that is, the changes in concentration of carbon monoxide and nitrogen dioxide were consistent with changes in concentration of other monitored exhaust components.

The limits previously discussed are a practical way of evaluating monitoring results, but, and this is important, the NIOSH description of diesel exhaust as a potential occupational carcinogen does not focus on any particular component, nor does it provide any recommendations regarding monitoring methods of exposure limits. According to OSHA cancer policy (29 CFR 1990), a substance is a potential occupational carcinogen if it causes cancer or speeds the onset of cancer in humans or in one or more laboratory mammal species. NIOSH's recommendation that diesel exhaust be considered a potential occupational carcinogen is found in NIOSH Current Intelligence Bulletin Number 50, entitled "Carcinogenic Effects of Exposure to Diesel Exhaust", which was published in August, 1988. The recommendation is based on laboratory animal studies and epidemiological studies.

It should be noted that, in 1986, NIOSH published a document on occupational exposure to diesel exhaust in underground coal mines. That document did **not** conclude that diesel exhaust was a potential occupational carcinogen.

Since the 1986 report, several laboratory animal studies have been published which involved longer exposures (up to 30 months) to whole diesel exhaust than earlier studies. In various studies, rats, mice and hamsters were exposed to whole or filtered diesel exhaust mixed with air. From the results, NIOSH concluded in 1988 that: Recent animal studies in rats and mice confirm an association between the induction of cancer and exposure to whole diesel exhaust. The lung is the primary site identified with carcinogenic or tumorigenic responses following inhalation exposures.

Prior to the 1986 NIOSH report on coal mines, only short-term occupational health effects were documented for humans routinely exposed to diesel exhaust. Since that report, NIOSH Bulletin Number 50 reports that two epidemiological studies for workers exposed to diesel exhaust have "indicated an increased risk of death from lung cancer". Both studies used selected populations of railroad workers as the group exposed to diesel exhaust. The principal author was the same for both studies. The studies used different epidemiological methods and worker populations but reached almost identical conclusions: the risk of lung cancer for workers exposed to diesel exhaust is approximately .14 times as high as unexposed workers. The 95% confidence interval for both studies was a risk range of 1.1-1.9 for exposed workers. Although NIOSH states that these studies do not provide "definitive evidence that diesel exhaust is an occupational carcinogen", NIOSH does conclude that: Limited epidemiological evidence suggests an association between occupational exposure to diesel engine emissions and lung cancer.

Based on the laboratory animal and epidemiological studies, NIOSH also concluded that "tumor induction is associated with diesel exhaust particulate" but that, "the gaseous fraction of diesel exhaust may be carcinogenic, as well."

You can obtain a copy of Bulletin Number 50, free of charge, by calling NIOSH Publications, Tel: 513-533-8287. If they are out, the publication can be ordered from the National Technical Information Service (NTIS).

The NIOSH Bulletin and the studies it is based on have attracted much attention and are stimulating additional work. Two months ago, EPA published a draft health assessment for diesel emissions. It is marked "Preliminary Draft, Do Not Cite or Quote". We found out about it from a Washington Post article entitled "EPA Links Diesel Fumes to Cancer" which ran the day after the EPA draft was published. This EPA draft would classify diesel emissions as a probable human carcinogen, a category B1 rating by U.S. EPA cancer assessment guidelines.

NIOSH and OSHA have been encouraged to develop monitoring methods and exposure limits to permit evaluation of working environments. The Association of American Railroads, AAR, has contracted with Southwest Research Institute to perform a literature study on worker exposure to diesel exhaust and potential health effects. AAR will also evaluate sampling and analytical methods, and will undertake some sampling.

You have no doubt noticed that diesel exhaust is not categorized as a proven carcinogen. Furthermore, measurements in locomotive cabs have not found any routine significant exposure to monitored exhaust components, using OSHA standards as a guideline. In other words, the jury is still out, but to be on the safe side it is important to take precautionary steps to minimize any potential exposure of workers.

In many cases, worker exposure may be reduced or eliminated by changing work practices. In shops, you may wish to limit or cease running locomotives inside. Consideration should be given to using alternate power sources in other equipment, such as forklifts and generators, when possible. In areas where diesels are run, good ventilation may limit exposure.

In conclusion, it is important to protect your workers from levels of exposure to diesel exhaust that may cause some illness. Regulations are based on accepted occupational health data and it is important to comply with all applicable regulations. As new information becomes available, it is possible that additional protective measures will be indicated. Therefore, as a precaution, it is recommended that worker exposure to diesel exhaust be minimized or avoided whenever possible. Finally, it is important to keep up with any new developments so you can take appropriate action to protect workers.

IV. FIELD EXPERIENCE WITH MULTIGRADE RAILROAD LOCOMOTIVE OILS

A. Abstract

Two Class I railroads have been active in testing multigrade oil with similar results in their field experience. This paper presents the results of one railroad's OEM approval field test as well as those of a fuel and lube oil consumption test. Test results show that the multigrade oil performed as well as, or better than, the single-grade oil. The reduced consumption of 18 to 22 percent resulting from the use of multigrade oils outweighs the higher product cost. Also described are the productivity gains from the conversion of both the railroads to multigrade oils.

B. Introduction

In 1988, a Class I Western railroad began an OEM approval field test of two multigrade oil additive systems in compliance with LMOA field test procedures. The purpose of this test was to gain both EMD and GE approval of multigrade oil and to verify good engine lubrication. In addition, a second test was also conducted for one of the additives to determine fuel and lube oil consumption savings. This paper summarizes the structure and results of the tests as well as the cost and benefit methodology used in the decision to convert to multigrade oils. Finally, the paper presents empirical data gathered from several months of operation after the conversion of the entire locomotive fleet to multigrade oils early in 1990.

C. Key Properties of Multigrade Oils

All petroleum-based oils exhibit a decrease in viscosity with an increase in temperature. SAE 40 oil is consistently more viscous at all temperatures than is SAE 20 oil. The key, and most obvious difference between multigrade and single-grade oils, is that the viscosity of multigrade oil does not change as much with temperature, one of the major reasons for the benefits found in the field tests. Fig. 7 shows the difference in viscosity between the traditionally-used SAE 40 oil and the new SAE 20W40 multigrade oil. The three lines represent the viscosity-temperature relationship classified by the Society of Automotive Engineers.

D. Test Descriptions

1. OEM Approval Field Test

Following the LMOA field test procedures, the OEM approval field test utilized both GE and EMD locomotive units for both of the multigrade oil additive systems. All of the test units selected were rebuilt within six months of the test and were active in heavy duty coal service. During the 12 month test, each unit averaged 8,300 miles per month, or 100,000 miles for the year. In addition, several units of each locomotive type were selected to operate as a control or reference group with the traditionally-used SAE 40 oil.

Each test unit was fitted with four new power assemblies at the beginning of the test, and each reference unit received two new assemblies. The power assemblies were premeausred to provide accurate wear comparisons. All of the units were inspected and rated for engine deposits in the top deck, air intake, and crankcase areas before going into service.

During the test period, routine oil analysis was used for comparing oil longevity with regard to viscosity stability (oxidation control) and base depletion (acid neutralization). Metals were tracked to give an indication of relative wear. At the end of the test, the pre-measured assembiles were removed and measured again to calculate wear rates. The piston rings and engine areas were also rated for the presence of deposits.

2. Fuel and Lube Oil Consumption Test

Although several test cases exist for load box fuel savings results of approximately one percent, the objective of the fuel and oil consumption test was to validate the load box findings in actual freight service. In this test, a pair of GE and a pair of EMD locomotives were instrumented to measure fuel and crankcase oil depths to determine fuel and oil consumption. One locomotive from each group was filled with the 20W40 multigrade oil, and the other was filled sith SAE 40 oil. After two weeks of operation in heavy hauling, the locomotives were drained and refilled with the opposite type of oil. For example, the unit originally filled with the SAE 40 oil was refilled with miltigrade. This two week cycle was repeated six times.

Identical computerized data instrumentation systems were used for both the multigrade and the control units. The custom instrumentation setup and analysis techniques were designed for this test. On-board sensors captured fuel and oil depth, power generation, operating temperatures, and air inlet pressure. Each sensor generated data every 10 seconds, providing a significant volume of data on which to base conclusions.

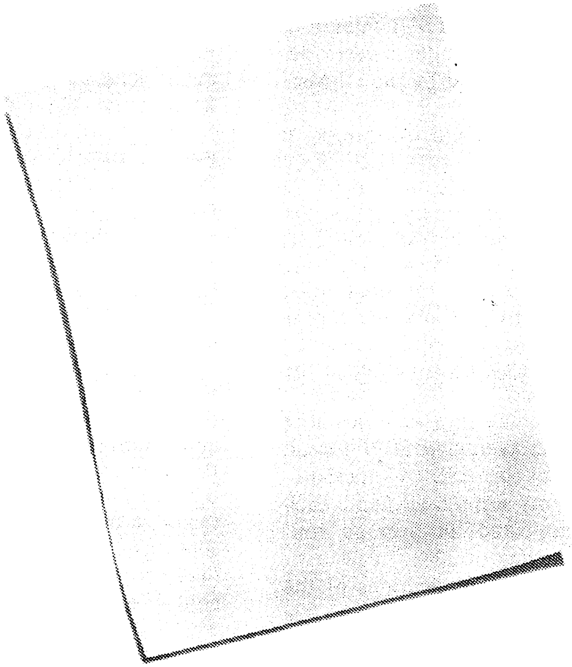
When the test was completed, the collected data were used to calculate fuel savings by comparing the brake-specific fuel consumption obtained with each oil. Operating conditions were statistically factored out as were oil savings. A backup method using a tracer provided an independent check of the results.

Statistical methods were used to analyze the date collected in the fuel and oil consumption field test. The data were then broken down into localized work segments, bracketed by idle periods during which accurate fuel and oil level determination were made. Fuel and oil consumption per horsepower hour was computed for each work segment and corrected empirically to standard conditions using the actual operational data recorded.

E. Test Results

1. OEM Approval Field Test

The results of the OEM approval



field test show that both of the multigrade oils tested performed as well as, or better than, the control oil with regard to oxidation stability, dispersancy and detergency control, total base number (TBN) retention, and wear. Both products were accepted and approved by the OEMs.

2. Fuel and Lube Oil Consumption Test

Fuel savings were measured in EMD and GE locomotive types. On the average, the fuel and oil consumption field test showed a saving of one percent fuel for multigrade oils. This figure is somewhat higher than the data collected by load box tests run on virgin oils earlier in the test program.

The lube oil savings were far more pronounced, averaging 20% for all test units. In this test, two measurement systems were used, and each method indicated an average consumption saving of 20%.

The economic implications of the field test findings provided the justification for the decision by the railroad to convert to multigrade oils. The reduced consumption of 18 to 22% resulting from the use of multigrage oils outweighs its higher product cost of 6 to 12%. In this analysis, the lube oil savings along were enough to justify the decision to convert. Any fuel savings were a welcomed secondary benefit. Fig. 8 demonstrates one simplified method that could be used to generate dollar savings in oil consumption resulting from multigrade oils.

F. Additional Benefits

Two areas not quantified in the tests, particulate emission and flow rate in cold climates, may yield additional benefits. With reduced lube oil consumption, particulate emissions may decline by as much as 10%, for reasons similar to why consumption declines with multigrades. Fig. 9 shows the temperature viscosity curve. Because the 20W40 oil is a higher viscosity lubricant for the piston rings, less oil is thrown into the combustion chamber when the piston reverses direction at the top dead center. Consumption declines, keeping the engine from burning oil. Since lube oil makes up a significant portion of particulate mass, using multigrade oil should contribute to reducing particulate emissions.

Fig. 10 shows that multigrade oils could be particularly important for railroads operating in colder climates. The 20W40 oil is much thinner than the SAE 40 oil in the winter.

The laboratory photos shown in Fig. 11 reveal a startling difference in the flow between single-grade oils and multigrade oils. The 20W40 oil flows much faster than the SAE 40 oil. Note the photos were taken with the oil at a temperature of 15 deg. F. The difference in the flow rates between the oils will be even greater at colder temperatures.

The study concluded that product waste will be reduced for drums of engine oil, and pumping will be significantly improved, allowing faster servicing of units. While no attempt was made to quantify this benefit, savings in materials handling are expected with less product waste and less energy required to heat the product to a pumpable condition.

G. Conversion to Multigrade Oil

The new 20W40 oils are fully compatible with existing SAE 40 oils, and the conversion process consisted of adding deliveries of the new oils to the existing oil storage tanks. A blend developed in both the storage tanks and the units as the inventories of single-grade oil were diluted with the multigrade oil. No problems were expected with this procedure, and none were discovered. However, the laboratory testing procedures may need to be modified to prevent the possibility of false indications with a blend of single-grade and multigrade oils.

With a conversion to multigrade oils, viscosity must be tested at 100°C (210°F) to obtain valid data for condemnation conclusions. If all railroads convert to multigrade, traditional viscosity testing temperatures can continue to be used. However, as long as the possibility exists that another railroad could top off a unit filled with multigrade with a single-grade oil, a new testing procedure is required. The single-grade oils are fully compatible with multigrades, so no opertional problems should occur.

One of the purposes of sampling and testing locomotive oils is to spot viscosity problems in the used oil. When single-grade and multigrade oils are blended, the viscosity characteristics become blended also. Fig. 12 shows that the only temperature where the viscosity is the same for both oils is at 100°C. When the two products are blended, the viscosity at 38°C will be between the viscosity curves and will depend on the percent of each constituent. If samples were tested at 38°C, the sample could be condemned for being too thick if you believed it to be a multigrade, or too thin if you believed it to be a straight SAE 40 oil. Needless false condemnations might occur because of the blend of the oils. However, testing at 100°C will give accurate testing results for SAE 40, 20W40, or blended oils. The study suggests that all railroads adopt this practice.

Other testing procedures for used oil analysis will produce the same results for multigrades or blends as with single-grade oils. However, the oil life with multigrade product appears to be at least as good as with the previously used single-grade products. Given this, and the fact that multigrade oils reduce oil consumption, the stress on the multigrade oil and additive system is more severe. Since multigrade oils are better than single-grade oils in oxidation resistance, the stress will be focused more on their base reserve and soot dispersion properties than on oxidation control. These properties should be carefully monitored and may require new condemning limits. The fleet conversion to multigrade oils has resulted in clear-cut fuel consumption savings.

H. Conversion Results

Fig. 13 shows that the average gallons of fuel oil consumed per million gross ton miles decreased 2.5% in April through July 1990 as compared to June through December 1989. The left bar represents the time frame in which only single-grade oils were in use. The middle bar represents the transition period, or the time frame in which the railroad was changing over to multigrade oils. The right bar represents the time that only multigrade oils were consumed. Note that there was a small increase in fuel consumption during the transition period, most likely caused by the effects of cold weather and a changing freight mix during that period. The 2.5% decrease in fuel consumption in actual freight service far exceeds the load box and the fuel consumption test data that showed a decrease of only one percent.

The most evident savings were in the reduction of lube oil consumption resulting from the use of multigrades. Fig. 14 shows lube oil consumption data from June through December 1989 to April through July 1990. The average gallons of lube oil consumed per million gross ton mile decreased 23.5%, showing a steady downward trend and supporting the data from the field test of savings in the 20% range.

I. Another Railroad's Experience

A Class I Eastern railroad has also been active in testing multigrade oils with similar results in its field experience. Without a direct comparison of data between the two railroads, Fig. 15 shows the average gallons of fuel consumed per million gross ton miles. As with the Western railroad, results show strongly improved fuel economy. In fact, the Eastern railroad experienced a 4.5% reduction in fuel consumption as a result of the conversion to multigrade oils. As noted earlier, these savings may indeed far exceed the lube oil consumption savings.

Fig. 16 shows that, like the Western railroad, the Eastern railroad also identified significant savings in lube oil consumption, realizing a 15.8% decrease compared to the use of single-grade oils. Both railroads have seen marked improvement in the lube oil to fuel oil ratio, with a 12.5% decrease for the Eastern railroad and a 22% decrease for the Western railroad.

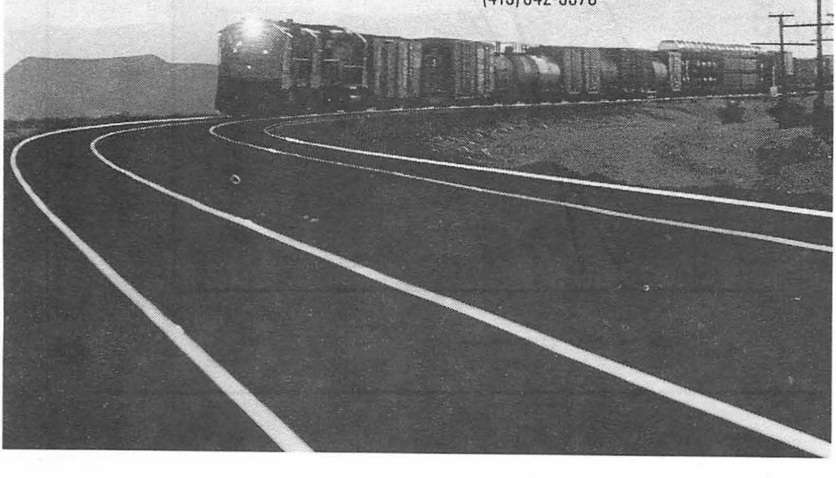
J. Productivity Gains

Reversing several of the earlier ratios produces some interesting results. For example, Fig. 17 and 18 show an 18.4% and a 30.7% increase in the average gross ton miles per gallon of lube oil consumed by the Eastern and Western railroads, respectively. Each railroad also improved productivity by increasing the average gross ton miles per gallon of fuel oil consumed, with a 3.9% increase for the Eastern railroad and a 2.3% increase for the Western railroad. Multigrade lube oil technology gives these two railroads a distinct advantage in reducing operating costs, improving locomotive engine performance, and increasing productivity. However, some of these types of savings are in part related to other efforts, including more fuel-efficient locomotives, the installation of concrete ties, rail lubrication programs, and improved training programs for locomotive operating personnel.

Conclusions

In summary:

- Performance of multigrade oil is at least as good as that of control oil.
- OEM approvals were obtained.
- Used oil testing modifications were minor.
- Lube and fuel oil consumption strongly support the conversion to multigrade oils.
- A second railroad's experience supports the conversion.



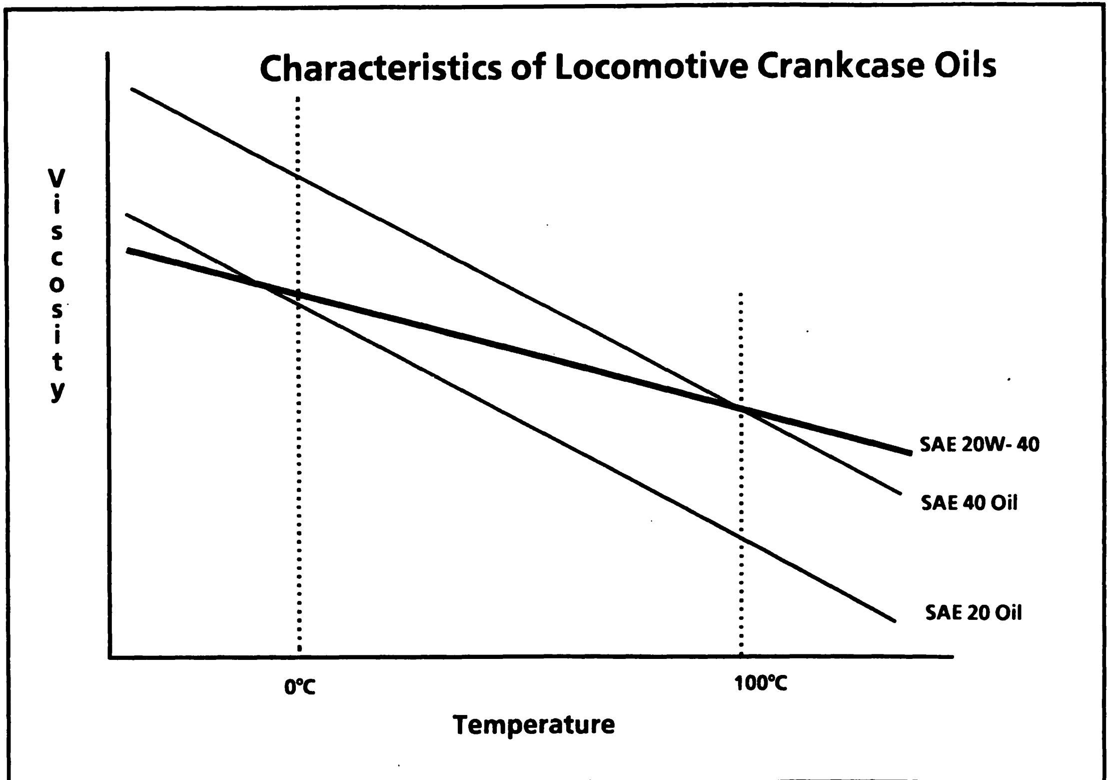

Characteristics of Locomotive Crankcase Oils
Viscosity
SAE 20W- 40
SAE 40 Oil
SAE 20 Oil
0°C
100°C
Temperature

Fig. 7

LMOA
Fuel & Lubricants
Committee

BENEFIT CALCULATION METHOD

• Total Annual Purchases (gallons)	6,000,000
• Drainings (30%)	1,800,000
• Consumption (70%)	4,200,000
• Multigrade benefit (20%) (4,200,000 x .20)	840,000
• Price (SAE 40)- $1.70/gallon (6,000,000 x $1.70)	$10,200,000
• Price (20W40)- $1.90/gallon (6,000,000-840,000) = 5,160,000 gallons	
• "Revised" Annual Expenditure (5,160,000 x $1.90)	$9,800,000
• Total Savings	$400,000

Fig. 8

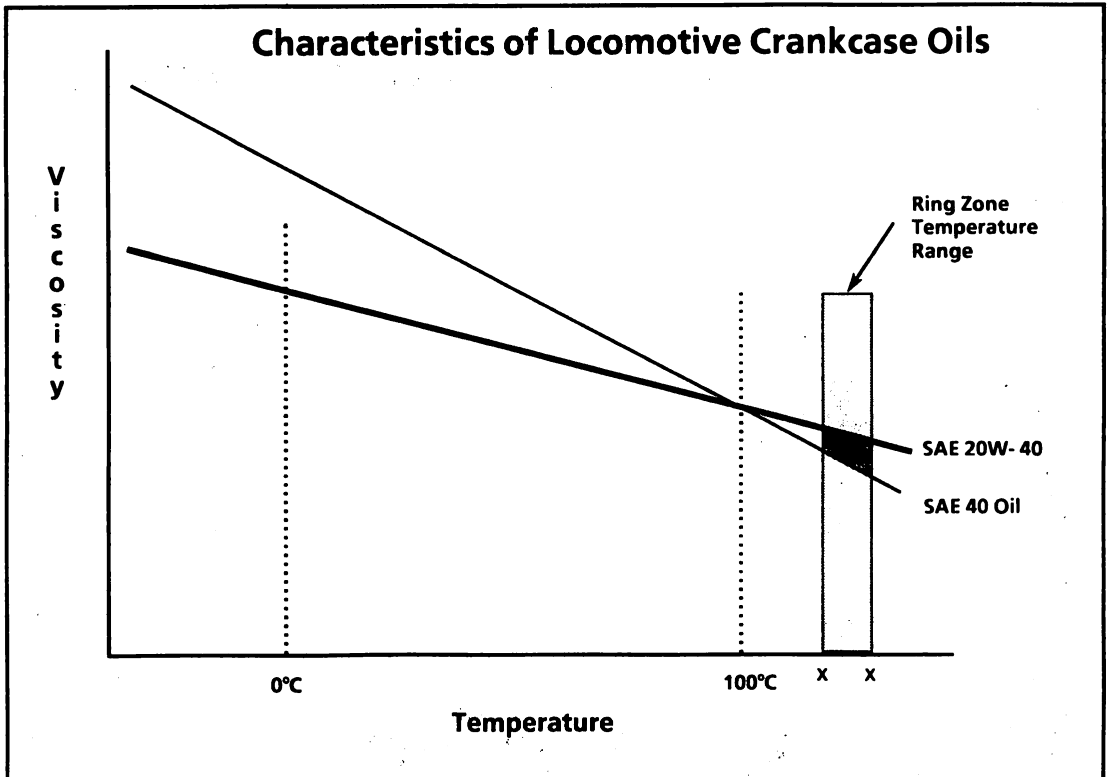

Characteristics of Locomotive Crankcase Oils
Viscosity
Ring Zone
Temperature
Range
SAE 20W- 40
SAE 40 Oil
0°C
100°C
X
X
Temperature

Fig. 9

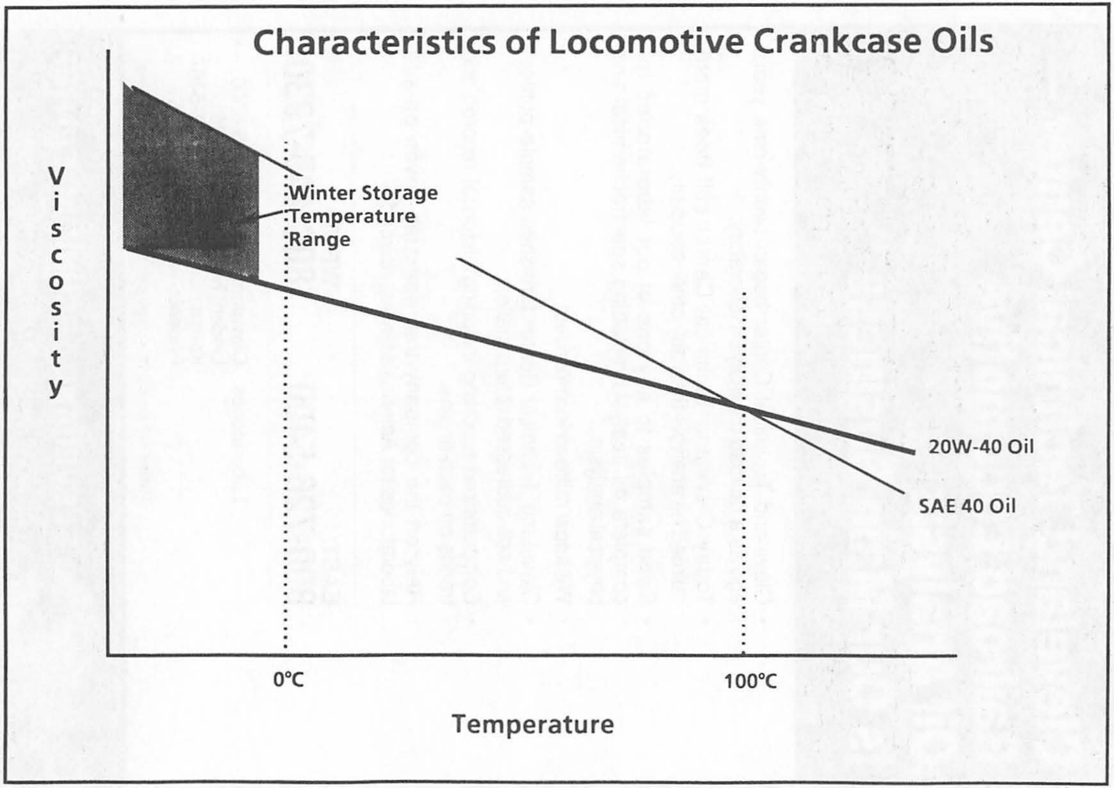

Characteristics of Locomotive Crankcase Oils
Viscosity
Winter Storage
Temperature
Range
20W-40 Oil
SAE 40 Oil
0°C
100°C
Temperature

Fig. 10

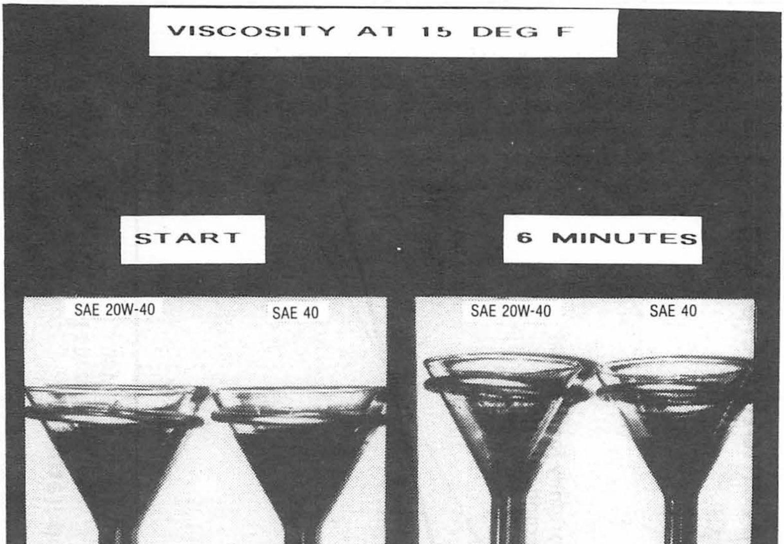

VISCOSITY AT 15 DEG F
START
6 MINUTES
SAE 20W-40
SAE 40
SAE 20W-40
SAE 40

Fig. 11

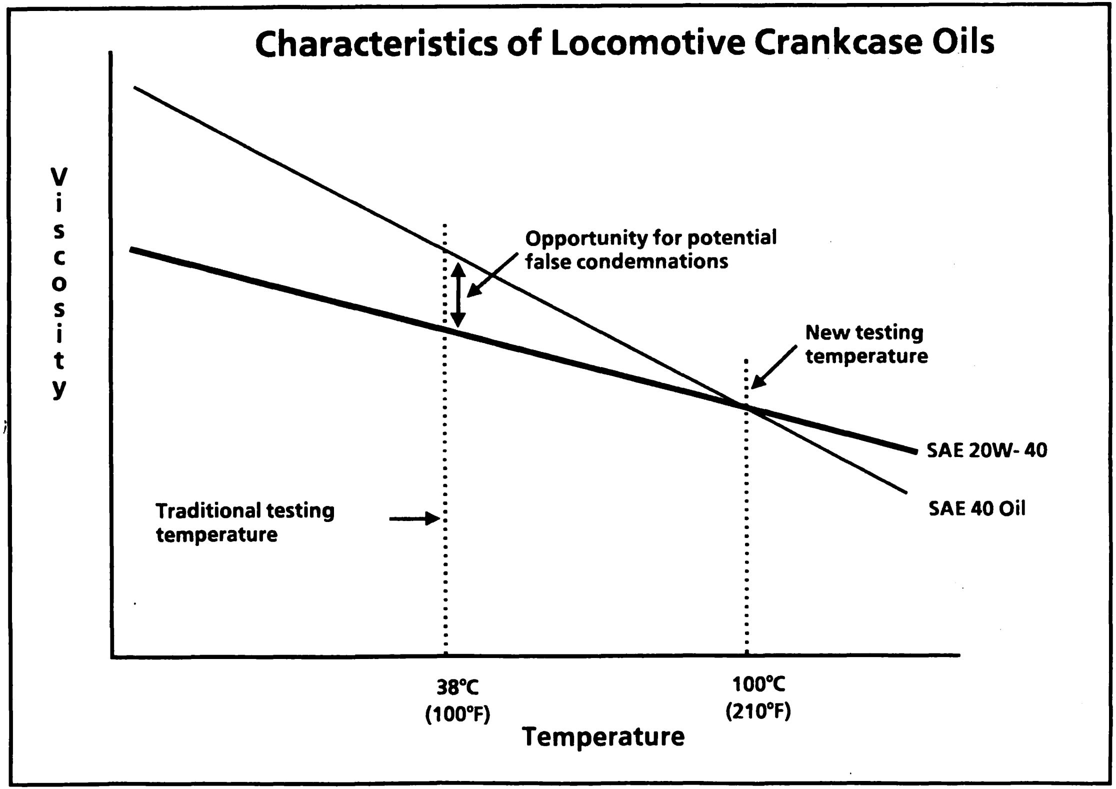

Characteristics of Locomotive Crankcase Oils
Viscosity
Opportunity for potential false condemnations
New testing temperature
SAE 20W- 40
SAE 40 Oil
Traditional testing temperature
38°C (100°F)
100°C (210°F)
Temperature

Fig. 12

AVERAGE GALLONS OF FUEL OIL CONSUMED PER MILLION GROSS TON MILES FOR WESTERN RAILROAD

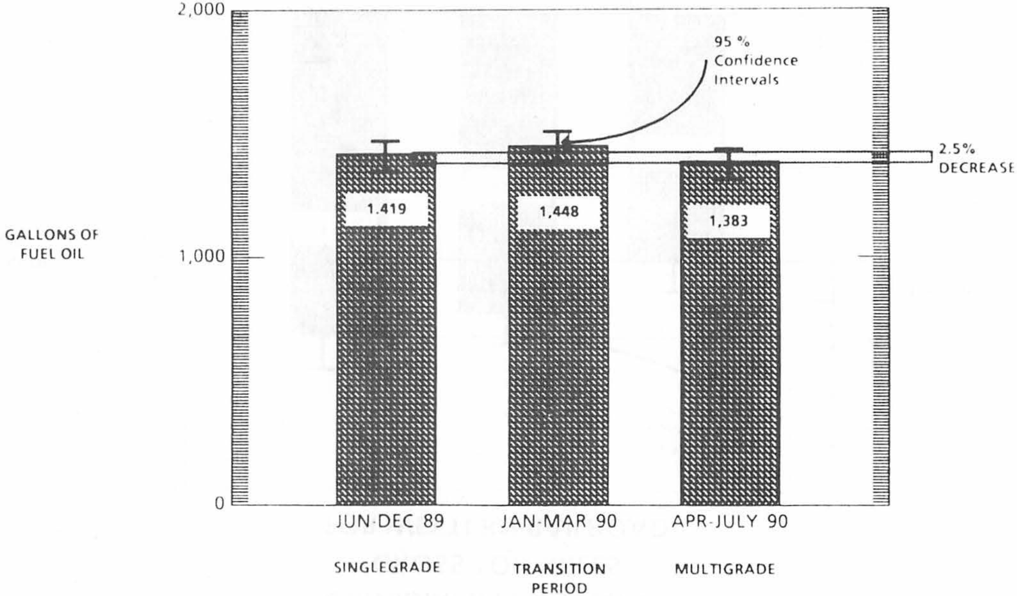


Fig. 13

AVERAGE GALLONS OF LUBE OIL
CONSUMED PER MILLION
GROSS TON MILES
FOR WESTERN RAILROAD

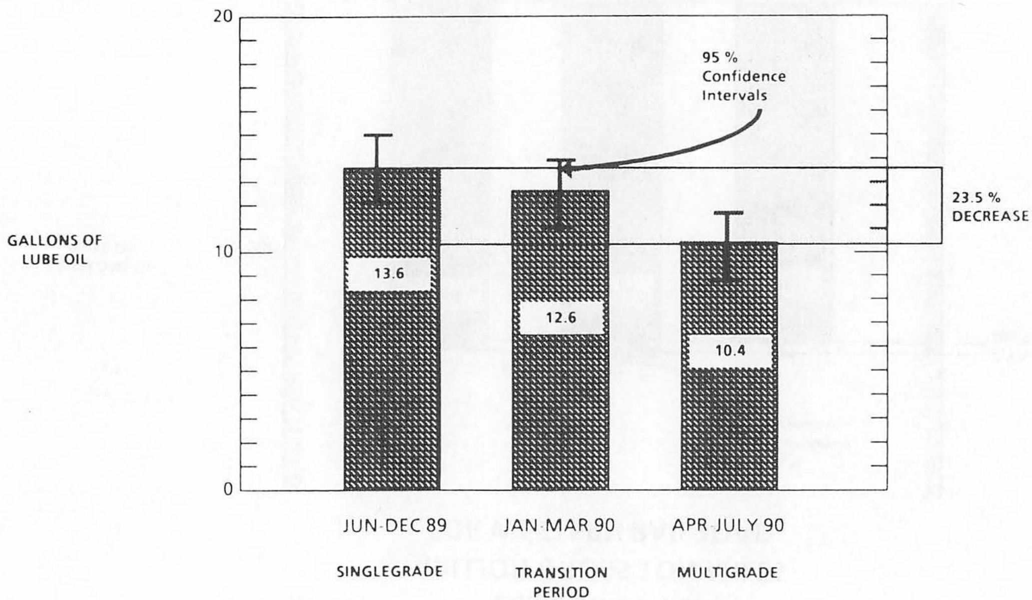


Fig. 14

AVERAGE GALLONS OF FUEL OIL CONSUMED PER MILLION GROSS TON MILES FOR EASTERN RAILROAD

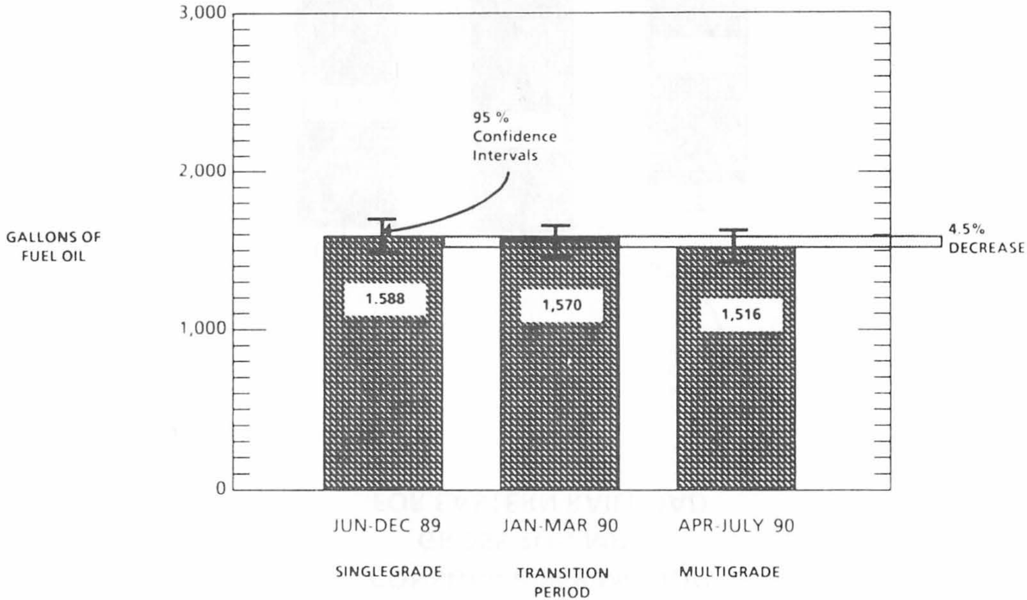


Fig. 15

AVERAGE GALLONS OF LUBE OIL CONSUMED PER MILLION GROSS TON MILES FOR EASTERN RAILROAD

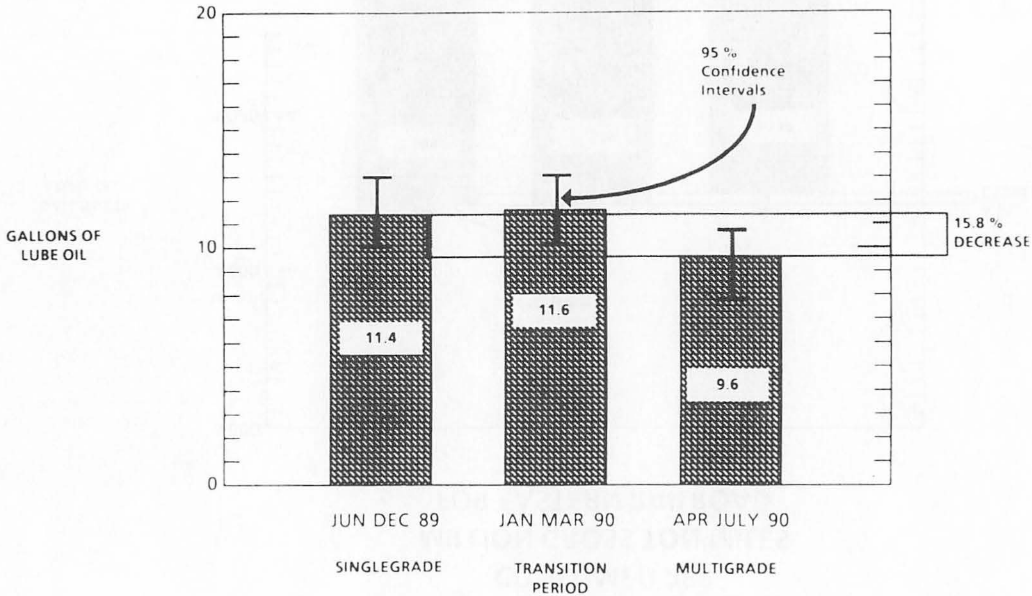
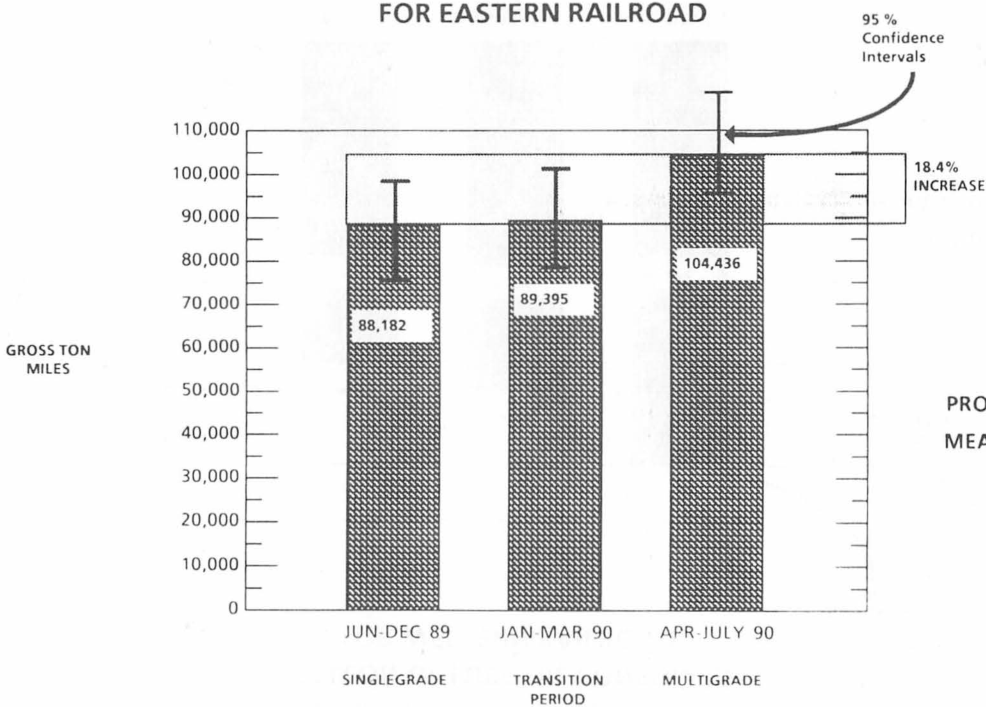


Fig. 16

AVERAGE GROSS TON MILES PER GALLON OF LUBE OIL CONSUMED FOR EASTERN RAILROAD



PRODUCTIVITY MEASUREMENT

Fig. 17

AVERAGE GROSS TON MILES PER GALLON OF LUBE OIL CONSUMED FOR WESTERN RAILROAD

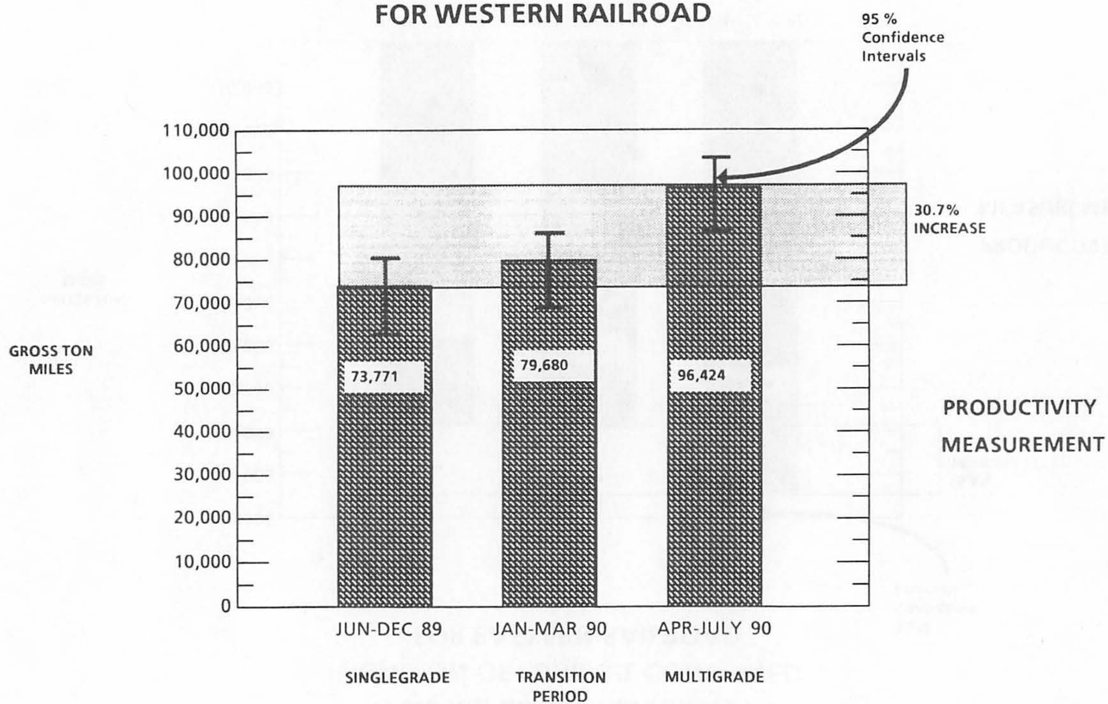


Fig. 18

V.
CONRAIL WHEEL/RAIL LUBRICATION UPDATE

Abstract

For the last several years, Consolidated Rail Corp. has been an industry leader in the investigation and implementation of wheel/rail lubrication. This has been a coordinated approach with evaluations of both wayside and on-board lubrication devices as well as the lubricants themselves. Various methods of ranking the effectiveness of wheel/rail lubrication have also been examined.

This paper provides an overview of the analytical justification of wheel/rail lubrication and describes the results of Conrail's testing to date. Particular attention is paid to recent resting at the Association of American Railroad's Facility for Accelerated Service Testing (FAST) at the Transportation Test Center in Pueblo, Col. A detailed description of the various quantitative measurement systems available to the investigator are discussed. The development of an analytical model to describe the wheel/rail lubrication environment is presented.

Consolidated Rail Corp. (Conrail) has been involved in wheel/rail lubrication for many years. It was the first railroad to make the commitment to on-board flange lubricators on a large scale. Today, it has about 700 locomotives in operation that are equipped with flange lubricators. Conrail is not content with the status quo in this area. It is constantly trying to improve not only the quality of flange lubrication itself, but also the analytical methods for evaluating revenue conditions as well as increasing the understanding of the wheel/rail interface and how lubrication affects it.

Since the rediscovery in the early 1980s of the energy savings due to flange lubrication, Conrail's Technical Services Laboratory has performed numerous tests to evaluate flange lubrication. Recently, this testing has been performed in conjunction with the Association of American Railroads (AAR) at the Transportation Test Center (TTC) in Pueblo, Col. This site was chosen to reduce the time and costs required to perform these tests as opposed to a comparable revenue test. The first of these tests had two objectives. The first objective was an evaluation of alternative lubricants to the on-board lubricant then being used on Conrail. The second objective was a study of the affects of increased output in curves by using a curve sensor. Conrail's original lubricant, a calcium based, non-EP (Extreme Pressure) additive grease, was originally chosen to be compatible with the on-board equipment being installed by Conrail. Subsequent to the initial lubricant specification, the lubricant evaluations that were being performed in the industry suggested that there was an increased advantage in using an EP additive grease.

Several different formulations of flange lubricant, all containing EP additives, were selected for testing. The selection process was nonrigorous and attempted only to include as many formula variations as could be tested within the budget set for the project. Testing was performed in the Fall of 1988 on the 3.5 mile long wheel/rail mechanism (W/RM) loop using a train of 24 cars, Conrail's test coach, and one 3,000 hp, six-axle locomotive. Electrical energy output from the locomotive main generator was the primary energy measurement. In addition, the coefficient of friction, as measured by the AAR tribometer, was used to determine the relative state of wheel/rail lubrication. These data were recorded for each lap.

Operation of the train was first conducted in a dry state to allow the locomotive and the train roller bearings to reach operating temperature and to determine that all previous lubrication had been removed from the wheel/rail interface. The on-board lubricator was then operated at a rate comparable to the existing Conrail setting. Operation continued until a steady state was reached. The on-board lubricator was then operated in the curve sensing mode. Again, operation continued until a steady state was achieved. The lubricator was then turned off, and operation continued until the dry state seen at the start of the test was achieved. This test regimen was repeated for each lubricant.

Results of this test indicated that while the existing lubricant provided a significant energy saving, further savings could be achieved by use of a lubricant containing an EP additive. Unfortunately, as can be seen in Fig. 19, all of the EP lubricants appeared to be about the same from a statistical standpoint. At the 95% confidence level, it is possible to draw a line connecting all but one of the EP lubricants. Thus no clear winner in this category could be established.

These results are quite good considering the repeatability of laboratory tests. The American Society for Testing and Materials (ASTM) states in numerous test methods for lubricants that repeatability and reproducibility is most difficult. For example, in method D2509, "Measurement of Extreme Pressure Properties of Lubricating Grease (Timken Method)", The ASTM states that, for repeatability, data taken by the same operator should be suspect if they vary by more than 23%. For reproducibility between laboratories, data should be suspect if they vary by more than 59%. Similar comments are made for other lubricant testing methods.

One other important result of this test is that, regardless of the lubricant used, improvement in the energy savings can be realized by using a curve sensor to increase the amount of lubricant dispensed in curves. Use of a curve sensor allows the amount of lubricant to be increased in curves without causing undue contamination of the locomotive underbody in tangent track.

During this time period, a static test of these same lubricants was being conducted at the laboratory in Altoona, Pa. This test was designed to evaluate the ability of the existing hardware in use on Conrail's locomotives to successfully apply the test lubricants. Some forms of graphite actually have abrasive properties under certain conditions. It was found that these graphitic lubricants attacked the dispensing nozzles during the static test rendering them quite useless. The manufacturer of the lubricating equipment subsequently redesigned its dispensing nozzles. Based on the results of these tests, Conrail changed its specification for an on-board lubricant to a lithium based product with a molybdenum disulfide EP additive. This lubricant could be handled in the existing equipment with no modification.

The second test at Pueblo was performed in June of 1989 to answer the question "Can an on-board system replace a wayside system of lubricators?" This test was done on the 2.8 mile long Facility for Accelerated Service Testing (FAST) loop using the Heavy Axle Load (HAL) test train. The train consist was composed of 5 four axle locomotives equipped with curve sensing lubrication hardware, the Conrail test coach, and 81 loaded hopper cars, 74 of which were 125 ton cars. The existing wayside lubricators at

FAST were used in conjunction with the on-board equipment. Operating conditions were in keeping with the existing FAST test plan: counter-clockwise operation, 40 mph train speed, lubrication dispensed only on the outside rail, and limitations on the amount of dry operation. Data were collected from the drawbar horsepower by the Conrail test coach, and from the tribometer at one point along the track in a 5 degree curve.

A baseline for energy consumption using the existing FAST wayside lubricator settings was obtained. The on-board lubricators were then used at different settings both by themselves and in conjunction with the wayside lubricators to evaluate different lubrication scenarios. The results of this test indicated that, on-this closed loop, similar lubrication levels could be achieved with either wayside or on-board hardware.

However, the additional lubrication obtained by operating both concurrently produced a further reduction in drawbar horsepower required to operate the train. Also, an excellent correlation between the tribometer data and the drawbar horsepower was observed. This last result encouraged Conrail to purchase two second generation prototypes of the original AAR tribometer for evaluating lubrication state in revenue situations.

A summary of these two tests can be seen in Fig. 20. It is possible to achieve a maximum energy saving of around 25% from the dry state. Of significance are the curve sensing data. With a short train, this same maximum saving can be achieved with only on-board lubricators. However, with a long train, wayside lubrication must also be used to achieve this maximum level. Clearly, the currently available lubricants and on-board hardware have difficulty in providing optimum lubrication for normally sized freight trains. The question that remains to be answered is "What is the current level of energy reduction in revenue situations?"

The next progression in Conrail's testing involved the trial of the tribometer in revenue service. This test was conducted in a five mile long section of double track main line just east of Altoona. There were two objectives of this test. One, to investigate the quantity of lubrication as a function of the distance from a wayside lubricator. Two, to observe the changing conditions at one location as a function of traffic. Very little control was attempted for this experiment and, as a result, the lubrication in the test zone was affected by both wayside lubricators outside the test zone and by on-board lubricators. Bi-directional operation on these tracks also distorted the date acquired.

Even without these controls, results were good. Excellent repeatability of the tribometer data was observed. What at first appeared to be a variation in the tribometer with temperature turned out to be a variation in the amount of lubricant dispensed by the wayside lubricators with temperature. As was expected, the effectiveness of wayside lubrication appeared to be inversely proportional to the distance from the lubricator. Based on the results of this limited test, the tribometer appears to be an excellent instrument for revenue evaluation of lubrication condition.

The next test is planned for Conrail's Boston & Albany Line and will be conducted in the Fall of 1990. The test objectives will be to determine the current level of lubrication effectiveness and to optimize the level of lubrication on this line by using the tribometer data. Particular attention will be paid to locomotive wheel slip and underframe contamination. Adjustments will be made to both wayside quantity and on-board quantity for both the tangent and curve sense modes of operation. Monitoring will be performed at one specific site on the ruling grade.

A few qualitative comments on Conrail's recent testing are in order. Testing on the W/RM loop offered the opportunity to observe the rail head condition for lubrication ranging from overlubricated to completely dry. Two basic conditions were observed on the contact surface: a smooth polished condition and a very rough abraded condition. The polished condition was obtained after a period of lubrication and the abraded condition was the result of dry operation. This abraded condition was observed to be so severe after one period of dry operation that there were actually flakes of metal welded to the gage face of the rail that had turned blue from excessive temperature.

These two conditions were found to be extremely significant for lubrication. It was observed that a large amount of lubricant was required to return the rail to a polished condition. Once this had been done, only a small amount of lubricant was required to maintain the polished condition. At one point during the second Pueblo test, when the test plan required a start-up from dry using only the on-board lubricators, it was necessary to also engage the wayside lubricators to achieve the polished condition. Once this was done, the wayside lubricators were turned off and effective lubrication was maintained with one-third of the lubricant that was dispensed by the on-board lubricators originally.

This has a tremendous significance for revenue service. If the lubrication hardware, either wayside or on-board fails, additional lubricant will be required to return to a state of effective lubrication. This will obviously require observation and adjustment by railroad personnel.

These differing rail conditions also appear to affect the coefficient of friction readings produced by the tribometer. The Technical Services Laboratory recently had occasion to evaluate the top of the rail in an area of tangent track, far from any wayside lubricators. This surface was very highly polished and readings in excess of 0.70 were obtained. It would appear from the testing performed so far that a well polished, well lubricated steel surface will have a coefficient of friction reading of between 0.07 to 0.10. An abraded dry surface will have a coefficient of friction reading of between 0.40 to 0.50. A dry polished surface will have readings in excess of 0.60.

This apparent anomaly in the data is probably caused by the fact that the measurement wheel on the tribometer is smooth. When the rail surface reaches the abraded state, the rail wheels will also assume an abraded state. Measurement of the track in an abraded state with the tribometer thus may not accurately reflect the actual friction conditions. This should not be a problem for most measurements since this abraided condition only occurs under the poorest lubrication situation.

The means for measuring the lubrication state have changed significantly in recent years. In the beginning, most work was done by mounting fuel flow meters on the inlet and return lines to the injectors of the diesel engine. This method used fuel consumption as a surrogate for lubrication effectiveness. Due to differences in the meters and the large flow rate, this often resulted in the locomotive "making fuel" at low horsepower outputs. Next came a modification to the fuel system to allow for only one meter. This improved the measurement ability but still reaulted in a difficult and time consuming task.

Fuel consumption of a locomotive is extremely well correlated to the main generator electrical output. This technique has been extensively used and is still a good one. It still requires time and effort to instrument a locomotive. This is reduced by using the on-board computers contained in the newer locomotives to record total electrical energy output.

Event recorders that record traction motor current can also be used to measure power output. Motor voltage is a function of motor speed which is, in turn, a function of train speed. Appropriate multiplication of traction motor current by train speed will yield electric power output. This method will produce an error of less than about 3% over a fuel consumption method.

The drawbar horsepower is also a good measure of fuel consumption or train energy. It requires precision setup and monitoring to avoid offsets. The tribometer now provides the first change at a direct measurement of lubrication effectiveness that is simple to make, instantly available, and repeatable. It should become the standard in a short time.

Analytically, very little work has been done in the area of wheel/rail lubrication. Empirical ideas for wayside lubricator placement have been used by maintenance of way forces for many, many years. These are usually based on degree of curvature and central angle subtended. Formulas for lubricator placement exist that use these two variables and they function reasonably well. Little attempt has been made to quantitatively evaluate these models, and no attempt has been made to develop models for on-board lubricators. The major reason for this dearth of study has been the difficulty with accurately measuring the state of lubrication under field conditions. The Technical Services Laboratory is convinced that it now has this ability with the AAR developed tribometer.

In order to optimize flange lubrication system-wide without having to devote countless hours to observing each and every location, it is necessary to develop a model to describe the operation of both wayside and on-board lubricators. This model will have to address not only the operation of the lubricators but must also accurately describe the method of lubricant transfer from one place to another. Lubricant transfer has been described by such terms as flowability, carry and spreadability, all implying that lubricant is transferred as a viscous mass by being squeezed out along the track. Near a lubricator, this is probably true, but within a short distance, there is so little lubricant remaining in the wheel/rail contact area that it is unlikely that this analysis still applies.

The author proposes a model for lubricant transfer called the "bubble gum" method. Imagine a person who has just stepped on a piece of previously owned bubble gum. As he raises his shoe (note: use of the masculine also implies the feminine), approximately half of the gum adheres to his shoe and the other half remains in place. For the next step, the same process occurs except now only one-half of the original quantity of gum exists on shoe and ground combined. This event occurs for each subsequent step until, finally, the amount of gum remaining on his shoe becomes vanishingly small. This must be the method of lubricant transfer at some distance arbitrarily far from the lubricator. Note also that, once the first step has taken place, it is impossible to tell whether the gum was originally located on the ground or on the bottom of the shoe. Thus, the type of lubricator, wayside or on-board, is not significant if the same amaount of lubricant is originally applied by either type of lubricator.

Another thesis is that there exists a maximum amount of lubricant that can be applied for one solitary application. In other words, attempts to apply more than this amount result in the lubricant being lost from the wheel or rail simply because there is no more room in the interface to hold additional lubricant. This excess lubricant ends up on the locomotive, the ground or in a location other than the wheel/rail contact patch. This phenomenon can be readily observed at any convenient wayside lubricator; however too close an observation may result in personal contamination.

Using these two theses, the distribution of lubricant versus distance from the lubricator should appear as in Fig. 21. The equation takes the form:

$$\text{Coefficient of Friction (H)} = H_{max} - (H_{max} - H_{min}) * e^{-k*d}$$

where: H_{max} is the maximum possible coefficient of friction
H_{min} is the minimum possible coefficient of friction
k is an empirically derived constant
d is the distance from the lubricator in feet

This is based on a wayside lubricator. To convert this to the on-board case, remember that the distance from the wayside lubricator can be expressed as the number of times that a given diameter wheel has rotated since it passed the libricator:

$$\text{Number of Revolutions} = d / (D * \pi)$$

where: d is again the distance from the wayside lubricator in feet and

D is the wheel diameter

The distance back in the train from the on-board lubricator to where a similar coefficient of friction to a wayside lubricator can be found is simply this number of wheels. Fig. 22 shows the same data as in Fig. 21, but expressed for an on-board lubricator.

Conrail hopes to establish a value for the constant, k, in its upcoming test. Based on historical data and data taken at Spruce Creek, a rough first attempt at this is shown in Fig. 23. The upper graph shows an on-board lubricator and the lower graph shows a wayside lubricator. The apparent minimum and maximum limits are shown as well as the data taken at Spruce Creek. The constant, K, seems to lie between the values 0.00005 and 0.0002. Again, remember that the actual data were influenced by lubricators outside of the test zone, bi-directional running, and by on-board lubricators. The data from Spruce Creek diverge from the model at distances from the lubricator that are relatively great.

If this model is validated, it should then be possible to evaluate on-board lubricants and lubricator strategies with a wayside lubricator similar in design to the on-board lubricator and using the tribometer. Modification to locomotives and train schedules will no longer be required and test crews can be stationed at one location.

In conclusion, there are still opportunities to improve the level of wheel/rail lubrication and consequently save money. Much technical work remains to be done but this should not prevent the implementation of on-board lubrication. The development of a good model to describe wheel/rail lubrication should not be far off. The laboratory test to evaluate lubricants may prove to be more difficult.

Wheel/rail lubrication systems are a maintenance headache whether one talks about wayside or on-board hardware. Ways must be found to reduce maintenance costs while improving reliability of all types of lubricators. New designs in wayside lubricators aimed at improving application techniques to reduce waste and at improving ease of maintenance must be developed. Techniques to streamline maintenance and reduce costs must be found for on-board systems. Management must insist that lubricators, both wayside and on-board, be maintained and kept in good working order.

The rail industry invests roughly $3 billion for diesel fuel each year in the United States. This amount is between 5% and 10% of the industry's gross operating revenue, and very close to the industry's overall net operating revenue. Thus, for each percentage point of fuel cost saved, the net operating revenue will rise by that same percentage. Based on the data taken by Conrail at Pueblo, equipping the locomotive fleet with on-board lubricators and curve sensors could conceivably reduce the industry's fuel costs and increase its operating revenue by an additional 5%. Such a simple analysis ignores any additional savings in wheel and rail wear. With the current crisis in the Middle East, fuel prices can only be expected to rise. Considering the competitive transportation environment, this is an opportunity that the industry cannot afford to waste.

Fig. 19

95% CONFIDENCE INTERVALS – W/RM LOOP

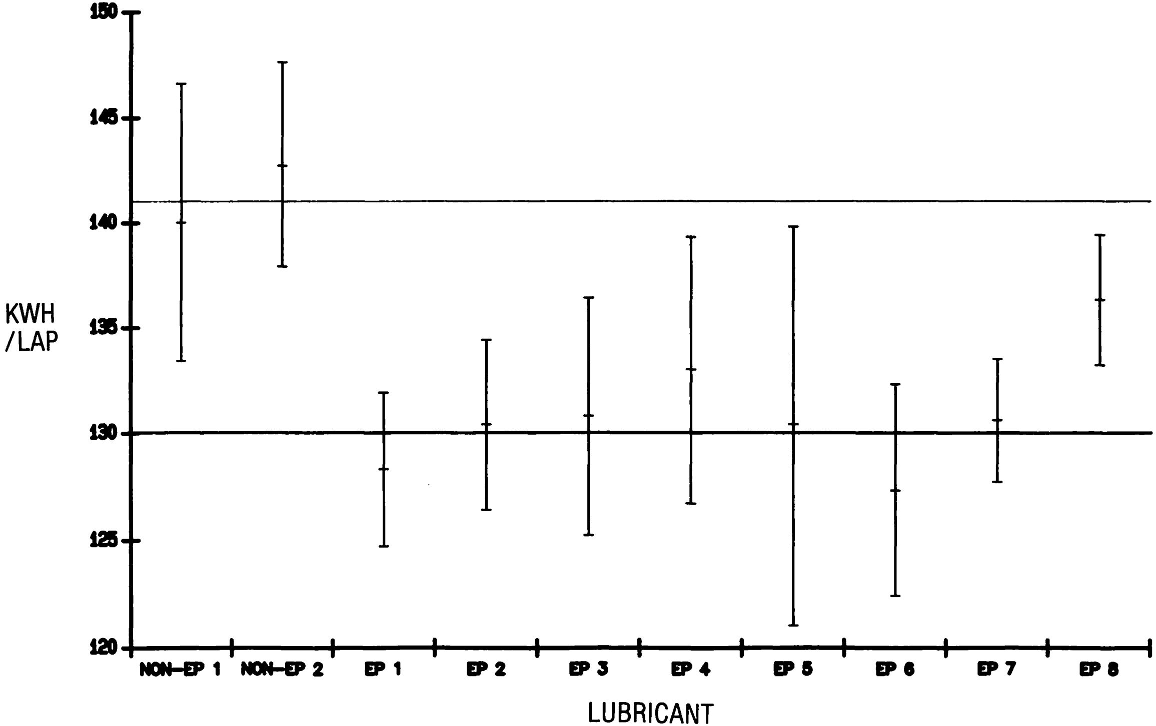


Fig. 20

SYNOPSIS OF CONRAIL TESTS AT TTC

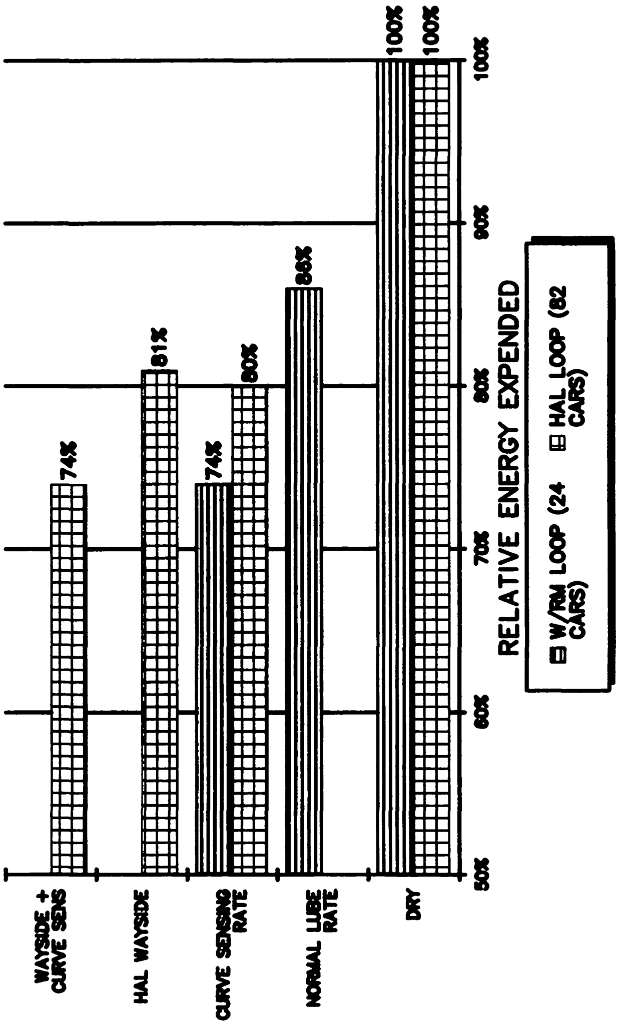


Fig. 21
PROPOSED MODEL

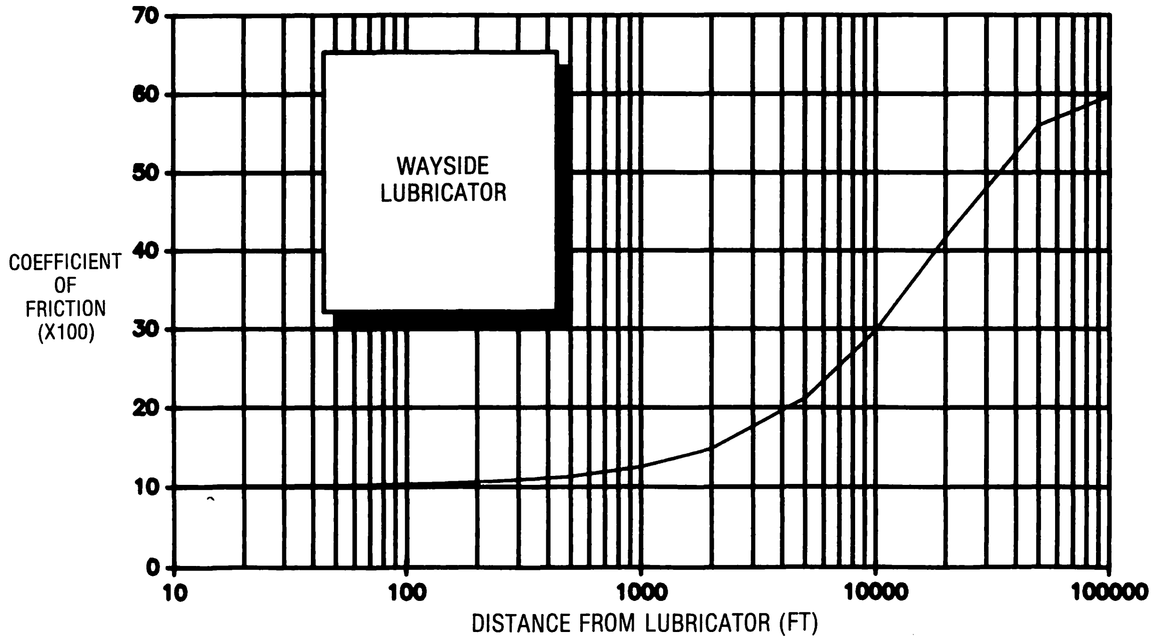


Fig. 22
PROPOSED MODEL

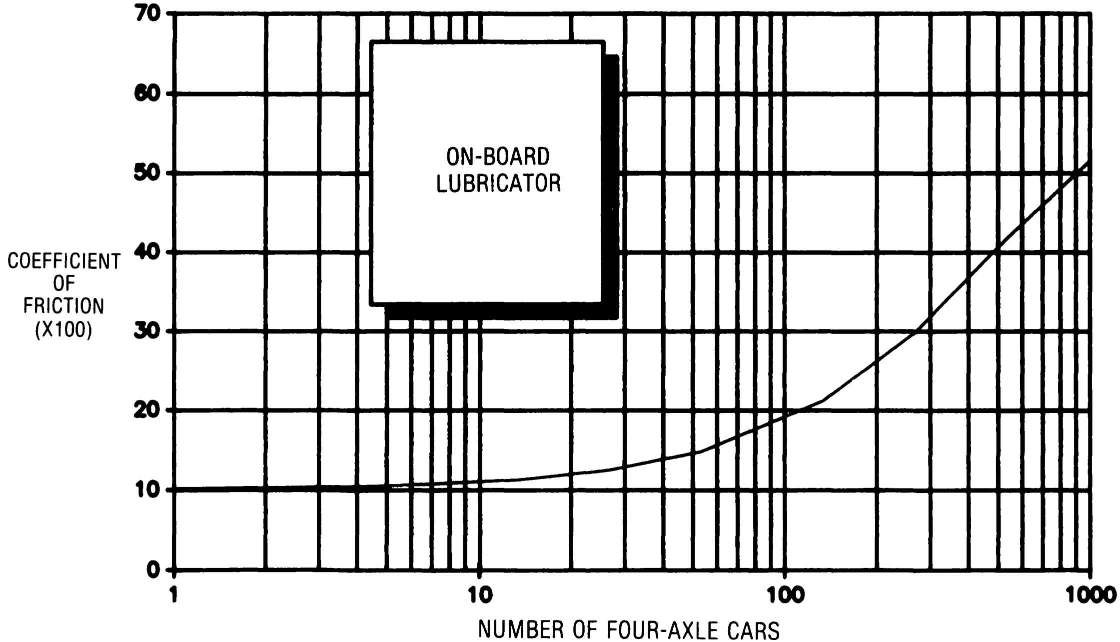
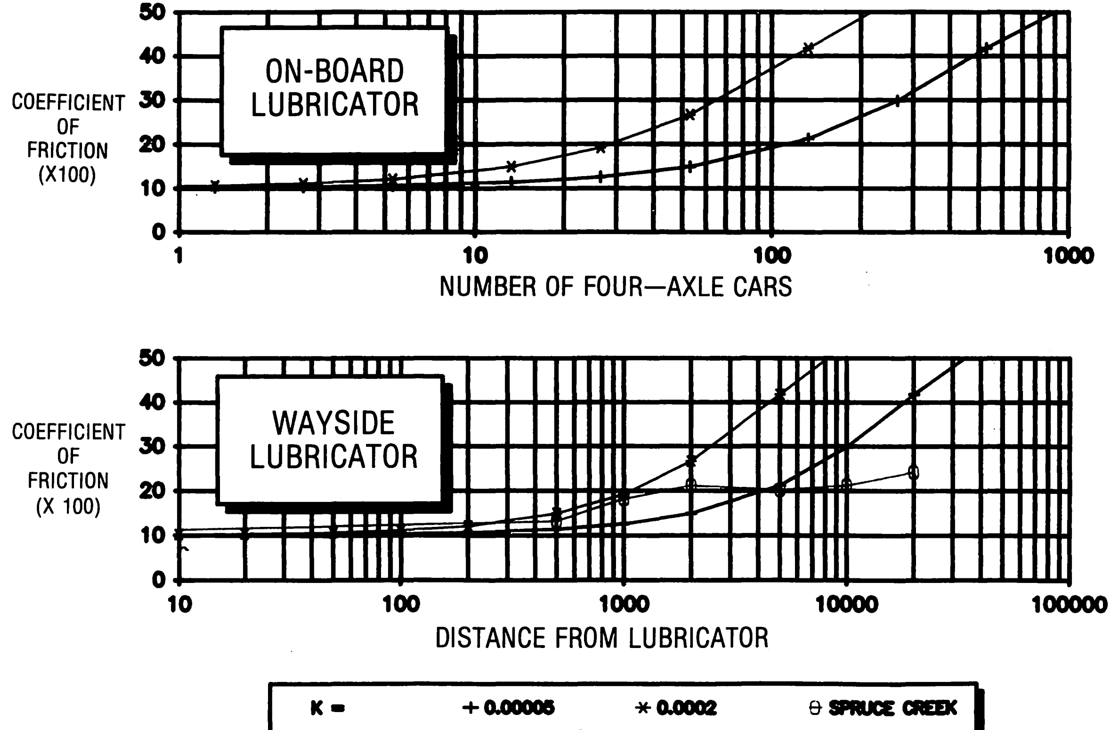
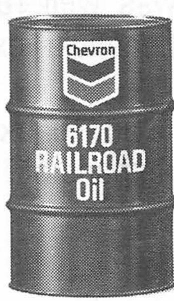


Fig. 23


ON-BOARD LUBRICATOR
COEFFICIENT OF FRICTION (X100)
50
40
30
20
10
0
1
10
100
1000
NUMBER OF FOUR—AXLE CARS
WAYSIDE LUBRICATOR
COEFFICIENT OF FRICTION (X 100)
50
40
30
20
10
0
10
100
1000
10000
100000
DISTANCE FROM LUBRICATOR
K =
+ 0.00005
* 0.0002
θ SPRUCE CREEK


Chevron
6170
RAILROAD
Oil

MR. J. R. NUSSSRALLAH
Asst. Vice President & CMO
Consolidated Rail Corp.
Philadelphia, PA 19103

LMOA wishes to express its thanks to Conrail for hosting the Pre-Convention Presentation in Altoona, PA.

Our Diesel Material Control Committee's presentation was well received in what we trust was a mutually beneficial experience.

Our thanks again to Mr. J. R. Nussrallah and others responsible for and participating in this activity.

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

Monday, September 17, 1990
2:15 P.M.

Pre-Convention Presentation Conrail

May 2, 1990
Sheraton Altoona
Altoona, PA

H. H. (MIKE) PENNELL, Chairman
Director-Material
Burlington Northern Railroad
Overland Park, KS

VICE CHAIRMAN

L. J. Cala, Mgr. - Material Control - Loco. Conrail, Altoona, PA

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H. E. Nash	Director of Purchasing	MRL	Missoula, MT
D. G. Schonauer	Parts Material Manager	EMD	Hodgkins, IL

PERSONAL HISTORY

Harry H. Pennell

Harry H. (Mike) Pennell was born in Childress, TX, where he began his railroad career in 1964 as a machinist apprentice for the Fort Worth and Denver Railroad. In 1968 he transferred into the Material Department and continued working there until his promotion to the Burlington Northern Railroad in 1970, at which time he assumed a position in North Kansas City, MO.

During the next several years he held various positions in West Burlington, IA; St. Paul, MN; Springfield, MO and Naperville, IL. His current position is Director Material for System Shop Stores, headquartered at Overland Park, KS.

Mike is married and has two daughters 17 and 14. His hobbies include golf and fishing.

BE A PART OF THE SOLUTION... NOT PART OF THE PROBLEM!

A. Waste Minimization

As you are probably aware, there is much discussion today about our polluted, poisoned water, our overloaded landfill sites, chemical and toxic run off as well as a "greenhouse effect" caused from polluting gases in our atmosphere. These are the results, in many cases, of hazardous waste mismanagement. Improper, illegal dumping and disposal has resulted in toxic contaminants in humans, aquatic species, and livestock. Improper and illegal disposal has also been linked to explosions, fires, and contaminated ground water.

Not too long ago, our general outlook on garbage and hazardous waste and its pollution was, "out of sight--out of mind". We have lived in an era of consumption, convenience and quick-fix solutions in a carefree society. In the past, even if we were concerned and willing citizens, it was difficult enough to find out what to do let alone where one could take part in waste reduction or recycling efforts.

This paper will discuss how to be a part of the waste minimization solution--not part of the problem. You will learn what part you can take in stopping this onslaught of pollution, what part each of you can take as responsible corporate citizens, and how, together, we can reduce the amount of hazardous waste generated and handle the remainder through proper disposal methods. But first, we need to make sure everyone understands what a hazardous waste is and the laws that govern these wastes.

A waste is any solid, liquid, or sludge that you can no longer use. A waste could be the by-product of manufacturing processes in the construction, metal, paper or chemical industry or simply residue from your household cleaning products. In fact, almost all industries generate some type of waste. Some of these wastes are recycled and others stored until there is enough to treat or dispose of properly.

What is the problem? According to the Office of Technology Assessment's most recent report on the reduction of hazardous waste, approximately $70 billion was spent nationally on environmental control. This spending was centered around the costs incurred with the disposal of 290 million tons of hazardous waste generated annually. Unfortunately, with increasing control standards and many hazardous wastes not yet regulated, annual expenditures for environmental control will only continue to increase. For these reasons, many plant environmental managers are moving toward the development of waste minimization programs to reduce the generation of waste during processing or treatment.

One of the many challenges we in our industry deal with is the influx of environmental regulations. All of the following abbreviations represent different regulatory agencies that govern hazardous wastes in some way or another. Many of you who handle hazardous waste can appreciate the dilemma of keeping up with the regulations.

There is no doubt about it, the 1980s was a decade of change in regulations and environmental laws flowing from Washington, D.C. We will not go into detail about the different regulations, but will briefly explain what these terms represent and where we are in regard to the regulatory agencies today.

Probably the most known agency is the EPA, Environmental Protection Agency. CERCLA, Comprehensive Environmental Response, Compensation and Liability Act, became law in 1980, followed by 1984 by an expansion to the Hazardous and Solid Waste Amendments (HSWA). SARA, The Superfund Amendments and Reauthorization Act, which relates to the obligations of owners of closed waste sites, was enacted in 1986. In addition, various states added their own hazardous waste laws and regulations patterned after CERCLA and SARA.

The Occupational Safety and Health Administration (OSHA) added regulatory requirements to protect employees engaged in hazardous waste operations. The United States Department of Transportation (DOT) issued a continuous series of changes in its regulations on the transportation of hazardous materials and wastes in the 1980s.

The term RCRA, Resource Conservation and Recovery Act, is most often used synonymously to refer to the laws, the regulations, and EPA policies and guidelines. The law describes the waste management program mandated by Congress and gives EPA the authority to develop it. The primary goals of RCRA are to:

- Protect human health and the environment from the potential hazards of waste disposal.
- Conserve energy and natural resources.
- Reduce the amount of waste generated, including hazardous waste.
- Ensure that wastes are managed in an environmentally-sound manner.

At this point, you are asking yourself, "What does waste minimization really mean?" Many times, waste reduction and waste minimization are used interchangeably. The term, "waste minimization" is an umbrella term that includes the EPA'S preferred hazardous waste goals of source reduction and recycling. The Waste Minimization Rules and Regulations require generators of hazardous waste to "reduce the volume or quantity and toxicity of waste generated" to the lowest extent possible. This means that according to the current rules, waste minimization is conducted by the generator on-site.

One advantage of businesses embracing a comprehensive set of waste minimization goals is monetary savings. The payoffs for this commitment can be great. By decreasing the waste generated, companies are reducing operating costs and thereby improving their bottom lines.

Secondly, waste minimization allows businesses to reduce liabilities. Potential liability for the generator can be reduced for environmental problems with on-site and off-site treatment, storage and disposal facilities. Potential reduction in liability for employee safety can be achieved by minimizing waste. Companies are now finding that outmoded waste disposal practices can expose them to uncontrollable and open-ended legal liabilities that could jeopardize their entire operations.

A third benefit of implementing waste minimization goals is that it aids businesses in complying with today's regulations. By reducing the amount of waste, businesses can more easliy comply as permitting requirements increase for waste handling and treatment. Minimizing your waste allows you to meet state and federal waste minimization goals. The 1984 RCRA Amendments require hazardous waste generators to certify that they have taken steps to reduce the volume of hazardous waste generated. Certification is required on each manifest that a waste minimization process is in place at your facility.

By minimizing waste, you can protect the environment, a fourth benefit. The less waste generated, the

lower the potential for negative environmental effects.

Finally, a strong effort to reduce waste also improves a company's public image with the EPA and the community. Waste minimization is a true win-win situation. It can enhance industrial productivity and efficiency while protecting the environment.

We have just described five key reasons why it is beneficial for you and your organization to reduce the amount of waste generated. Everyone is responsible for creating, and everyone is responsible for solving the waste challenges ahead of us. Be part of the solution.

B. Hazardous Materials End Cost

Mineral spirits, paint thinners and other cleaners and solvents have an "end cost" that is considerably more than the initial purchase cost because each requires its own way of handling and disposal. Most major railroads' policies, procedures and related problems for the handling of hazardous waste are similar. Now many small regional railroads are also beginning to encounter these problems and the tremendous costs.

Our industry's traditional means of dealing with hazardous waste in the past was to utilize landfills or fill containers and transport them to some corner of an unused building in the shop area. However, the introduction of federal and state hazardous waste regulations made it necessary to review existing policies and procedures and to make concentrated efforts to adopt a plan to manage generated hazardous waste.

An effective waste management program is essential to ensure regulatory compliance, to protect workers and to minimize the high costs associated with waste disposal. Shops are classified as large quantity waste generators when more than 1,000 kilograms (approximately 2,200 pounds) of hazardous waste are generated per month. The waste comes from our locomotives and car repair and rebuilding operations. Examples are: grease and oils from engines, chemicals used in components cleaners, paint scrapings, excess paints and associated solvents used in painting our equipment.

Some generated waste is collected in 55-gallon, DOT-approved drums, properly labled, placed on pallets for ease of movement and staged at an approved storage area. This area is equipped with fire extinguishers and a spill containment station. On a regularly scheduled basis, the waste is removed and disposed of by a licensed waste disposal company. All hazardous waste shipping is documented on a shipping manifest. Some final treatment methods utilized by the commercial waste disposal companies include thermal destruction, fuels blending and waste water neutralization.

Numerous waste minimization activities have been implemented in our industry. At one major railroad, the technical service laboratory is responsible for analyzing and granting approval for the use of all chemicals. This approval indicates that the chemical is needed and a less hazardous or a non-hazardous chemical is not available as a substitute. All chemicals' performance characteristics are monitored to determine the period of time they can be utilized before requiring changeouts and disposals. At this railroad, waste has been reduced as a result of properly segregating the materials into drums without mixing a hazardous and a non-hazardous stream.

The life cycle cost of hazardous material includes the initial cost of the material and all associated standard inventory and purchasing costs. Some of the additional costs incurred by the industry are for protective equipment, including spill response packs which run between $200/$300 per team. Also to be considered is the cost of training. Twenty-four hours of initial training and eight hours of annual training for the first responder in protecting the environment is required for emergency situations, while 40 hours of initial training and eight hours annually are required for cleanup of hazardous materials.

Another cost is that of cleanup which can include anything from putting down a little oil dry to tearing up the concrete floor for a PCB spill. In addition, we are required to have weekly inspections of the drums, tanks, barrels, etc. Labor is again required for inspection, weighing, labeling, logging the manual and loading the drums into trucks or cars for shipping to approved disposal points.

Identification of used hazardous material is labor intensive. All drums must be properly identified according to DOT regulations. An improperly marked drum must be segregated and secured. Samples must be taken to the lab for positive identification. Determining the contents of the misidentified drums inflates cost. The lab cost may run anywhere from $50 to $600, depending on how exotic the material is found to be.

Storage of the material is not to exceed 90 days. We must carefully track the storage to assure compliance with the 90-Day Rule. An inspector must have the responsibility to track the time frame of all stored hazardous materials. We have to keep track of ever-changing regulations, which costs about $300 per year.

There are several agencies, including the EPA (SARA, RCA), DOT and OSHA, which do not always appear to agree, but generally are not in conflict. Great care must be taken to assure that we satisfy all agencies that have control over the particular part, product or situation.

The last intermediate, but not least associated cost, is in obtaining and maintaining the MSDA forms. Computer programs for maintaining the forms are a great aid and need to be set up or we face the manual filing and massive retrieval problems connected with the requirements for the MSDS forms.

The final element in life cycle costing is the disposal cost. This phase, at times, is considerably more expensive than the original cost of the material. There are three questions that must be answered in the disposal area - HOW, WHERE and WHEN.

We will begin with HOW. Again, there are several basic methods for disposal. There are short- and long-term advantages and disadvantages. Recycling is the method which is the most advantageous because it reduces the amount of waste that has to be dealt with, and in some cases, the recycled product can be used, thus creating substantial savings. Incineration may also be an option. Incineration does cost more, but is another of the accepted ways of disposing of some waste materials. This brings us to the landfill, another acceptable method of disposal. There are times when this is the best method. The problem, our responsibility for the wastes, never ends even though buried. The possibility of future liability and related expenses hangs over our heads.

WHERE is answered when you find the facilities that can fill the bill for the HOW portion of the equation. Several approved facilities are available.

Last of all is WHEN. The hazardous material must be disposed of within 90 days or less from the time the material becomes hazardous. A satellite drum (a drum that is being filled a little each day with waste) is allowed to be kept until full. You may have one partially-full satellite drum and one empty drum. The 90 days start when the satellite drum goes to a central storage location. Some examples of life cycle cost are:

LIFE CYCLE COST

Perchoroethylene — Used in a vapor degreaser vat for cleaning wheel sets and various components.

Initial Cost	Dispsal Cost	Labor Cost	Variable Cost	Initial Cost/Gal.	Final Cost/Gal.
$55,812	$38,632	$3,100	*	$2.97	$5.19

Caustic Cleaners — Caustic cleaners are used in lye vats for cleaning blocks, heads, liners, pistons, etc., and ferrous type metals, but not aluminum. These are all agitator or turbulator type vats.

Initial Cost	Disposal Cost	Labor Cost	Variable Cost	Initial Cost/Gal.	Final Cost/Gal.
$69,144	$77,139	$2,000	*	$.54	$1.14

Purchasing, materials and mechanical groups are key players in the reduction of hazardous waste. Purchasing groups have traditionally looked to the lowest initial up-front cost when awarding bids with no idea of what the end costs will be of that product. The people on the other end of the spectrum who are responsible for disposal of the waste have little or no input as far as what products are used in the operation. Before any purchase of a hazardous material is completed, the end cost should be known. This is commonly referred to as "end-of-the-pipe" purchasing.

One solution is to improve purchasing techniques, or what we call front-end purchasing. Purchasing must gain more knowledge in chemical composition and product identification. This will enable purchasing managers to purchase fewer toxic and nore nontoxic materials. They should become familiar with different products and analyze the MSDS before they purchase the product, not after. They should always purchase with end cost in mind -from cradle to grave. They should know the disposal method and cost for every product used before purchasing. They should limit the purchase of materials that cannot be recycled.

Another solution is equipment modifications. We could transform equipment or product lines to produce less waste, convert the equipment to enhance recovery or recycling options, install efficient equipment that produces minimal or no waste and provide for preventive maintenance of equipment.

A third solution is process modification, by substituting nonhazardous for hazardous materials, separating waste by type for recycling or recovery, removing and eliminating sources of leaks and spills, reformulating end products to be less hazardous and finnaly expanding recycling in our shops and offices to all waste.

Finally, when you have made every effort to improve the facility and the efficiency of the processes used to generate waste, the fourth strategy comes into play — recycle and reuse. Recycle on- and off-site whenever possible. You can recycle many items used in your office and factories, such as paper products, corrugated

cardboard, aluminum and other metals, glass, plastics, batteries and motor oil.

Many of these strategies involve source reduction, which as we have discussed before, is the preferred avenue of waste minimization. Others deal with physical changes in the plant or manufacturing process of a particular waste stream. Source reduction and recycling are very much site-specific because many operations are unique in and of themselves, but a number of these strategies can be used. In fact, many of these strategies are being used in this country today, thus reducing overall disposal costs and operating costs as well.

The challenge of the future for all industries will be the continued proper management of hazardous waste. Be part of the solution.

C. The Role of Suppliers

The majority of hazardous material issues facing the rail industry revolve around disposal of toxic substances primarily resulting from cleaning processes, a part of maintenance operations. A number of disposal issues are associated with the material being maintained and the packing/packaging used to ship this material between suppliers and users. Our purpose is to identify some of those issues, examine some of the root causes, and initiate a process of reducing the waste generated by the maintenance of locomotives. Additionally we will attempt to establish a guideline that can be used to evaluate the true total life cost of alternative materials.

As a consequence of maintaining diesel-electric locomotives, railroads are faced with the issue of disposing of materials that are classified hazardous. Also, there are a number of materials that, although not designated "hazardous," can represent a disposal problem. These materials result from a variety of sources, but can be classified within one of several broad categories.

The issue for the railroads and their suppliers is the development and implementation of processes to identify and then reduce the amount of material that represents a disposal risk. A critical element is the appropriate analysis of the true total life cycle cost of alternative materials and packaging. The railroads and their suppliers would then be able to make more environmentally-sound decisions.

With a growing environmental awareness, a closer examination of the disposal consequences is necessary. using the broad categories previously listed, a short list of some potential disposal problems includes the following:

May Be Initially Hazardous
battery acid
cleaning solvents
lubricants

Initially Non-Hazardous May Become During Use
gaskets
fuel filters
air filters
gear cases
bearings
pedestal liners
absorbants
drums

Non-Hazardous/May Be a Disposal Problem
wood crates
pallets
cardboard boxes
shipping "peanuts"
shrink wrap
polyurethane foam

These lists by no means are all-inclusive. They do represent some preliminary thinking as to potential causes of disposal problems and may be useful to provoke thought concerning other potential sources of disposal concerns. To gauge the impact of these and other materials on the rail industry, a survey of railroad materials will be sponsored by LMOA. To facilitate sharing the best practices within the industry, LMOA will make copies of the results of this survey available to its members.

How can the railroad industry influence suppliers to make more environmentally-sound materials available? Suppliers to the rail industry and their suppliers in turn cannot provide environmentally-sound solutions without guidance from users. While this guidance can take various forms ranging from strictly enforced pre-qualification of materials to casual comments, a middle-ground interactive approach is recommended. This cannot be a shifting of the disposal burden to the supplier, but rather a joint venture to address the problem.

STEP ONE — Inform your suppliers of the need.

Make sure they understand the necessity of providing environmentally-sound products. Since many purchased items are not initially hazardous or a disposal problem, it is suggested that the disposal-sensitive source categories and health/safety issues be reviewed with your suppliers.

STEP TWO — Develop total life cycle cost evaluation criteria and use them.

Advise your suppliers of the ramifications of disposal and the associated costs. Make sure they understand that future procurement decisions will not be based purely on initial purchase cost.

There is likely to be a great deal of pressure to design biodegradable or other acceptable forms of packaging in the near future. Substitute designs could very easily be heavier, larger and less efficient in both cost and performance than those they replace.

Many states are considering making their own laws dealing with packaging forms. Will the people hired to enforce these laws be proficient in package designs? Probably not, but these will be the people passing judgment on what are acceptable packaging forms. This could cause disruption in the packaging process as it now exists. If packaging becomes less efficient, we could see a rise in damage claims and larger packages.

It is suggested that suppliers be involved in the process of developing the evaluation criteria. If this is done, the suppliers will be able to provide valuable technical input and will have a greater "buy in" to the final decision.

It is critical your suppliers see your commitment to more environmentally-sound materials in your purchase decisions. The old adage applies, "Put your money where your mouth is." The real message here is that we must **act now** rather than **react later.** We must not only look at future package designs, but also at current designs.

STEP THREE — Establish environmental impact review team.

In conjunction with your suppliers, establish a joint team to determine ways of addressing the issues. Many suppliers to the industry have resources available to assist in the process of reducing disposal problems and would be happy to make them available. Set targets with each vendor and provide them with the appropriate support to ensure their involvement.

How do we evaluate alternatives! Environmentally-sound decisions concerning choices among alternative materials and/or packaging must examine the total life cost, including any and all costs associated with proper disposal or recycling. Too frequently this decision is made purely on the basis of initial purchase cost alone. To ensure a quality decision, other elements contributing to total life cost must be added to the evaluation. These include:

- transportaion costs
- packaging costs, storage
- recycling/disposal costs
  material
  packaging
- administrative/reporting costs
- safety and health costs
- replacement costs

Each railroad must evaluate its own situation. Some of these costs, particularly the administrative and statutory reporting process costs, can be very elusive.

What are the options? The goals for the joint railroad/supplier teams should target three areas for improvement:

(1) Eliminate the root cause. What are the materials and processes that can be modified or replaced so as to totally eliminate the disposal problem? Peel back several "layers of the onion" to determine what the true root causes are. Whenever possible, work to alter the root cause. Use the list provided and results of the survey as a starting point.

(2) Reduce where elimination is not possible. Not all root causes of disposal problems can be completely eliminated in the short term. Where complete elimination is not possible, work with your suppliers to indentify means of reduction. "Quantities" and "intervals" are prime candidates for improvement. Where can the quantity be reduced or the interval be lengthened without sacrificing reliability or performance?

(3) Recycle or reuse. Certain materials practices, particularly packaging, which currently are drivers of disposal problems, can be altered by going to a reusable or recyclable product. Current cost evaluations favor lowest first-cost practices (e.g., cardborad boxes), but tend to ignore total costs. Analyze the tradeoffs with your suppliers. Let them know what it costs to dispose of a pallet, a box or a drum.

In conclusion, waste minimization opportunities are limited only by the imagination of the people involved in the material loop. Everyone is responsible for creating and everyone is responsible for solving the waste challenges ahead of us. Be part of the solution.

THE SOUTHERN AND SOUTHWESTERN RAILWAY ASSN.

717 Pinecliffe Drive
Chesapeake, Virginia 23320

PURPOSE

The purpose of the Southern and Southwestern Railway Association is to promote customer and supplier relationships and provide an educational opportunity. The Association is aimed at middle management including shop, service, engineering, purchasing and sales personnel. Meetings are held to discuss current and developing trends in the industry. Presentations are made by railroad and supply representatives. The meetings also provide opportunities to cultivate ideas and personal relationships in social atmosphere.

The Southern and Southwestern Railway Association holds four (4) meetings per year at important railroad cities in the southeast. The format of the meeting is to gather on Wednesday evening for dinner followed by a speaker. The next Thursday morning, business is handled and additional presentations are made.

Please drop our Secretary a line for an application or further information.

J. S. Mastrangelo
Secretary
717 Pinecliffe Drive
Chesapeake, Virginia 23320

REPORT OF THE COMMITTEE ON NEW DEVELOPMENTS

Tuesday, September 18, 1990
9:00 A.M.

Pre-Convention Presentation
Southern & Southwestern Railway Association

April 19, 1990
Holiday Inn-Gateway
Huntington, WV

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Director-Motive Power Engineering
C&NW Transportation
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PERSONAL HISTORY

Michael Iden

Mr. Iden was born in Milwaukee, WI on June 27, 1950, where he attended public schools. He graduated from the Milwaukee School of Engineering with a Bachelor of Science degree in mechanical engineering in 1972. He subsequently attended Northwestern University in Chicago and Evanston, IL, from which he graduated in 1978 with a Master of Management degree in transportation and operations management.

He began his railroad career in 1970 as an engineering trainee in the Railway Track Machinery division of Nordberg Manufacturing Co. in Milwaukee. After graduating with his engineering degree in 1972, he joined Southern Railway System as a management trainee in the Engineering and Research department, subsequently promoted to assistant engineer in 1973.

In 1974, he resigned from Southern Railway, and joined Electro-Motive Division of General Motors in LaGrange, IL as a mechanical designer in the Plant Engineering department, subsequently promoted to mechanical engineer in 1973.

In 1978, he left EMD and joined Chicago & North Western Transportation Co. in Chicago, as operations analyst in the Corporate Industrial Engineering department. He transferred to the Operating department in 1979 as senior operations analyst in the Operations Planning department, subsequently as Manager Operations Planning in 1980. Much of his work involved planning of the western coal operation in Wyoming's southern Powder River basin, including train operations and mainline plant design.

In 1986, he was promoted to assistant superintendent motive power in the Motive Power department, and in 1989 to director motive power engineering, his current position.

Mike and his wife, Andrea, have two sons, Jay and Nicholas and reside in Barrington, IL.

I. MOTOR-DRIVEN AIR COMPRESSORS FOR DIESEL-ELECTRIC LOCOMOTIVES

A. Introduction

For many years, diesel-electric locomotives have been built with reciprocating air compressors to supply the air needed for locomotive and train brakes, horn, sanders, and various other auxiliary devices. The drive method employed is conceptually the simplest and most straightforward possible — a mechanical connection between the compressor shaft and the diesel engine. Because of the need to operate the engine over a wide range of crankshaft speeds, the compressor is obliged to perform in a similar fashion, with the result that air delivery is frequently marginal at the lower engine speeds. Physical alignment of the compressor with respect to its drive shaft and the engine is a time-consuming process requiring skilled labor, and must be repeated each time the compressor is replaced on a locomotive.

Several years ago, a few diesel locomotives appeared with air compressors that were electrically driven. As the news spread and interest grew, various locomotive rebuilders and motor manufacturers became involved. Eventually this led one of the OEM locomotive builders to incorporate a compressor drive motor into its new locomotive design. More recently, there has been some interest in the possibility of retrofitting older locomotives with motor-driven compressors, which exposes more potential shortcomings relating to the need for a power source.

The following discussion will focus on the technical factors that one should consider before adopting the electrical drive, and will conclude with a description of several examples that are in present use.

B. Advantages of Electric Motor Drive

Obviously, there is a price to pay for the motor-driven air compressor because of the amount of hardware needed. In addition to the electric motor, one needs an auxiliary power source capable of driving the motor, or at least sufficient extra capacity from an existing source, plus the apparatus necessary to start, stop, and protect the motor. To offset these factors, we will look at some advantages of the electric motor drive which might be used as justification:

1. The compressor can be shut down when there is no demand for air. This not only saves fuel by eliminating a parasitic load from the engine, but also extends the service life of the compressor. The realizable savings will depend on many factors, including air consumption, time spent at each engine speed, and cost of diesel fuel. From recent tests conducted on several Norfolk Southern locomotives in typical service, it appears that the compressor delivers air from 25 to 45 percent of the time that the engine is running.
2. With electric motor drive, the compressor is no longer restricted to operation at the engine crankshaft speed. Depending on the type of motor selected, the compressor can be driven at a relatively constant speed, or at least over a range more narrow than that of the diesel engine. This permits the compressor to charge a train quickly without advancing the throttle from idle.

3. The elimination of direct drive also removes an obstacle that would otherwise hamper the use of a smaller, high-speed diesel engine on a locomotive, since presently available air compressors cannot be operated much in excess of 1000 rpm.
4. With the compressor drive shaft no longer needed, there is more freedom in locating and positioning the compressor itself. While this primarily of benefit to the locomotive builder, it could also permit easier replacement for repair or overhaul, which would benefit the railroad as well.
5. Should the air compressor "seize" while in operation, engine damage which might occur with a direct drive is prevented.

C. Electrical Considerations

Of considerable importance is the selection of the specific drive motor to be used, giving due consideration both to its operating characteristics and compatibility with a convenient power source. The physical means contemplated for coupling the motor to the compressor should be kept in mind; a belt drive arrangement will permit a much wider selection than a shaft coupled arrangement.

Although universal commutator-type motors have been used on electric locomotives to drive the air compressor, a three-phase induction motor is probably the best choice for a modern diesel locomotive. For a given horsepower rating, the cage-rotor induction motor is the least expensive and most reliable design available, provided that its constant speed/frequency ratio can be accommodated. Many present-day locomotives incorporate an auxiliary three-phase power source, already required for the radiator fans, which might have sufficient reserve capacity for the compressor motor. In newly designed or rebuilt locomotives, an auxiliary alternator can conceivably be selected to carry the added load of the compressor.

One problem with using the existing alternator, in the case of EMD locomotives, is its volts/Hertz ratio which is roughly half that required by motors that are commonly available within the electrical industry. This condition will also affect locomotives rebuilt from EMD units if the OEM radiator fans or the individual traction motor blowers are retained, because these devices will perpetuate the existing volts/Hertz ratio whether or not the original alternator is kept. However, if other considerations dictate a motor to be specifically manufactured for the locomotive air compressor, no added cost should result from the need for a non-standard winding.

It goes without saying that the motor should have a horsepower rating sufficient to carry the load, which is typically 40-50 hp at 900 rpm when delivering air at 140 psi. Unfortunately, the above load is only an average value, with excursions during each revolution that extend from some negative value to more than twice the average. Depending on the combined angular momentum of the motor-compressor system, the motor will respond to these torque pulsations with corresponding variations in shaft speed, which in turn will cause a pulsating current in the motor windings and excessive copper losses.

Although costly and yet to be manufactured, a different compressor with a more uniform torque distribution would provide a direct solution to the problem. Short of this extreme, there are several corrective steps that can be taken individually

or in combination to minimize the current pulsations, listed below with their predicted side effects:

1. Increase the motor size, and therefore its rating, to accommodate the torque excursions. A larger core structure will be required, which will place a greater demand on the power source for magnetizing current.
2. Use a flywheel to absorb the speed variations. This will prolong the startup time and therefore the duration of inrush current, which could overheat the windings.
3. Select a motor having a higher-than-normal rotor resistance, which permits a greater reduction of shaft speed (slip) for a given amount of load current. This measure will control the current pulsations at the expense of reduced efficiency and greater heat dissipation within the motor.

The method of coupling the motor to the compressor shaft was mentioned earlier as a factor to be considered, important at this juncture as it determines the premissible shaft speeds of the motor, and thus its electrical performance. An induction motor requires more iron and therefore magnetizing current to permit operation at reduced speed while maintaining its power output, whether accomplished by frequency reduction or by simply including more poles in the winding. For this reason, a motor that is suitable for direct-coupled operation might exceed the size and weight of its belt-drive counterpart by a factor of four.

D. Starting Characteristics

The basic induction motor does not have the most desirable starting and overload characteristics. Fig. 1 shows torque vs. shaft speed for a typical induction motor being operated at line frequencies of 30, 60, and 120 Hz, with its terminal voltage adjusted proportionally to maintain rated field strength in the core. To carry loads ranging up to a moderate overload, the shaft speed "slips" below its synchronous value until the resulting higher rotor current can balance the applied load. Eventually, however, a point of diminishing returns is reached, at which the added rotor current is more than nullified by increasing phase shift, whereupon the torque becomes progressively weaker as the shaft speed continues to zero.

It can be seen from Fig. 1 that the locked-rotor (stall) torque is less at higher line frequencies, because of the added phase shift. Higher resistance can be built into the rotor to reduce phase shift and improve the starting torque somewhat, but this becomes detrimental at normal speed due to the added losses in the rotor. There is also a "deep bar" rotor design that can give the effect of high resistance only when the rotor frequency is high, making use of skin effect to confine the rotor current largely to the portion of the bars that lie near the surface.

E. Source Requirements

Because the average torque requirement of an air compressor is largely independent of its speed, the drive motor should be expected to draw approximately the same current at all throttle positions, with its line voltage and frequence rising or falling in direct proportion to speed. The current will consist of a load component which pulsates with compressor rotation, and a steady magnetizing component which lags the voltage and does not impose a mechanical load on the alternator shaft.

The alternator must be able to supply this current, plus any current required by all other connected loads that might operate simultaneously, for a reasonable time without overheating. In addition, it must supply the inrush current needed each time the motor starts. The starting current will typically be seven to eight times the rated current in a conventional 4-pole motor, with less than 0.5 power factor. In a slow-speed motor wound with more poles, the considerably greater magnetizing current does not imply a proportionately greater starting current, so the ratio of inrush to rated current will be less extreme.

F. Conclusion

It can be seen from the foregoing that many factors become involved in electrifying the air compressor drive on a diesel locomotive. Each must be considered in view of its cost impact. For a retrofit application, the present availability or lack of an AC power source with surplus capacity will be a major factor, which will most likely eliminate many locomotives from further consideration. It is not the author's intention to recommend either for or against the use of an electric drive; this must be decided in each case after examining the total cost as it compares to prospective benefits, which will differ according to the circumstances existing on each railroad.

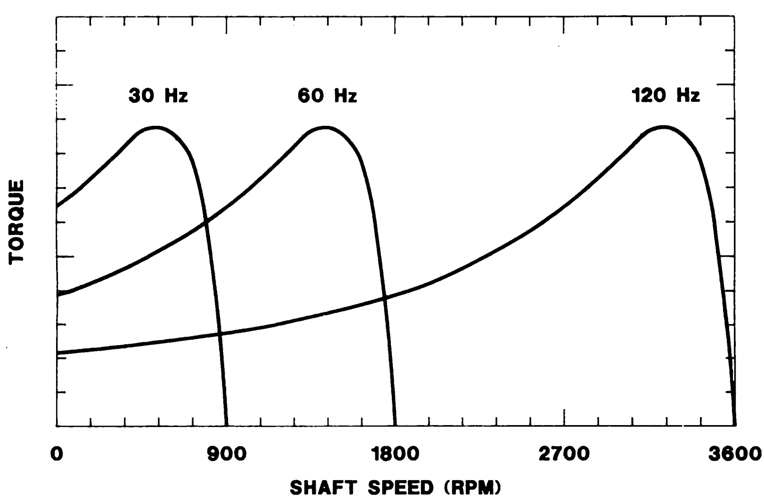


Fig. 1. Typical Speed-Torque Characteristics

II. LOCOMOTIVE CAB HVAC SYSTEMS

In the early 1800's, when railroads first started, little thought was given to climate control in the locomotive cab. The operators had protection from the outside elements by having the steam boilers in front of them and openings at the sides for plenty of fresh air. The cabs were very noisy, air was dirty and dusty, and temperatures varied from extreme hot to bitter cold. They were described as the "iron horses" and their heating/ventilation/air conditioning systems were every bit as advanced as those of a flesh and blood horse.

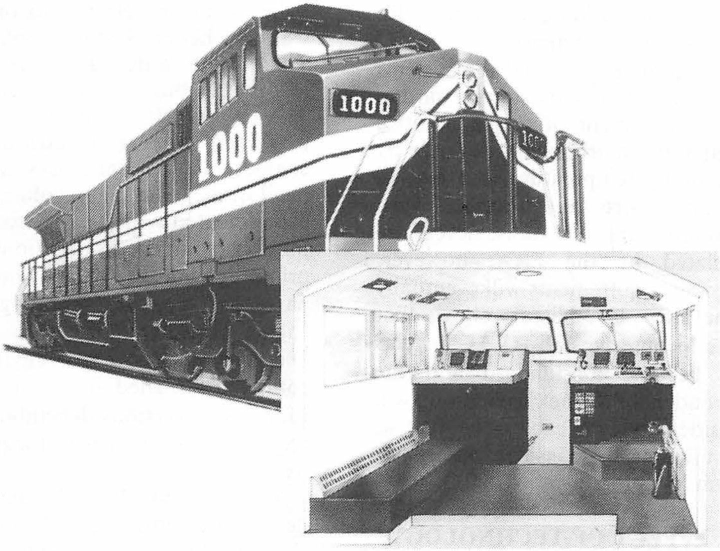
Through the nineteenth century and into the twentieth century only minor changes took place concerning climate control in locomotive cabs. In the 1920's and 1930's great advancements in climate control were made for rail passenger coaches. Filtered air was either heated or cooled and pumped into the coaches, making a comfortable environment for the passengers. One of the prime reasons for this development was the smoke, soot, and cinders from the locomotives that sometimes engulfed the coaches. These HVAC systems were very large, labor intensive, and not practical for application to locomotives.

The 1940's and 1950's brought on the most significant change in locomotives. This was the period when 20,000 diesel electric locomotives replaced some 47,000 steam locomotives. The climate control in the diesel electric locomotive was far superior to that of the steam locomotive. The diesels were comparatively clean running, quiet, and had hot water heaters with electric fans. These, combined with vents and windows that could easily be opened and closed, made the HVAC systems state-of-the-art.

The 1960's and 1970's introduced electric heat and high capacity vent blowers with better insulated cabs that made them more comfortable in extreme hot and cold working environments. Electrical cabinets were sealed off reducing the entry of combustion gases into the cabs, drastically reducing the noise levels in the cabs. The heaters, vents, and blowers were now wall mounted, thus reducing obstructions in the cab, and could either recirculate cab air, take air from outside, or any combination thereof.

Although the 1980's did not provide significant industry-wide improvements in HVAC systems, numerous organizations and companies have been testing a wide variety of equipment. The 1990's will show the most significant changes in cab climate control since the conversion from steam to diesel electric locomotives. Recirculated or additive fresh air will be filtered, making cab occupants as comfortable as in their own homes. These units will provide 30,000 to 40,000 Btu/hr cooling and from 35,000 to 50,000 Btu/hr heating which will be sufficient to keep any standard size cab comfortable in any weather condition.

Presently, both major locomotive builders offer HVAC units as optional equipment on their six-axle wide cab units. In addition, five companies (Prime, T.C. Johnson, MEI Motive Equipment, Sigma, and Vapor) offer retrofit units. These HVAC systems draw approximately 12 Kw of auxiliary power which is available on most modern locomotives. To retrofit an older locomotive, however, would almost certainly require a larger capacity auxiliary generator. The units can be located in the nose, on top of the roof, under the floor, or behind the cab on the running board. They are hermetically sealed making them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relatively maintenance free. When failures do occur, the entire unit can be changed in a couple of hours, rather than holding the power for time consuming repairs.

Locomotive cab HVAC systems represent a significant step forward in the improvement of the locomotive occupants' environment, not only by controlling temperature, but also in reducing dirt and noise levels. Presently, only the noise levels are regulated by the FRA; however, clean air requirements will eventually come into play. History shows that these locomotive cab HVAC systems will become a standard and the railroaders of the next generation will consider today's cab to be just as primitive as we consider yesterday's steam locomotive cab. (Fig. 2)

III. EFFECT OF TECHNOLOGY ON STANDARDIZATION OF CAB CONTROL EQUIPMENT

The industrial revolution of the late 18th and early 19th centuries gave birth to the steam engine and later the steam locomotive, which became a legend and a symbol of the progress of our industrial society for more than a century.

The power of steam had been harnessed; but to control this mechanical giant, gauges were needed to read pressures, and mechanical devices such as a throttle and reverser were needed to control speed, direction and compressed air. Steam valves were needed to control braking and auxiliary functions.

Some decades later, electricity began to be applied as a means of locomotive propulsion, first in urban transit situations and later in main line railroad operations where smoke emission was a problem. In electric locomotives cab controls similar in function to those in steam locomotives had to be incorporated, with the addition of meters to monitor the electric power.

Locating these control devices in either steam or electric locomotives was a helter-skelter application. There were wide variations among locomotive builders and railroads.

After World War I, gasoline-powered internal combustion engines, another landmark development in the industrial revolution were experimented with as a railroad propulsion source. Applications were primarily limited to self-propelled passenger coaches. The gasoline engine was later replaced by Rudolf Diesel's more powerful engine that could be designed in either two or four stroke versions depending upon requirements of speed, torque and weight.

After World War II, the diesel electric locomotive quickly made its mark as the most efficient form of motive power; the age of steam ended in the 1950's as Electro-Motive Division, Alco-GE, Fairbanks Morse and Baldwin-Lima-Hamilton introduced their power plants on wheels.

The 50's and early 60's were exciting times — but also challenging and bewildering times to those who had to understand and operate these new locomotives. They all had different throttle controls, reverser handles, transition levers, dynamic brake handles, meters, air gauges, speed recorders, etc.

The only standard in the cab was the output of the trainlined air brake system: the manufacturers, Wabco and New York Air Brake, built from George Westinghouse's patent design valves. Each railroad, and their were hundreds, specified what it wanted in the cab configuration and the layout of these controls and their operation.

With electric and diesel electric locomotives, it became possible to operate multiple-unit consists. However, differences among builders, railroads and even among

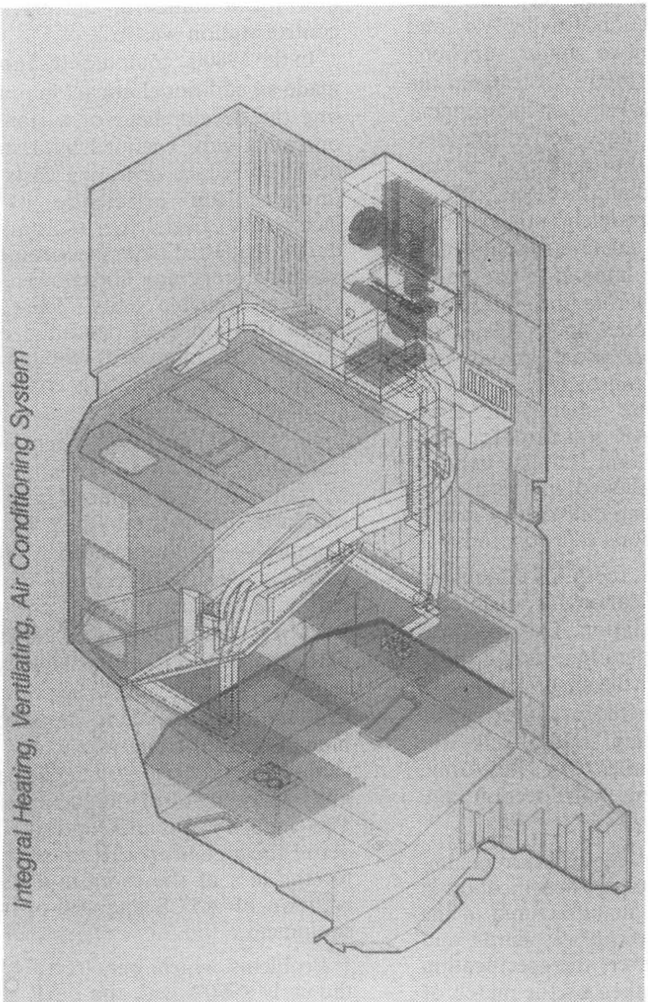


Fig. 2

locomotive classes became major obstacles to multiple-unit (MU) controls.

By the 1960's some earlier diesel manufacturers had ceased locomotive production, leaving Alco and EMD as the two major suppliers; though in the 1960's GE entered the locomotive market as an independent diesel-electric locomotive builder. But despite the reduction in the number of manufacturers, design compatibility problems still existed.

Diversity in cab controls and functions existed among these three builders and within their individual locomotive model lines. Again, the only standardization among the builders and railroads was the air brake trainline operation. Even though an AAR standard for electrical multiple-unit trainline connections was developed in the 1960's, variations among railroads in several trainline functions still exist today.

In the 1970's, the AAR established the first specification for a cab control operating station. This specification defined operation, design, position and size of the air brake gauges, brake values, meter for motoring and dynamic braking, radio and the operating handles for motoring, dynamic braking and direction control.

The leading manufacturers implemented this design specification in all locomotives manufactured in the late 1970's. The cab was simple and uniform. However, the specification was soon overtaken by the march of technology. Dictated by economics and a fuel shortage, after-market vendors responded to the railroads' needs with energy efficiency and monitoring control devices, thus again creating unique cab control operating stations. During this same period, railroads saw the need for recording speed and distance, air brake, throttle and load positions. This lead to the milti-event recorder monitoring systems. End-of-train monitoring equipment made an impact on a cab layout, and the aspiration for a standard, universal cab control station was lost.

In the 1980's, computer technology made an additional impact in preventing the development of a standard operating cab. Dictated by a strong desire to reduce operating costs and improve the efficiency of its locomotive fleet, the railroad industry requested from the locomotive manufacturers high horsepower, fuel efficient, reliable units. They also asked for improved operating ergonomics and improved maintenance diagnostic and operating crew efficiencies.

In the beginning, computer technology was an ad hoc approach by railroads and vendors with no standards being established by the locomotive manufacturers. Now, each locomotive builder has a definitive approach — but only for its own locomotive designs. No standard has been established for software or hardware interfacing or control station equipment to accommodate end-of-train telemetry, advanced train control system telemetry units and control of the locomotive. The industry has not indicated a desire for a comfort cab to make up for the loss of the caboose and the addition of ATCS and end-of-train equipment.

Problems which were rectified in the early 1970's with the AAR standard are not recurring as a result of this new computer technology plus the continual development of new functions and devices. Locomotive controllers as well as the placement of the devices are changing.

The question that arises and should be addressed before the trainline air brake connection once again becomes the only similarity among differing

cab designs is should the railroads or the AAR set the standards? Keep in mind that any standards should be established in cooperation with the manufacturers so as to allow and stimulate the OEM'S to continually introduce new technology and improved ergonomics. (Fig. 3)

IV. LOCOMOTIVE DURABILITY, RELIABILITY, AND AVAILABILITY UNDERSTANDING YOUR ABILITIES

This discussion of "Understanding Your Abilities" relates to locomotive durability, reliability, and availability; terms which in many cases are not well understood and in many cases misused. We will attempt to define these terms and explain how these three different but related locomotive performance measurements can be determined, and how standardized use of these measurements can be of benefit.

As the cost of new locomotives climbs, particularly taking into account the cost of capital dollars (interest rates), and in view of the increasingly competitive environment in which we operate, effective management of our locomotive fleets becomes even more important.

Overall, the Class I railroads have reduced their fleet of locomotives by 25 percent in the last ten years. Recent changes in federal laws governing mergers have resulted in significant reductions in the number of Class I roads. The mergers, necessitated by competitive pressures, have resulted in the elimination of numerous interchanges, and distinct train movements. Additional reductions have been achieved through the use of run-through power agreements between roads. The end result has been a need for fewer locomotives.

Recessionary times, marginal traffic increases, and significant cost reduction requirements have forced some roads to place locomotives in storage in order to stay competitive. Usually those locomotives with the highest failure rates or highest maintenance and/or operating costs are stored. In some cases, when traffic levels improve, many of those older stored locomotives are not returned to service.

With the developement of the newest high-horsepower, high-productivity locomotives, fewer locomotives are required to pull the tonnage. In many cases, two for three, or two for four reductions are possible. The provision of extra "insurance" locomotives on a train (in case of failure) is a luxury we can no longer afford.

These factors just discussed have forced railroads to maintain their operable power more efficiently, to insure that preventive and running maintenance procedures are performed completely, correctly, and in an expedited manner, and to better utilize the power now available.

Many Class I railroads have over a billion dollars invested in their locomotive fleets. In order to effectively manage these assets, we must first be able to measure the performance of locomotives, whether it is by individual locomotives, duty cycle, model years, or the entire fleet. There are many ways to measure the performance of locomotives quantitatively.

Some railroads use a "bad order ratio", some use "failures per million miles" or "mean time between failures" or some use unscheduled shoppings. The terms "durability", "reliability", and "availability" are also widely used.

These measurements are not well understood. The names are used interchangeably and in many cases incorrectly. It is the intent of this

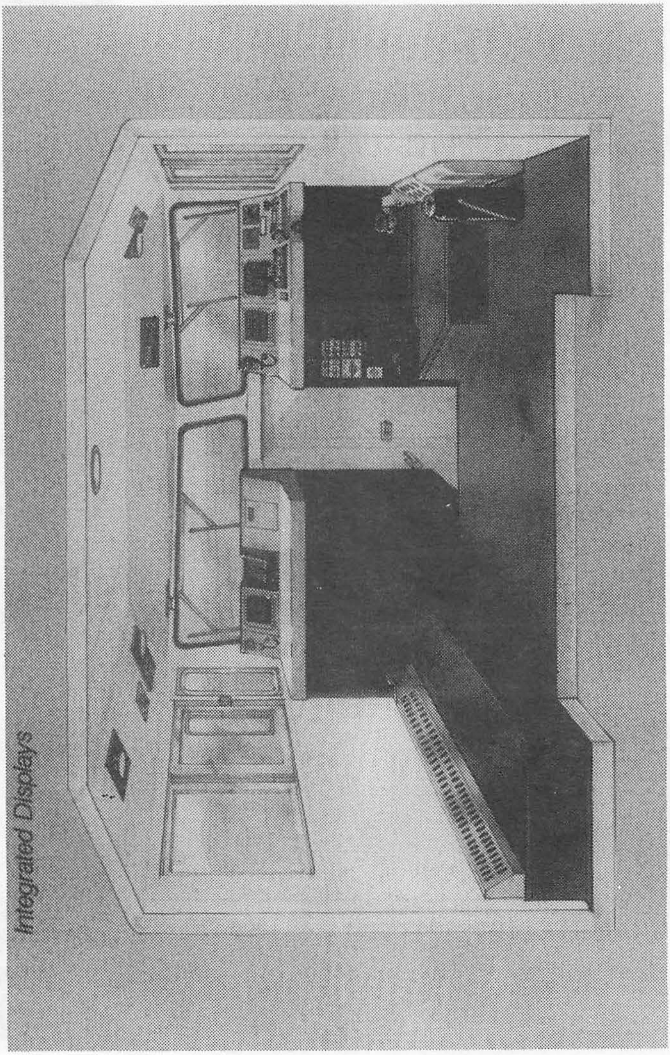


Fig. 3

presentation to define these terms, explain how they apply, and highlight the benefits of proper and consistent measurement. In short, "understanding your abilities".

At present there is no standard measurement in the industry. We all measure locomotive reliability and availability in different ways. Often, locomotive performance measurements differ not only among railroads, but also between departments of the same railroad. The operating department is concerned primarily with having sufficient locomotives available to run all of the trains on time. A road failure can have a significant effect on train operation and regardless of the cause, each failure is recognized. The mechanical department, on the other hand, does not want to be "charged" with a road failure that is totally out of its control and is not related to its maintenance policy, procedures, or quality — for example, accident damage, flat spots on wheels, vandalism, or improper operation. Placing responsibility for failures often becomes a finger-pointing session between departments.

The lack of standard measurement can create significant problems when comparisons are made between different railroads. For example, railroad "A" has a fleet availability of 93 percent, while railroad "B" has a fleet availability of 90 percent. On the surface, it would appear that railroad "A" does a better job of maintaining its fleet. However, when the components of the availability calculations are examined, it is found that railroad "A" does not count "stored unserviceable" locomotives. When all the numbers are accounted for, it is possible that railroad "B" could actually have the better overall availability percentage.

The two primary measurements used by North American railroads are reliability and availability. In addition, railroads should be cognizant of the durability of their equipment and the inherent value of that durability to them. In order to facilitate standard measurement, the definitions of the measurement terms and their component parts must be understood.

A. Durability

Durability is the length of time a component or sub-system can operate without attention before there is any degradation in performance.

Durability can be illustrated with a bathtub curve having three major areas of interest, the infant mortality area, the useful life area **or** area of random failures, and the wear out area.

"Infant mortality" is that portion of an item or sub-system life where failures usually occur due to problems of material, manufacturing quality, or assembly procedures, and will occur at a declining rate as time in service increases. Infant mortality failures can be reduced if a good quality process is in place that will effectively govern material inspection, manufacturing or reworking procedures, testing, and component or system assembly and installation.

The "useful life or random failure" area is where failure occurrences are unpredictable or random. Random failures are usually attributable to the design of a component or sub-system and should occur infrequently. Prevention of these failures is difficult. However, a good testing program during product development can minimize the failure rate. The failure rate during the useful life is directly related to the reliability of the component, sub-system or locomotive.

The "wear out" portion of a component or sub-system life is where failures are no longer random and occur at an increasing rate as time in service increases. It is at this point that the component, sub-system, or locomotive should be overhauled or replaced.

Durability is designed into a component or sub-system. It should be understood, however, that the durability of a given component or sub-system may not be the same for different applications. An example would be the expected life of a power assembly in a switch engine operating in a low duty cycle vs. the same components in a higher duty cycle road locomotive. As long as the useful life or random failure interval is identified, and maintenance or replacement intervals and procedures are properly set and adhered to, the overall reliability of the component, sub-system or locomotive will be maximized.

The locomotive and component manufacturers constantly strive to improve the design of components to extend the useful life of components, sub-systems, and locomotives, and at the same time reduce the number of random failures, which in turn increases the reliability. Retrofitting the newest design components into older locomotives can significantly improve the reliability of older power and in many cases increase intervals for maintenance or overhauls.

B. Reliability

Of all the different measurements used to evaluate locomotive performance across the country, the most common measurement used is reliability.

"Reliability" can be defined as the ability of a component, a sub-system, or a locomotive, to perform failure-free service for a given period of time, under a specified set of conditions. From a railroad operating perspective, this is a measurement of the level of confidence that a railroad can send a locomotive into service without an expected failure. A failure can be defined as the inability of a component, sub-system, or locomotive to perform as defined within its performance specification.

The two most common reliability measurements used by railroads are mean time between failures and failures per million miles. These measurements can be calculated for individual locomotives, locomotive models, or an entire locomotive fleet or assignment. Properly used, reliability measurements are a very effective tool to identify specific problem units, ineffective maintenance procedures and improper maintenance intervals. These measurements are calculated as follows:

MEAN TIME BETWEEN FAILURES = Total "available" locomotive days divided by the total number of failures.

FAILURES PER MILLION MILES = Total miles accumulated divided by the total number of failures.

These calculations can be made for monthly, 92 day, yearly, or any other data collection intervals desired. The resultant reliability data can then be plotted to indicate positive or negative trends.

"Time between unscheduled shoppings" is another reliability measurement, that while similar to the "mean time between failures" calculation, measures the intervals to failure following scheduled shoppings. This measurement provides a very useful tool in evaluating scheduled maintenance requirements, and when broken down by shop, can assist individual shop managers in improving the quality of work being performed, and therefore improving the reliability of units dispatched.

As stated earlier, a failure is the inability of a component, sub-system, or locomotive to perform within its performance specification. Failures can be classified by various

characteristics or combinations of characteristics. For example some railroads break down their failures as follows:

1. Dependent failure: One which is caused by the failure of associated components, or sub-systems.
2. Independent failure: One which occurs without being related to the failure of associated components or sub-systems. (Awaiting material)
3. Railroad related failure: One which results from improper operation or maintenance.
4. Manufacturer related failure: One which results from defective components infant mortality, or random failure, or design defect.
5. Critical failure: The failure of a component or sub-system that prevents a locomotive from completing its assigned mission, requiring maintenance prior to resumption of operation. Example: a turbocharger failure.
6. Major failure: Any failure not including critical failures, of a component or sub-system that causes a delay in the completion of the assigned mission, that requires unscheduled maintenance.
   Example: radiator leak; train delayed for watering; and radiator is replaced when unit tied up at final terminal.
7. Minor failure: Any failure that does not interfere with the locomotive's accomplishment of the scheduled mission and which can be repaired quickly without a shopping, or during the next scheduled maintenance period. Example: cab light failure.

Any of the previously defined reliability measurements may be calculated looking only at certain types of failures. For example, as part of a settlement based on a performance guarantee contract, it may be necessary to evaluate the performance of a group of units based on manufacturer related critical and major failures only, on a per million mile basis.

C. Availability

Of all the "abilities", availability is probably the least understood measurement, and the one which has the greatest variation between railroads. A generic definition of availability is: a measure of the percentage of time a locomotive is in the operable state and available for revenue service.

Availability % = **Potential operable hours - Total hours unavailable** ÷ Potential hours available.

Availability becomes harder to define, and a significantly more complex measurement, when efforts made to identify responsibility for time the locomotive is inoperable and not ready for work. Locomotive failures can be classified as builder related or railroad related. Maintenance actions can be broken down as inspections, preventive maintenance, and running repairs. Repairs can be broken down into trouble shooting, actual repair time, and test. The balance of unavailable time can include stored unserviceable (awaiting overhaul, accident damage, or awaiting retirement), dead-in-consist time, awaiting shop time, **and** servicing time.

The availability equation that includes all of the above items is actually the operational availability as experienced by the railroad. It is a measurement that indicates the railroad's ability to serve its customers in a cost effective manner.

Where the greatest differences occur between railroads and also between different departments of the same railroad, is in which components of the "unavailable time" are to be included, particularly with respect to locomotives stored unserviceable. There are also those who disagree with **counting** locomotive servicing time and when that time begins and ends.

There are other variations of the availability equation that are improtant measurements for other purposes. Examples are:

Builder availability: This is a measure of the availability attainable for a locomotive based solely on design and manufacturing quality. In this case, the unavailable time consists only of design, manufacturing and corrective maintenance.

Inherent availability: This is a measure of the availability attainable for a given time interval based on design, manufacturing, quality, and scheduled maintenance. This is similar to the builder availability with the exception that the unavailable time also includes scheduled maintenance time. The scheduled maintenance is based on that work required to insure the locomotive will meet its reliability goals.

Inherent availability can also be described as the optimal availability that can be obtained if the only work performed on the locomotive is servicing and scheduled preventive maintenance.

All of the above measurements are based on locomotive hours. A locomotive spot availability can also be a useful management tool in daily locomotive management decisions. A spot availability calculation may be defined as follows:

Spot Avail. % = **Total active locomotive fleet - Number of non-available units** ÷ Total active locomotive fleet.

The formula listed above does not take into account stored serviceable or stored unserviceable locomotives. As a daily management tool it may not be necessary, as the stored numbers can be managed on an individual count basis, as long as all parties involved have understood limits. If stored locomotives are to be included, the formula must be adjusted accordingly.

The spot availability is a "snapshot" in time, and may vary significantly on a daily or even hourly basis. Even so, it tends to track fairly well with the longer term measurements described above.

D. Standardized Measurements

It is important that these performance calculations, particularly the reliability and availability measurements, be agreed to by all affected departments within a railroad. Different equations may be used by each for various purposes. However, all groups should understand the limitations and benefits of each measurement. Once the measurements are developed, it is very important that the measurement criteria not be changed, as it is virtually impossible to recognize true cause and effect for increasing or decreasing trends if there is no consistency in the components that go into the calculations.

Internal benefits with standard measurement include the added advantage that everyone plays by the same rules which encourages teamwork in the organization. In addition, team effort produces higher quality locomotives, in turn improving customer service. Internal benefits with standard measurement also allows consistent measurement for evaluations and a better utilization of motive power.

Effective performance measurement will then allow the railroad to operate more efficiently through a more direct channel to the causes and cures to quality problems.

How do railroads go about getting the data required for reliability and availability measurements? In the past decade, railroads have made significant advancements in the use of new computer technology to gather the data necessary to calculate these performance measurements. We now have numerous types of computer programs that will generate almost any type of data. Many railroads have computer generated reports that can identify where a locomotive is located, its operational status, the locomotive failure and shopping history, accumulated mileage, etc.

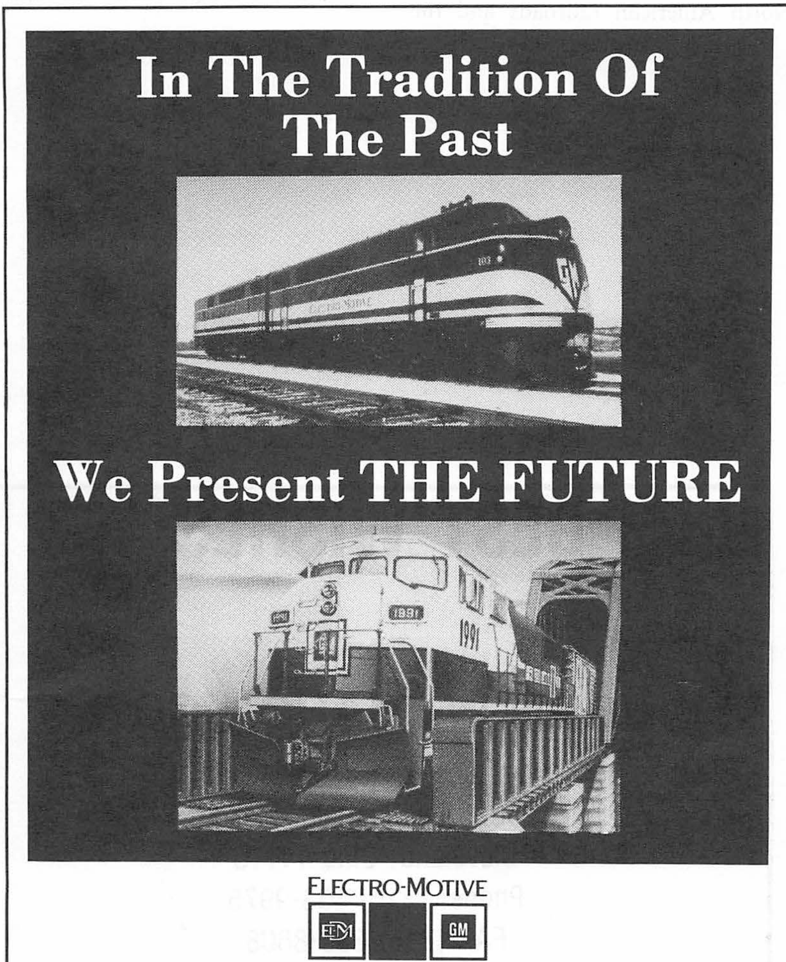
Unfortunately, while there is a wealth of data collected, in many cases it is either in a form that cannot be directly obtainable for use in the calculations; or an important component of the required data is not collected. Once the formulas for the calculation of the reliability and availability data have been agreed upon, the required data components can be identified and steps taken to obtain the measurement. The expense to make this information available can easily be justified by the benefits obtained through the use of consistent reliability and availability measurements.

As stated earlier, there is no industry standard for measurement of the three "abilities". Standard measurements become particularly important when comparing the performance of new, second hand, repair and return, and unit exchange components, sub-systems, or locomotives, for one vendor or between vendors. The use of standardized measurements can provide an essential tool in the management of the locomotive fleet, particularly with respect to overhaul programs, locomotive retirements, storage of excess locomotives, shop assignments, preventive maintenance intervals, etc.

Represented on the New Developments committee are members from three original equipment manufacturers (OEMs). It became apparent during the study of the "abilities" that (OEMs) would also benefit from standardized measurements. The OEMs have traditionally gathered data from their customers with little similarity in calculations or format. This in turn hinders the determination of the root causes of problems encountered, particularly with respect to new products, and therefore slows the response and correction time.

Standardized performance measurements would allow the OEMs to identify where developmental dollars should be spent and better direct their limited engineering resources, which can promote a higher standard of excellence. Standard performance measurements will also assist the OEMs to analyze component failure trends. Thus, for OEMs, standard measurement will provide a management tool when targeting their marketing strategies.

In summary, the new developments committee recommends that standardized measurements of durability, reliability, and availability be adopted both within each railroad, and within the railroad industry. Standard performance measurements can save the railroads and OEMs millions of dollars when used as a management tool to measure effectiveness of asset utilization, maintenance practices, and cost reductions. Standard performance measurements will allow the original equipment manufacturers to better


In The Tradition Of
The Past
We Present THE FUTURE
ELECTRO-MOTIVE
GM
Division of General Motors Corporation

direct their product development dollars, which in turn will result in locomotives with greater durability, higher reliability, and higher optimum availability.

As we move into the 1990s, the North American railroads and the original equipment manufacturers jointly face many challenges related to locomotive power. We will be managing our assets to provide more efficient utilization, better customer service, and high quality throughout.

V. H. MIZRAHI
Chief of Motive Power
& Car Equipment
CN Rail
Montreal, Quebec H3C 3N4

G. W. BARTLEY
Chief Mechanical Officer
CP Rail
Montreal, Quebec

LMOA wishes to express its thanks to the Canadian Railroads for hosting and participating in the Pre-Convention Presentation of our Diesel Electrical Committee in Montreal on May 24, 1990.

The attendance and interest exhibited was most gratifying.

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

Tuesday, September 18, 1990
10:30 A.M.

Pre-Convention Presentation CP/CN	*(Photo Not Available)*	**May 24, 1990 Le Chateau Champlain Montreal, PQ, Canada**

DON GEZON, Chairman
Asst. CMO-Motive Power
Grand Trunk Western Rwy.
Battle Creek, MI

VICE CHAIRMAN
R. J. Vasquez
Supvr. Loco. & Car Maint.
AAR-ITC, Pueblo, CO

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R. E. Wickstrom	Senior Service Engineer	GE	Erie, PA
C. S. Wilkerson, Jr.	Diesel Supt.-Mech. Dept.	NS Corp	Roanoke, VA

PERSONAL HISTORY

Don Gezon

Don Gezon is Assistant Chief Mechanical Officer - Motive Power, Grand Trunk Western Railroad. He came to GTW in 1972 after ten years with the Pennsylvania Railroad and Penn Central. He attended MIT and graduated from Michigan State University with a B.S. in Mechanical Engineering. He started with the Pennsylvania Railroad during summer vacation of his junior year and resumed the junior engineer training program after graduation. He lives in Battle Creek, Michigan with his wife Trish and they have two daughters in college.

I. MODERN TOOLING FOR ELECTRICAL TROUBLESHOOTING

The LMOA Committee on Diesel Electrical Maintenance is presenting an additional catalog of meters and testing devices used to troubleshoot diesel electric locomotives. Our purpose is to provide the electrician with a ready reference to the tools available to assist him in the troubleshooting of locomotive problems. This list is by no means a complete listing of all that is available. Other items will be included in future papers as they are submitted by the manufacturers or their representatives. This list is for reference only and is not to be construed as a recommendation by the LMOA.

A. Locomotive Speed Limiter (LSL) Test Set

Quantum Engineering, Inc. has developed a test set that allows the locomotive electrician to test the Harmon LSL equipment by injecting a dual axle drive signal, one at 20Hz/wheel revolution and the other at 60Hz/wheel revolution, into the LSL equipment (Fig. 1). The Harmon LSL uses both a 20-pole and a 60-pole axle drive and compares them against each other to insure the correct speed is being read by the onboard equipment.

The test equipment can produce a speed signal from 0-99 mph in 1 mph increments, by rotating a pair of thumbwheel switches on the front panel of the tester. The tester is set up to use locomotive control voltage to power the device, thereby making it truly portable.

The axle drive outputs (20/60-pole) are independent of each other so the tester has the added capability of being used as a speed indicator or speed recorder calibration/verification device. The tester may be used on a locomotive system that employs any manufacturer's 20- or 60-pole axle drive. In addition to being used for the Harmon LSL equipment.

Wheel size determines the distance traveled during one wheel revolution, and therefore how many feet a pulse from the axle drive represents. At a railroad's request, Quantum has compensated for this by setting the wheel size to a fixed limit, around which the maximum variation would not violate any FRA guidelines for accuracy, even if the locomotive wheel was not the same size as the wheel compensation factor. However, for complete accuracy, the test set can be equipped with another set of thumbwheel calibrators that allow the exact wheel size of the locomotive being tested to be input to the tester, thereby ensuring a 0% error from actual conditions.

For further information:
Quantum Engineering, Inc.
6196 Lake Gray Blvd., Suite 101
Jacksonville, FL 32244
Phone: (904) 777-3550

B. Engineman Alerter

Pulse Electronics, Inc. manufactures a tester for the Pulse Train Sentry III Engineman Alerter, Part #17330 (Fig. 2). The tester enables shop personnel to test, verify and or trouble-shoot the Pulse Train Sentry III. The Train Sentry tester is housed in a rugged enclosure which requires 110 VAC for power. The tester has a permanent cable attached which supplies the power and simulated reset inputs to the Train Sentry III control-alarm unit. The tester has a self-contained speed generator to simulate different speeds. The resets, which include a manual reset, throttle, horn, dynamic brake, bell, etc., are operated by an array of toggle switches and push-buttons. The tester has an LED to indicate the magnet valve dropping out.

For further information:
Pulse Electronics, Inc.
5706 Frederick Ave.
Rockville, MD 20852
Phone: (301) 239-0611

Fig. 1

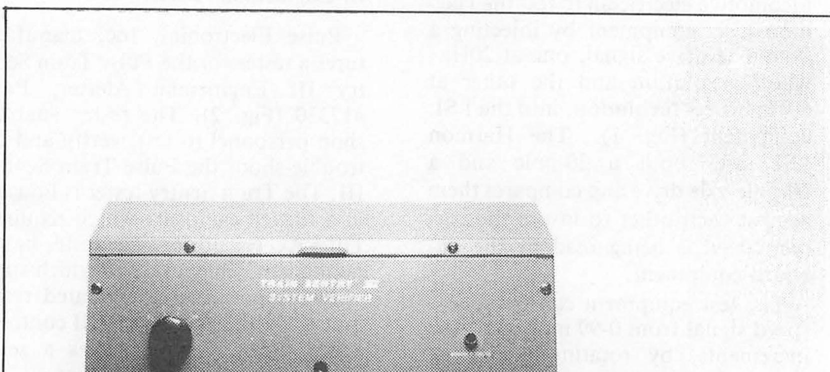


Fig.2

C. Coil Insulation Analyzer

P. J. Electronics offers high frequency surge testers which are used to detect defective coil insulation in series fields, shunt fields, armatures, and stators for all types of industrial AC and DC machines during coil manufacturing, installation, and connection.

They may also be used to detect an incorrect number of turns. Each surge tester is capable of delivering a continuously variable peak test voltage from an established minimum of 200 volts for the Model 6905C and 400 volts for Models 6910C, 6915C, 6920C, and 6925C. This voltage can be accurately set by a voltage adjust control located on the front panel and can be read directly on a large meter mounted in the center of the top panel. These testers use a comparison method for detecting defective coil insulation, i.e., the coil-under-test and an identical reference coil are compared to one another. The voltage is applied to each coil and the resultant current waveform from each coil is displayed on a wide-band oscilloscope. If the insulation of both coils is good at the applied test voltage, essentially one stable waveform will be observed. If, however, the insulation of one of the coils-under-test can no longer support the level of applied voltage, two distinct waveforms will be observed on the oscilloscope. The two distinct waveforms will appear even for a high resistance short or momentary insulation breakdown.

For further information:
P. J. Electronics, Inc.

II. MAINTAINING SOLID STATE EVENT RECORDERS

Introduction

In recent years the Diesel Electrical Committee has published several articles on existing event recorders and their utilization in the industry. The new solid state event recorders were also treated. Particular consideration was given to their characteristics and performance thanks to the use of the microprocessor as the essential component of their design.

The solid state construction and the self-diagnostic capability now possible because of the microprocessor, make these devices both very reliable and easy to maintain. Manufacturers of the solid state event recorders claim that these devices are practically maintenance free. This has been proven to be essentially true in practical use.

Nonetheless some maintenance is still necessary; it consists mainly of periodic verifications, checks and in some cases the replacement of internal components. We will examine in detail such requirements, noting that they can vary from one manufacturer to another and depend mainly on the quality and level of design sophistication.

Event Recorder Basic Maintenance Requirements

Most of the existing solid state event recorders require the following periodic maintenance interventions:

a) Resetting of the internal clock

The solid state event recorders are generally equipped with an internal clock that provides real time and date for the recorded data.

The event recorder clock, like any commercial clock, has its own precision, i.e. the clock indicated time will drift proportionately to the clock error which directly depends on the precision and stability of its crystal oscillator. Wide changes in ambient temperature, common to the locomotive environment, will also negatively affect the clock precision. Consequently, to correct for the accumulated error, the clock needs resetting at regular intervals. This operation is normally performed using the same lap top computer that is used for memory downloading and system verification.

The process is as follows: the portable computer internal clock is reset to the precise time and then the event recorder clock is reset in its turn to the portable computer time either manually or automatically. This process insures that all event recorders are reset to the same time and it greatly reduces possible human errors.

Although the clock resetting is in itself a simple operation, it can become a difficult task when needed too frequently.

This is the case when the clock precision is poor. An interval of six months between resetting should be considered quite acceptable. It can be scheduled with other important maintenance inspections such as the semi-annual air brake inspection.

It is also recommended that the clock be reset whenever the event recorder memory data are extracted. This will provide for an additional clock error correction and improve the overall precision of the recorded data.

For the many railroads having locomotives running through different time zones, it is advisable to use a common time standard for all event recorders. Moreover, to avoid any further complications, only the standard time should be used the year around, to eliminate the need of frequent changes and any possible confusion.

b) Replacement of the back-up batteries

Some of the event recorder internal circuits are provided with back-up batteries (lithium type) to supply power whenever the main DC locomotive battery power is cut out. The back-up supply is needed to keep the clock running and to feed the RAM memory chips (this memory battery back-up is not needed if EEPROM memory chips are used).

The expected life of lithium batteries is very long and they are only discharged when the locomotive battery is disconnected from the event recorder. Nonetheless, as a preventive measure, suppliers recommend their replacement at intervals of about five years or less (this takes into account the time the event recorders are not powered, as in the case of long locomotive shut downs or event recorder storage as spare equipment).

Some event recorders are equipped with a special internal circuit to detect low charged back-up batteries. An indication is activated to display the need to replace the battery well before it has completely run out of energy.

The replacement of back-up batteries does require the intervention of a qualified electronic technician. The alternative is to return the event recorder to the manufacturer, who at the same time would perform a complete verification of the unit. For this reason, it is recommended that event recorder battery change-out be done concurrently with locomotive scheduled major maintenance repairs.

Since back-up battery replacement is the most important maintenance requirement of the event recorder, it should also be considered one of the most critical factors in event recorder selection. Number of batteries, longevity, ease of replacement and verification, availability (multiple sourcing) etc. are some of the important points to verify and carefully evaluate.

Other maintenance requirements

These are in the form of periodic inspections and verifications, which will insure that the event recorders are indeed functioning satisfactorily even though no actual work is performed on them.

a) Verification of the event recorder status

The event recorder is normally

equipped with indicating lights to display the working condition of the equipment. These indicating lights are controlled by the event recorder's microprocessor to indicate if it is able to perform its required functions or it needs any repairs. This visual inspection should be carried out before any locomotive trip as a normal qualification procedure.

b) Verification of recorder operation

The recorder must be verified on a periodic basis to make sure that all inputs are adequately recorded. This verification should be carried out at least every six months. It could, for example, coincide with the semi-annual air brake inspection and consists mainly of the following:

i. running the complete self test of the event recorder (if this feature is available);
ii. verification of all inputs, both digital and analog, by the actual operation of the related circuits while monitoring the recorded inputs through the real time view on the lap top computer. The analog readings should be checked against the locomotive's gauges and meters;
iii. resetting of the internal clock;
iv. retrieval of all the memory data for further analysis and verification.

c) Verification of the recorder accuracy

This operation consists of the periodic verification of the accuracy of both the digital and analog inputs. To test the digital inputs, the actual circuits are operated with the locomotive at standstill. The status of each input is monitored through the lap top computer using the real time view mode.

This verification will insure that all digital inputs are present and their change in state is correctly recorded. The same verification is carried out for the speed and the other analog inputs like air brake pressures, motor current, voltage etc. In this case accuracy of the recorded inputs is verified against accurate meters like master gages, precision voltmeters and ammeters.

The complete process is automatically recorded by the event recorder. A subsequent memory downloading of the event recorder will provide a recorded copy of such verification for filing and locomotive event recorder follow-up. All the other verifications like self testing, clock resetting etc. should be carried out to insure that the event recorder is fully functional. An interval of two years between such verifications should be considered adequate.

The following table summarizes the maintenance requirements of a solid state event recorder:

Maintenance Task	Interval
1. Check alarms	6 days
2. Verify operation	6 months
3. Check accuracy	2 years
4. Change batteries	4 years

Conclusion

Today's event recorders are very reliable and their maintenance costs are generally low.

These costs are directly related to the complexity and the quality of the chosen equipment. It is at the time of acquisition that such characteristics must be kept in mind to avoid long term high maintenance costs as well as reliability problems.

There is another aspect that, unfortunately, has not yet been addressed by the industry: standardization. As it stands now, event recorders are not built following any standards on size, mounting, inputs and outputs, input and output connectors or fire and impact resistance. The non-existence of standards has already resulted in a multiplicity of event recorders that are not interchangeable, both physically and electrically.

The customer railroad will choose one and "be stuck with it".

It is the strong LMOA opinion that such standardization is not only useful but necessary. There is still time for its implementation before all railroads engage individually in full fleet-wide applications of this very important and also expensive device. We are confident that these needed improvements will be soon implemented as the result of the good cooperation that exists and will exist between the railroads and the supply industry.

III. WHY CAN'T WE HAVE ONE CENTRAL COMPUTER?

How many times have you stepped on a locomotive, only to come face to face with a cab that has become so congested that there are no more places to mount "black boxes"? These boxes are used in the locomotive cab to house electronic control devices. A locomotive cab often contains a dozen or more of these units. Some of the black boxes may have been installed due to the requirements of labor agreements with the transportaion unions. In some cases, they are there to control or monitor a particular operation or function. We could go on and on about why we need these "black boxes" and what the payback is of each particular system.

This paper will discuss some of the equipment now commonly installed in black boxes in the locomotive cab. We will look at the feasibility of incorporating this equipment into a central computer and will discuss the impacts (both negative and positive) associated with integration of some of these functions into a central system.

A. Advantages of Centralizing

The advantages of centralizing many of these electronic control devices into one computer would be as follows:

1. Clean Cab Concept

Operations would be simplified by consolidating the numerous engineering control devices into a unitized package. One display screen could be mounted on the control stand enabling the engineer to monitor all functions on the one screen.

2. Ease of Maintenance

Maintenance would be simplified by consolidating all Black Boxes into one central control box. This would greatly reduce the number of cables, relays, and components needed to perform the work required. With fewer components, the maintenance requirements would be reduced correspondingly.

3. Onboard Diagnostics for Fault Identifications

Maintenance would also be simplified by the diagnostic capabilities of the microcomputer. Faults could be pinpointed and displayed to the maintenance personnel on the display screen.

4. Expandable and Flexible

Additional features could be added by changing the software. Additional slots should be left in the computer to accommodate additonal boards. Other functions could be added to the central system as they become available.

B. What Functions Should Be Included?

This next section details several functions that should be considered for consolidation into our proposed computer system.

1. Automatic Train Control System

The first black box function that could be a candidate for consolidation into a central computer is the automatic train control system (ATCS). ATCS requires an on-board computer and a display screen on the engineer's control stand. Because of these requirements, ATCS would be a natural candidate for incorporation into our central computer.

All functions that are recorded on the central computer could be displayed to the dispatcher for better train operations. For example, the dispatcher could readily determine the amount of fuel remaining on every unit in the consist. With this information, he could better decide when the consist would need to be fueled. Locomotive performance factors such as speed, amperage, throttle position, etc. would be available to the dispatcher as well as the engineer. This information could also be transmitted to the mechanical department when a locomotive performance problem is reported by the engineer. There is nothing like having real time data to insure that the locomotive is repaired right the first time.

2. Brake Control Systems

Both New York Air Brake and WABCO are currently working on computer-controlled air brake systems. Although these systems are now only in the prototype stage, they will most likely replace the standard 26L air brake system. Like the ATCS system, a computer-controlled air brake system also requires a screen on the control stand to display the air brake functions to the engineer. As presently designed, this calls for a separate on-board computer.

Installation of the air brake control system in our master computer would allow all air brake functions to be displayed on one screen. This would eliminate the need for three separate air brake gauges (including the air flow gauge for those of us who use it as a standard).

Connecting the computer-controlled system into the central computer would give the dispatcher the ability to apply the air brakes and stop the train in the event of a runaway locomotive. (It should be noted that this will only work if ATCS is also tied into the central computer).

Transportation could monitor the operation practices of engineers to insure that they were complying with all train handling rules. This would greatly reduce the number of trains that a road foreman would be required to ride to insure compliance with operation guidelines. Also, if engineers know that their performance is monitored, they will be more likely to comply with all rules.

3. Speed Recorders

Most railroads presently use some sort of speed recorder. This device records the speed of the locomotive at all times. The FRA is now studying the feasibility of requiring all railroads to have a multi-event recorder on board any main line locomotive. Most of the functions that would have to be recorded would already be in the computer. This information could also be passed along to the dispatcher and maintenance personnel if ATCS is incorporated in the central computer.

4. Alertness Monitoring Systems

The purpose of alertness monitoring is to stop the locomotive if the engineer fails to respond to visible and audible signals over a set period of time. With the speed recorder and air brake system as part of the central computer, all of the functions required to monitor the engineer's actions would already be in place. The on-board screen could respond as a visible and audible alertness system and the dispatcher could become a back-up if the alerter failed to stop the locomotive. (Again, it would require ATCS to perform this function.)

5. Automatic Speed Control

This is a device that controls the speed of the locomotive through the use of air brakes and electrical controls. If this device were part of the central computer and tied to ATCS, the dispatcher could control the locomotive speed for slow orders, etc. Since this is a very precise means of control, there should never be a case where an engineeer would exceed the speed limit. This would definitely be an advantage to all transportation departments.

There are other devices that can be incorporated into the central computer, such as fuel gauges, end of train (EOT) devices, wheel flange lubricators, and traction motor short-time rating regulators, just to mention a few.

C. The Problems

Two factors have prevented the major railroads from implementing a centralized computer system such as the one defined in this report: Cost and reliability. The costs to install a central computer on all locomotives as well as all the support systems required at waystations would be excessive. There are currently a few prototype programs throughout the country. None of these prototypes have been reliable enough to justify the investment required to implement such a project on a large scale.

With the advent of microcomputer-controlled locomotives, a central computer system could be incorporated into the locomotive mainframe. This would require the locomotive manufacturer to take the initiative. If the manufacturers were to expand the capacity of the on-board computer, it would facilitate incorporation of all these functions into the mainframe. Several of the large Class I railroads have already approached both manufacturers about this subject.

With some long term planning and cooperation between the railroads and manufacturers, one day we may have a locomotive control stand that looks uncluttered but is powerfully functional! (Fig. 3 and 4)

IV. EPA AND REGULATION DRIVEN CLEANING

For more than fifty years railroads have been cleaning locomotive electrical equipment. Beginning with the earliest diesel electric locomotives we soon learned that oil and electricity don't mix. To borrow a maxim, "cleanliness is next to Godliness" has been the credo of electrical maintenance for the entire diesel locomotive era and is certainly still valid today.

To make life challenging, connecting an electrical generator with controls and traction motors to an oil

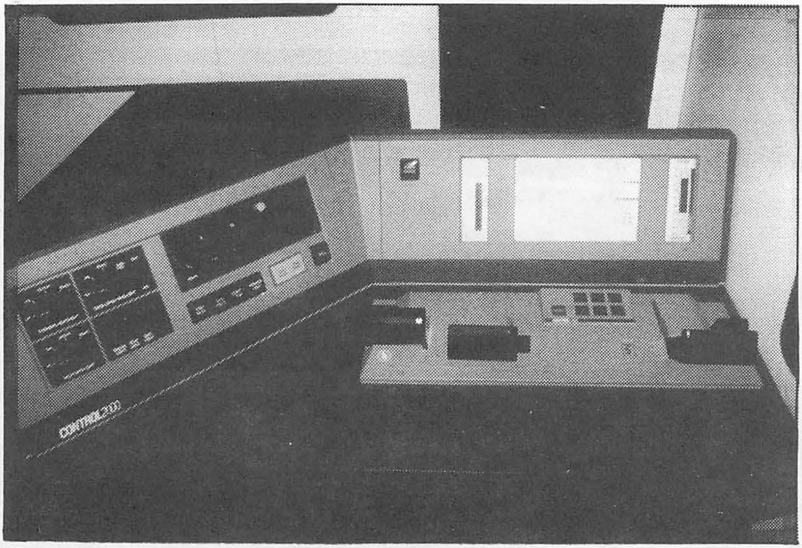


Fig. 3

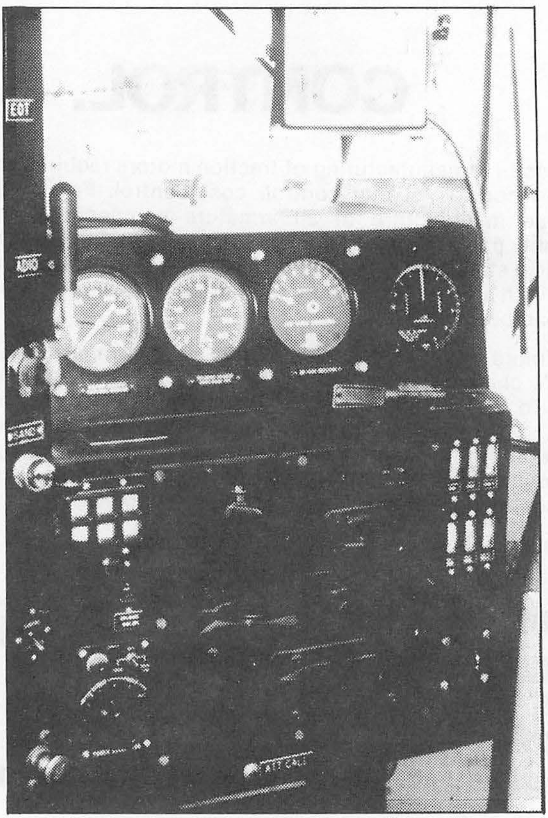


Fig. 4

burning, oil leaking diesel engine on a moving, vibrating platform created the worst imaginable environment for these electrical components.

Shortened component life, shorted wiring, fire and disabling failure have been and are today the effect of oil and dirt in and on motors, relays, wireways, cables and compartments.

Cleaning electrical equipment both on board locomotives and in repair shops is the major function of electrical maintenance. It is also the function most affected by shop consolidations and closings, increased maintenance intervals and plain old cost cutting. An informal poll of our committee, which includes representatives of railroads operating more than two-thirds of the locomotives on line haul railroads, concluded that we no longer are able or perhaps willing to live up to industry guidlines.

A review of manufacture's literature gives us direction of what ought to be done.

From EMD maintenance instruction 3317-1 (Revision E), AR type traction alternators, we hear these words of wisdom: "Both the interior and exterior of the traction alternator should be kept clean and free of dust, dirt, oil, and water which are likely to have a detrimental effect on insulation and performance...the alternator should be blown out with low pressure air...lintless wiping cloths should be used as necessary to remove oil, grease, and accumulations of dirt. It is essential that the rectifier be kept as clean as possible at all times".

EMD repeats these instructions for traction motors in maintenance instruction 3900 (Revision G) adding, "in severe cases it may be necessary to dampen a cloth in solvent such as Stoddards to loosen and remove inbeded deposits".

GE weighs in with service and maintenance instruction 32000-001A and 32000-2A for 752 AG traction motors. Steam cleaning is preferred but avoid the forcing of moisture inside the motor as much as possible. Remove all possible carbon dust, road dirt and moisture.

GE also specifies using a lintless cloth to wipe dirt and grease from the brushholder insulators; "if necessary use a cleaner such as MEK to clean insulator surfaces".

For GE 5MG186 and 187 alternators in SMI41502, they also instruct us to use a recommended solvent and lintless rag. GE admonishes us to follow government and railroad safety regulations. A warning is also stated in the use of cleaning solvents not to inhale fumes, use adequate ventilation, avoid skin contact and observe manufacturers' caution statements.

In SMI65001A GE states that the cleaning procedure for the propulsion rectifier modules of Dash 8 locomotives is limited to "the blowing out of any dirt accumulation with an air hose". Precaution in the use of compressed air is required. Finally in section 4 of GEK-30150 the same statement is made for cleaning power rectifier panels on series 7 locomotives.

Instructions on cleaning other rotating electrical equipment, auxiliary generators, exciters, blower motors, etc. are very similar but not as detailed. All cleaning instructions include blowing out the device with clean, dry compressed air and wiping exposed surfaces with a clean cloth to remove accumlations of dirt, oil and grease.

While it is common knowledge that any accumulation of dirt, oil or grease on and particularly inside of electrical rotating equipment is detrimental and in extreme cases destructive, locomotive electrical equipment must be able to function normally within a dirty, slightly oily environment. Cleaning a motor or generator of light accumulations is as impractical as designing equipment blower systems that remove all airborne dirt and oily residue from ambient air.

Cleaning the interior of rotating electrical equipment while applied to the locomotive should be reserved only for extreme cases of accumulation. Heavy accumulations of dirt reduce heat dissipation, causing breakdown of insulation and shortening the service life of electrical equipment. Oil and grease as well as residue from treated cooling water will attack motor and generator insulation as well as attract and hold dirt on surfaces. Much of the dirt in the locomotive environment is carbon based. Exhaust gas and dust from brush wear increase the tendency of locomotive rotating electrical equipment to develop carbon path grounds, especially after a flashover. Dirt accumulation can retain moisture, further increasing ground problems particularly in traction motors.

What constitutes heavy accumulation is a matter of judgment but can be described in general terms as that which blocks free flow of cooling air through passages and or completely covers the surface of armatures, fields, brushholders, or rectifier panels.

Practical methods of cleaning rotating equipment are really a matter of both commitment to apply the labor and facilities to perform the necessary cleaning, and of using environmentally and personally safe, effective procedures.

The most common roadblocks to performing recommended cleaning procedures for rotating equipment while it is applied to the locomotive are:

Accessability—

Not only the component itself, but the internal parts that require the cleaning.

Environment —

Where to clean, personal safety from airborne dirt and from cleaning solvents, as well as the disposal of the solvent and contaminants from the component.

Facility —

Source of dry air at low pressure, high volume, pit access for traction motors, methods of drying out the component after cleaning with steam or water.

Design —

Some components are difficult or impossible to thoroughly clean with the recommended methods when applied in their normal position. Rectifier panels are a prime example.

Traction Motors

Most of the above mentioned problems come into play when considering the cleaning of traction motors. While it makes sense to blow out a traction motor with clean, dry air whenever a locomotive is shopped for periodic inspection, this procedure should not be performed in a location where personnel conducting other work are in the vicinity of the airborne dirt produced. Blowing out of traction motors should be performed in an isolated, protected area of the shop. The person performing the cleaning must wear protective clothing and use face, eye, and breathing protection. The motors must be as dry as possible and for this reason should not be air blown outside on a damp or rainy day. Few shops can dedicate the kind of inside area to place a locomotive for this cleaning.

Blowing out through the exhaust vents of a traction motor will not get dirt out of the commutator chamber end of the motor. The inspection covers must be removed, requiring pit access. If the amount of airborne dirt is to be controlled, a vacuum fixed to an inspection cover may be

placed on each motor but will have to be moved from motor to motor as cleaning progresses.

Air pressure must be regulated to a maximum of 30 psi, and training given to personnel in safety and use of personal protection equipment. Training is needed to assure thorough cleaning is accomplished.

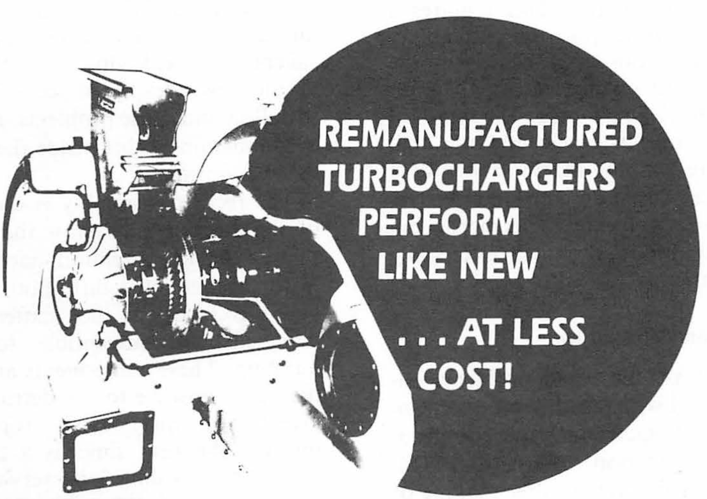
If grease, oil, or cooling water treatment have entered the motor, a solvent must be used to remove this and the accumulated dirt that air alone cannot remove. Safety precautions for the solvent must be observed, while the rise of personal injury is of course higher. Disposal of the spent solvent and contaminants may also pose a problem particularly if large quantities are used. A spray wand will have to be used to direct the solvent to critical areas of the motor, some of which are difficult to access from the commutator chamber through inspection covers or from the air vents. Solvents used, of course, should be those recommended by EMD or GE. If only one type of solvent or a different product is desired, approval should be obtained for its use or it may affect warranty considerations or cause damage to one or the other type of motor.

Wiping of exposed interior surfaces with a rag to remove dirt and oil is recommended by both manufacturers. While this can be accomplished through the inspection cover, access is limited to the commutator, brushholders, and commutator chamber. Critical areas are the brushholder insulators, and the commutator end "vee ring" or string band. Use of epoxy or Teflon coverings has eliminated the need for painting the string bands and has made removal of dirt much easier. Carbon tracks still pose a problem and removal of these by wiping or with a solvent is an important part of any traction motor inspection.

All the critical surfaces are not accessible through the top and bottom inspection covers and when wiping of these surfaces the back access cover of the motor must be removed for wiping the 9:00 brushholder and the back of the vee ring. This procedure is difficult to accomplish on switcher locomotives since the back access cover is an air inlet. GE, AF and AG type traction motors were produced without a back access cover. Without this cover it is virtually impossible to wipe the top side of the 9:00 brushholder, and approximately one-third of the commutator is inaccessable whild the motor is applied to the truck. Grounds caused by carbon tracks on the top of the 9:00 brushholder require the removal of the motor, since replacement of the brushholder itself takes much more time and labor than practical when removal is possible only through the bottom inspection cover.

When all these factors are considered, the cleaning of traction motors while applied to the locomotive should be limited to wiping off the brushholder insulators and commutator vee ring insulating surface as necessary at each periodic inspection. Solvents should be used only when required. Chlorinated hydrocarbon solvents are not recommended by EMD, yet the common aerosol type "electrical" cleaners are of this type. These solvents are effective in cleaning carbon tracks on Teflon brushholder insulators of GE motors.

Motors with carbon tracks that cannot be cleaned with the recommended solvent and wiping and those with oil or grease soaked areas that cannot be cleaned with small amounts of solvent and wiping should be replaced rather than "washed" with solvent. Extremely heavy dirt accumulation is also a reason for replacement, since blowing may be a difficult procedure in the shop.


REMANUFACTURED
TURBOCHARGERS
PERFORM
LIKE NEW
. . . AT LESS
COST!

In most cases a motor change on the drop table takes one and one-half to two hours. This requires a replacement motor; the availability of a motor can weigh heavily on the decision to change rather than attempt to clean a motor. The removed motor can now be cleaned in a high pressure washing machine such as a Proceco washer designed to effectively clean the motor. The motor can then be dried out and, if electrically requalified, returned to service.

Traction Alternators

Most of the same problems encountered with traction motor cleaning are of equal concern in the cleaning of traction alternators. Oil, grease, and cooling water soaking of the internal components is less likely due to the alternator's location above the deck. However, EMD alternators are subject to this if the generator pit aspirator is plugged and an extremely high level of liquid accumulates for a long period of time. Soaking of the terminal board area is the most common result of this. After clearing the generator pit, the terminal board and box must be cleaned and wiped dry. A completely oil soaked alternator should be replaced. Cleaning of the alternator can be done more effectively in a high pressure washer. Then the alternator can be electrically qualified to assure that no permanent damage has occurred. If the alternator has been applied less than two years, serious consideration can be given to cleaning it in place. GE alternators are more likely to be successfully cleaned in place as more direct access to the interior is possible through the air vent openings on the engine end.

The slip rings and brushholders can be cleaned by wiping. Again the use of solvents should follow manufacturer's instructions. Slip ring and brushholder cleaning should be done as a normal part of periodic inspection.

Blowing out of the interior of the alternator is seldom necessary. The salient pole field allows free flow of air and fewer restricted areas for dirt to collect and cause problems. A light accumulation of dirt inside the alternator is normal.

The rectifier assembly is one part of the traction alternator that does require cleaning attention, particularly for accumulated dirt. Both EMD and GE rectifiers, no matter how designed, are susceptible to dirt build-up. These components are also the most sensitive to the detrimental effects of dirt. Heat rejection through the heat sinks is a critical factor in providing long service life for diodes, and dirt reduces cooling efficiency. In the past several cleaning methods have been tried, from blowing out at each periodic inspection to washing with various solvents. In all cases dirt re-accumulates almost immediately. Most railroads have learned that this periodic cleaning is of little benefit for the long term.

Heavy accumulations of dirt will require cleaning. For EMD rectifiers this can be done in place, but precautions must be observed for using air for blowing in the enclosed environment of the generator room, and for using solvents in an enclosed area. A vacuum may have to be used to remove all of dust from inside of the rectifier area and generator room. Air pressure should be regulated to as low a pressure as possible to avoid blowing dust into the rubber protective boots on the diodes and fuse indicators. An industrial vacuum works well here. The exhaust air can be directed at the panel to loosen dirt while the intake is placed close to the area to collect it immediately.

Removal of the rectifier assemblies for thorough blow-out and cleaning is usually the best solution for GE locomotives. Disconnection is simpler, and this also allows for cleaning and inspection of the back side of the panel. Because of the more complex wiring, EMD rectifier assemblies are removed only if the locomotive is tied up for other maintenance long enough to make the extra work of replacement practical. This work can be programmed at shops that do inspections such as triannual and where facilities for complete rebuild and cleaning of the panels are available.

GE Dash 8 locomotives with the rectifier modules (RM's) require only periodic blowing out of accumulated dirt according to service manual instructions. Experience, however, has shown that the press-pak diodes in these modules are subject to carbon tracks across the ceramic of the diodes. These tracks break through only at high voltages associated with faster locomotive speeds and result in blown fuses. An ohmeter test of the rectifier will not indicate a shorted condition. In addition to blowing out of the RM modules, the diodes should be carefully inspected for carbon tracks particularly in the back, which may require a mirror. If wiping cannot remove the tracks, replace the RM module. GE could help with this problem by recommending a cleaning procedure that removes carbon based dirt, generated from exhaust smoke. This cleaning should be performed during periodic maintenance.

Auxiliary and Exciter Generators

Simple blowing out with low pressure air is usually the only cleaning procedure necessary for this equipment. Blowing out should only be done if the accumulation of dirt and dust is excessive and is reducing the normal air flow through the generator. Again, all necessary precautions for use of air pressure and protection of personnel in the vicinity from flying debris and dust must be observed.

If oil or grease soaked, replacement of the generator is recommended. The generator can then be disassembled and cleaned in an environmentally controlled operation and electrically qualified for service.

GE auxiliary generators and exciters applied to models prior to the Dash 8 are subject to oil filming on the commutator and brushes due to an accumulation of oil in the equipment air ducting below the deck. This can stick brushes and film the commutator surface causing commutation problems and poor performance of the generator. Wiping of the commutator and cleaning of the brushholders with solvents is necessary to correct this. Even after cleaning some of this oil will remain impregnated in the commutator copper. The commutator and alternator slip rings should be given treatment with a cleaning stone, followed by brush seating stone. In extreme cases the commutator surface will require extensive cleaning to remove all of the oil film impregnation.

Policy vs Practice

These instructions are the foundation of all railroads maintenance policies. Unfortunately modern practice and stated policy are far from consistent.

For instance the instruction to use an approved solvent is often impossible to follow. The solvent may not clean well, or will leave residue or be so qualified with safety requirements as to assure its non-use. "Lint free rags" require the use of reusable shop wiping cloths, and most railroads don't pay the price but buy bales of scrap cloth for rags. Restricting blowout air pressure to 30 lbs. for safety results in an ineffective job of removing dirt.

Another fallacy of cleaning instructions is caused by the merger and consolidation movement. Because of the consolidation of work at fewer shops, each of which is responsible for hundreds of locomotives, and reductions in manpower, the opportunity to periodically and routinely clean equipment has been reduced from occasionally to non-existent. In other words some shops do some periodic cleaning, with others only cleaning in attempts to avoid a changeout.

Another cause for the decline in periodic cleaning is that on locomotives of 3,000 hp or higher, the effectiveness of trying to salvage by cleaning a traction motor that is causing ground relays to trip is practically nil. This does not refer to those cases where the problem can be corrected by cleaning an insulator or changing one or two brushholders, but to those cases involving internal faults.

We do know that cleaning high voltage components will prolong useful life and extend time before failure. If for the reasons mentioned we are not able to effectively clean motors, alternators and auxiliarys as frequently as necessary to keep them free of dirt, what then can be done to minimize the consequences?

First and foremost the sources of oil, grease, dirt or water entering the cooling air supply must be found and corrected. Manufacturers have done an excellent job of designing modern locmotive equipment cooling air systems that provide reasonably clean air to rotating equipment, through ducting systems that are sealed against entry of liquid contaminants.

But these systems require periodic attention and may fail occasionally or develop openings that permit liquids to enter and be introduced to the equipment. Assuring the integrity of these systems is the best method of keeping rotating equipment clean and is essential to avoid the necessity of cleaning electrical equipment.

The EMD central air supply system has met these requirements since the introduction of turbocharged engines. The design of the GE equipment air system has been faulty because it was located below the engine and between the frame members where the natural flow of engine liquids can enter the system through poor seals or cracks. However, the GE Dash 8 equipment blower system shows great promise of providing a permanent solution to this problem. Location of the intake primary filters above the deck level is the greatest improvement.

A motor or generator does not have to be oil soaked to experience problems. Air borne oil directed to commutators and slip rings can impregnate the copper and cause high resistance between the brush and contact surface and also cause a "gumming" residue that can result in sticking brushes and increased dirt accumulation.

Progress has been made, but a lot more must be done to clean up the cooling air supply. We all find it necessary to remove rectifiers for cleaning knowing that the source of the dirt is the cooling air. Not only must external oil leaks on the locomotive be corrected, also the amount of unburned oil in the exhaust system must be reduced, because a certain amount of exhaust gas gets circulated through the air system. The need to meet clean air standards will give us a dividend in accomplishing this. Whether the improvement is by manufacturer design changes or better maintenance, this is the most important improvement to be made.

GE locomotives in the Dash 7 series now are being modified to provide cleaner cooling air to the lower electrical cabinet. One major railroad elected to stop the air circulation through this cabinet because air

borne dirt caused malfunctions and is willing to risk the heat build-up as a trade off. This points out the problem with the cooling air supply.

The secondary source of oil and dirt is the system of passageways and ducts. Cracks, openings and oil dripping on traction motors can be sucked into the system and be deposited in the motor. This is happening and is proved by contrasting the dirt condition of alternators and traction motors. No locomotive can operate successfully for any length of time with oil in the air passages. Here the cure is to stop the oil leaks, which is a topic this year and last year of the LMOA Diesel Mechanical committee. They are to be commended and supported in their effort to clean up the engine and piping systems.

Summary

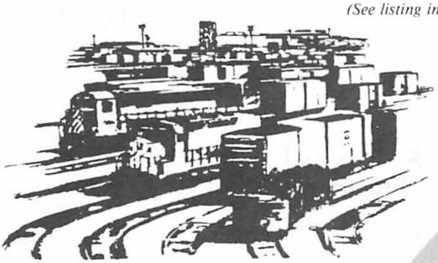
In summary we acknowledge that cleaning practice does not adhere to instructional standards because some effective cleaners are environmentally prohibited, and because of lack of facilities and manpower. We acknowledge that failure to keep high voltage equipment clean does cause failures and shortens component life. The tradeoff has been made, whether consciously or not. The trend is to further reductions in shops and forces which will reduce the already limited resources for electrical maintenance cleaning.

The single most effective measure to minimize the need for electrical maintenance cleaning is to clean up the cooling air supply. The railroads can help themselves by cleaning and maintaining the integrity of the air passages and ducts, correcting external oil leaks and cleaning up exhaust emissions.

Finally, we ask General Electric and Electro-Motive to continue to improve the filtration of cooling air so that locomotives can run from new to overhaul without cleaning rectifiers, alternators and motors. This goal is certainly ambitious, but only if efforts to reach it are made will needed improvements be forthcoming.

In the past when railroads have asked for improvements, the manufacturers have responded. To contrast an SD-60 with a GP-7 or a Dash 8-40C with a U25B demonstrates what has been accomplished.

Today railroading is a very tough competitive business. The uneconomical, inefficient and unresponsive railroad will not survive. Strict emission standards, clean locomotives that do not drop oil or dirt on the ground, greater fuel efficiency, noise emission standards and collision standards are with us now. To this list we add the need for clean cooling air. It is a lot to ask. Yet it is just one of the many improvements that we need if railroads are going to prosper. Railroad maintenance forces are stretched thin and challenged as never before. We need the benefit from continued locomotive improvements.



Southwestern Railway Club

Started in 1946, the Southwestern Railway Club this year is celebrating its 44th Anniversary.

The organization consists of Railroad and Railroad Supply members who cooperate to discuss locomotive and freight car maintenance and other aspects of the Railroad Industry.

Railroad personnel and Railroad suppliers and builders are welcome members in the Southwestern Railway Club. Contact our Secretary-Treasurer for details on meeting dates and locations.

Application for membership should be directed to the Secretary-Treasurer.

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Kansas City
Southern Rwy. Co.
Kansas City, MO

SHARON D. KOCH
Secretary-Treasurer
Southwestern Railway Club
P.O. Box 515
Omaha, NE 68101-0515
(402-271-3512)

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT

Tuesday, September 18, 1990
2:15 P.M.

Pre-Convention Presentation
Southwestern Rwy. Club

May 25, 1990
Marriott Hotel
Omaha, NE

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Warranty Officer
CSX Transportation
Corbin, KY

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PERSONAL HISTORY

David M. Wetmore

David was born in St. Johns, MI on June 13, 1949. Following high school, he attended Delta College at the University Center, Michigan where he received an Associate Degree in Industrial Supervision and Management.

David began his railroad career in 1968 with the C & O Railway as a machinist apprentice. He was promoted to round house foreman in 1978. Since then he has held 10 different management positions in locmotive maintenance with CSX Transportation and its predecessor roads. Included in these are plant manager production, Huntington Locomotive Shop; plant manager Russell Locomotive Shop; assistant mechanical superintendent, Evansville division. In June of this year he was appointed warranty officer responsible for Corbin, Nashville, and Atlanta locomotive facilities.

David resides in Corbin, KY with his wife Marilyn and their four daughters, Heather, Kelly, Christine and Kate. His major hobbies are flying and airplanes.

I.
EMD VALVE BRIDGE MACHINE

Some of the greatest improvements in productivity at a railroad shop can be gained by focusing on tasks that are performed repetitiously. When gains in productivity can be combined with a better quality product, the benefits are even greater.

Such was the case with development of an EMD valve bridge machine at Norfolk Southern's Chattanooga Assembly Shop in Chattanooga, TN. This facility provides rebuilt EMD engine components for about 1,400 locomotives operating on the system. The majority of these components are used in the overhaul program at the Chattanooga Assembly Shop. The balance of the components are distributed to running repair shops across the system. Annual production of EMD power assemblies is about 6,600 units.

The Chattonooga Assembly Shop has a long history of developing automation for EMD power assembly and engine component work. By the early 1980s management had identified a need to build a modern valve bridge machine. A primary concern was to assure quality valve bridge assemblies in an effort to prevent dropped valves.

Most locomotive maintenance officers are familiar with how the valve bridge assembly and lash adjuster work on EMD locomotives. Lubricating oil from the rocker arms is fed into the valve bridge assembly through a button in the center of the valve bridge. From here, internal passages feed the oil to both ends of the valve bridge assembly where the lash adjusters are located. The lash adjusters have a ball check valve which closes shortly after the lash adjuster is compressed by the downward stroke of a rocker arm. The lash adjuster takes advantage of the incompressible qualities of a fluid by stopping further travel of the plunger and depressing the exhaust valve.

The EMD valve bridge machine that is the topic of this paper is a second generation machine. The first generation machine is still operational and works in conjunction with the later machine. The first machine was completed in 1984. This machine does not have the material handling system but did establish the testing method both machines use.

A few words about the test procedure are appropriate. This testing method does not attempt to measure leakage by the lash adjusters, as called for in the traditional EMD specifications. Instead, the machine counts the strokes it can make against the lash adjusters over a given time period. Early in the design of this machine, tests were made to correlate the number of strokes in this time period to the EMD specification of minimum and maximum leak down times from the engine manual. On this machine, if the number of strokes during the time period is too low, the valve bridge fails the test. If the number of strokes exceeds a maximum, the valve bridge fails the test. This method of testing is field proven on tens of thousands of valve bridges which have been in service since the mid 1980s.

It should be noted that the lash adjusters themselves are not rebuilt at the Chattanooga Assembly Shop. They are treated as a vendor item and are purchased new from suppliers. All lash adjusters are tested for leakage by the vendors prior to shipment. Lash adjusters come in three different sizes based on outside diameter. Valve bridge bodies are gauged in the socket where the lash adjuster will be inserted and matched up with one of the three sizes of lash adjusters.

Let's take a look at the operation

of this EMD valve bridge machine. To begin with, valve bridges are brought from the parts washing machine for qualification and assembly. Valve bridges are visually inspected and gauged across the rocker arm guide ears. Spring seats are replaced as necessary. Clean valve bridge bodies are then turned upside down and placed on the chain conveyor of the second generation machine. Once placed on the conveyor, the two socket holes of each valve bridge body are measured with an inside micrometer providing an electronic readout. Based on this measurement, one of three sizes of lash adjusters is selected. A slight interference fit is desirable between the lash adjuater and the valve bridge. Excessive interference may cause the plunger of the lash adjuster to bind.

With a lash adjuster of the appropriate outside diameter, the valve bridge assembly progresses on the conveyor towards the "grabber". The grabber closes to grip a valve bridge assembly and lifts it off the conveyor. The grabber then moves the valve bridge assembly to one of two test stations at opposite ends of the work bench. As the grabber approaches the test station, a sliding platform moves out from under the test apparatus to receive the valve bridge assembly.

Once the inverted valve bridge assembly has been set on the sliding platform, the platform slides back under the test apparatus. At this point a hydraulic fluid called Exxon Univolt is pumped into the valve bridge body from the underside. The fluid should purge most, if not all, air from the valve bridge body. Next the Modicom 884 programmable logic controller begins the test cycle. The two pistons on each side of the test stations are driven alternately by both a low pressure hydraulic fluid and a high pressure hydraulic fluid. This two pressure hydraulic system, located beneath the machines bench, is completely separate from the Exxon Univolt oil pumped through the valve bridge. Initially each of the two pistons presses down on its respective lash adjuster driven by the low pressure hydraulic fluid. Then a second stroke takes place where each piston is driven by high pressure fluid. Transducers measure the distance traveled by each piston as an input to the programmable controller. For the valve bridge assembly to successfully pass this portion of the test, there must be some differences in piston travel between the low and high pressure strokes.

Next the test station begins a work cycle for the purpose of break-in. This cycle lasts 15 seconds. During this time period any remaining air in the passages of the valve bridge assembly should be pumped out. Then the programmable logic controller operates solenoid valves to switch the pistons back to the low pressure hydraulic fluid for the test cycle. During the test cycle, the programmable controller counts the strokes of both pistons of the test station over a given time period. If the number of strokes falls within prescribed limits, the lash adjuster passes the test. The programmable controller stores in memory which lash adjusters pass and fail. The sliding table of the test stand then offers the valve bridge to the grabber. The grabber then retrieves the tested valve bridge assembly and returns it ot one of the places on the conveyor. The programmable controller remembers if either or both lash adjusters on this particular valve bridge passed the test.

The grabber itself is a hydraulically operated mechanism. A cylinder opens and closes the jaws of the grabber to pick up or release the valve bridge assembly when gripped around the spring. The grabber then

moves across the back of the work bench when a ball screw is driven by a hydraulic motor. An encoder at the end of the ball screw counts revolutions as an input for positioning the grabber. Several steps are taken to enhance accuracy of positioning. The temperature of the hydraulic fluid driving the ball screw is regulated by an electric heater and a heat exchanger. A proximity switch along the path of the grabber mechanism establishes a home point as a referrence to eliminate accumulative error from positioning.

Once tested, the grabber returns the valve bridge assembly to the conveyor. The conveyor is constructed on the side of a link chain moving across the top of the machine. The conveyor will hold 113 valve bridge assemblies. Special little platforms mounted on the chain were machined from aluminum. The shape of the platform conforms to the valve bridge body for adequate support. Sprockets guide the chain conveyor through curves and nylatron ways guide the valve bridges in the straight sections. Beneath the work bench, an air motor drives the conveyor on command from the programmable controller.

As a tested valve bridge completes its return loop on the conveyor it passes over a proximity switch. At this time a display tells the operator if one or both lash adjusters on this bridge passed the test. Three zones indicate the test of both lash adjusters was successful. An indication of one, zero, zero indicates the left adjuster failed. A zero, zero, one display indicates the right lash adjuster failed. A one, zero, one would indicate both lash adjusters failed the test.

When any lash adjuster fails the test, the operator takes the valve bridge and removes the failed lasher adjuster. A special fixture on the adjacent first generation machine pulls the failed lash adjuster out of the body and deposits it in a bin below. Another lash adjuster is then inserted and the valve bridge is tested again on the first generation machine. The first generation machine is also controlled by a programmable controller and the test criteria are the same. Upon completion of the second test, a light indicates whether each of the two lash adjusters passed or failed the test. Very few valve bridges fail a second test. All the time this is going on, the adjacent second generation machine continues the uninterrupted testing of valve bridges.

The operator's console of this second generation machine is relatively simple since the programmable controller does most of the decision making other than measuring. For safety's sake, an emergency stop button is available to shut down the machine.

Production of valve bridges is about 160 per eight hours. The majority of these completed valve bridge assemblies are loaded onto a specially designed cart. These valve bridges are delivered to a nearby area where they are placed on completed power assemblies. A smaller number of valve bridges are shipped to running repair shops as replacement parts.

II.
GE TRACTION MOTOR ROLLER SUSPENSION BEARING REPLACEMENT EQUIPMENT AND PROCEDURE

Introduction

The single biggest advance in traction motor support bearings is the rolling element suspension bearing. The GE752AH traction motor with its rolling element suspension bearings is beginning to find its way onto North American railroads, including Canadian National, BC Rail, Conrail, Southern Pacific, and Santa Fe. This is not a new concept though, since a similar design which is the forerunner of the current roller suspension bearing was introduced in 1974 on Amtrak and in 1976 in Taiwan.

Although we will concentrate on the special tools used for wheel assembly procedures and setting lateral end play, let's first note some of the differences between the rolling element suspension bearing and the sleeve bearing.

The rolling element suspension bearings are encased in a bearing housing commonly referred to as a U-tube. The traction motor which clamps on to this "U" tube assembly (also known as a motor suspension unit) can be replaced without affecting the bearing assembly or adjustment. Since the bearings are completely enclosed in this assembly, they are protected from dirt and water even when the motor has been removed.

There are basic differences between the sleeve bearing and rolling element bearing. The sleeve bearing:

- is simple, occupies least volume;
- requires periodic inspection of oil reservoir and wick;
- requires critical axle finish;
- is more susceptible to contamination.

Whereas, the rolling element bearing:

- has higher initial overall cost for bearings and U-tube;
- eliminates wicks which require periodic cleaning;
- eliminates need for critical axle finish;
- is less susceptible to environmental contamination (water and dirt in oil and on wicks).

Special Tools

A wheel press is required that is capable of providing a controlled spike of 5 to 10 tons, after the wheel meets the U-tube assembly. This can be done on some machines manually where this spike is left totally to the feel and expertise of the operator. Ideally, though, this spike can be controlled hydraulically with electronic feedback loops. Depending on the press that the shop proposes to use, a modification package recently developed at GE may be adapted to that machine.

The wheel press cart is specially designed to suppport the motor suspension unit (MSU) and to center the axle to the press rams.

Wheel Assembly Procedure For Motor Suspension Unit

1. Following assembly of motor suspension unit (MSU) with gear and axle, transfer unit to a wheel press station.
2. Using an overhead crane, lift assembly and set on wheel press cart which centers the axle to the press rams.
3. Lift wheel guide tool with an overhead jib hoist and slide it over commutator end of axle. This tool helps to center up the wheel as it is pressed on the wheel seat.
4. Position guide tool on gear end of axle.
5. Lift first wheel with an overhead jib hoist and wipe inside diameter of wheel fit and hub face with a clean rag. Apply mounting compound to ID of wheel seat.
6. Move wheel over into position on commutator end of axle, carefully aligning it over guide tool.

7. Lift second wheel with an overhead jib hoist and wipe ID of wheel bore and hub face with a clean rag. Apply mounting compound to ID of wheel bore.
8. Move wheel over into position on gear end of axle, carefully aligning it over guide tool.
9. Move cart with wheels, axle, and MSU assembly into position in wheel press.
10. Initially using ram move commutator end wheel into position on axle until it registers on shoulder of wheel fit.
11. Lift cylindrical pressing tool with an overhead crane and position it over axle, registering on wheel hub face. This tool helps to keep even pressure on the outside hub face during pressing operation.
12. Press on the commutator end wheel at 110 to 155 tons with an additional five to ten ton spike to assure that the commutator end collar and the commutator end bearing cone are solidly seated. Remove cylindrical pressing tool and set aside.
13. Move wheel into position on gear and (pinion end) of axle, until it registers against axle fit shoulder.
14. Press on wheel to gage.
15. Move cart with assembly from wheel press.
16. Remove wheel set from press cart with an overhead crane and set assembly aside on floor.

Setting Lateral End Play In The Axle Bearings

1. Following assembly of wheels, move wheel, axle & MSU assembly to lateral checking fixture station. Fixture registers on motor MSU.
2. Remove the split "master" spacer by applying two jack-out bolts on the side away from the motor to remove the first 180 degree master shim (.095"). Immediately replace with spacer (.090") Remove the two jack-out bolts and apply the two jack-out bolts on the motor side. Remove the second 180 degree master shim and replace it with the second spacer. Replace and torque bearing cap bolts 76 to 85 ft.-lbs.
3. Assemble a magnetic base indicator on the "U" tube bolting surface adjacent to wheel opposite gear end. Register indicator tip against inside wheel face.
4. Fixture has two air cylinders at each end with rollers that can be actuated to register against wheel rim. Fixture also has a drive motor that registers on the OD of wheel, opposite gear end. Wheels are rotated and axle can be shifted back and forth to assure that the bearings are properly seated.
5. Rotate wheels and move axle to one end with air cylinders, set indicator to zero and shift axle to opposite end with air cylinders. Read indicator to determine lateral end play. Repeat above operation to verify repeatability of indicator readings.
6. Alternate method — utilize the pry bar process. Determine the lateral end play in the axle bearings as the "U" tube is rotated back and forth to assure that the bearings are properly seated. Repeat this process three to four times to verify repeatability of indicator readings.
7. If the mounted end play setting

is .001 inch to .007 inch, pump specified amounts of grease (D50E22 - Gulfcrown EP#2) into the cavities while the axle is being rotated:

Commutator End - 26 oz.
Pinion End - 43 oz.

8. Assemble two pipe plugs at each end of "U" tube and assembly is complete.
9. Lift wheel, axle, and MSU assembly out of fixture with an overhead crane and set unit aside on floor.

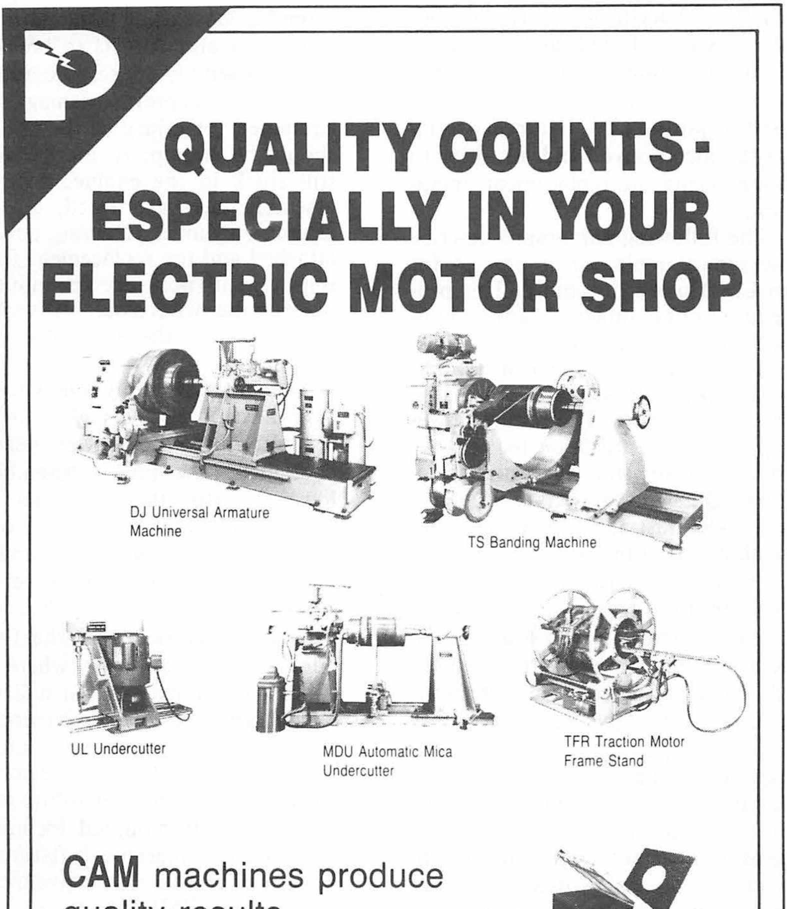
III. LOCOMOTIVE COMPONENT REPLACEMENT FORKLIFT ATTACHMENT

When a western based railroad asked one of its locomotive running repair facilities to perform the simple task of replacing EMD power assemblies, it turned out to be imposible because there was no crane coverage available at the shop. The location did not have a portable crane and if one were purchased, it could not operate in the shop because of the close track centers. In the absence of the overhead or mobile cranes, it was impossible to perform EMD power assembly or other locomotive component replacements using an "Iron Hand" or other material handling devices. The installation of new overhead cranes was considered cost prohibitive, while jib cranes would provide only limited coverage.

The solution to this problem was provided by one of the employees working at this facility. Using available materials and hydraulic systems obtained from farm implements, he constructed a fixture that could be mounted on any forklift of 6,000 lbs. or more capacity. This fixture taps into and runs directly off the forklift's hydraulic power system. The resultant machine is now being successfully used on a daily basis to perform EMD power assembly and component replacements at this locomotive repair facility.

The original fixture was tested, modified, and refined by mechanical engineers. Subsequent improvements were made in construction materials, bearing surfaces, and hydraulic components. The finished product has hydraulic cylinders or motors to accomplish all directions of machine movement. These directions include: mast traverse across the skid, mast rotation, boom up and down, boom retraction and extension and swivel plate extraction and extension. The control valves are mounted in a block configuration. The movements are defined on a diagram and the control handles and cylinders are color coded to match axis movement. The valves are adjustable to compensate for flow and pressure differences encountered in various forklift hydraulic systems. A pressure relief valve is also installed in the system to protect the fixture and the operator. A torque limiter is installed on the hydraulic motor to protect the ball screw drive mechanism from damage.

The use of this forklift mounted locomotive component replacement fixture is a relatively simple operation. The device is mounted on its own skid and all necessary attachments and hoses required for operation are mounted or placed directly on the skid. The skid has channels specifically constructed to accept the lifting lines of any forklift. There are two requirements that the forklift to be used with this machine must meet. It must have a rated capacity of 6,000 lbs. or greater at 24-in. load centers, and it must be equipped with an optional hydraulic side shifting mast carriage. The 6,000 lb. capacity is necessary to safely handle the fixture with an attached EMD power assembly at the heights


QUALITY COUNTS-
ESPECIALLY IN YOUR
ELECTRIC MOTOR SHOP
DJ Universal Armature Machine
TS Banding Machine
UL Undercutter
MDU Automatic Mica Undercutter
TFR Traction Motor Frame Stand
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necessary for removal. The power side shaft is required for two reasons. First, it provides a source of power for the replacement fixture. Second, after the forklift and the fixture have been positioned adjacent to the locomotive, the power side shift is used to position the fixture correctly on the locomotive handrails prior to commencing the replacement operation.

The following paragraphs describe the typical replacement process for an EMD power assembly. This procedure will be similar for any component that is changed using this fixture. To use the replacement fixture, it is picked up with the designated modified forklift. The fixture power supply hoses are attached to the forklift power side shift mechanism hoses. Quick disconnects are supplied to provide fast and simple hose connections. After the hoses are coupled, the machine is placed into the correct position for removal of the power assembly. This position is a location adjacent to the assembly to be removed. The hydraulic mast side shifter is used to accurately place the fixture handrail positioners over the locomotive handrails. The fixture handrail positioners must be placed over the locomotive handrail. The handrail does not support the weight of the fixture but is used as a guide and a method to inhibit lateral movement. Quick release pins are used in the guide to adjust the handrail positioner as necessary to compensate for different handrail heights.

Once the fixture has been positioned, the forklift operator opens the side shaft mechanism valve to supply the machine with hydraulic power. The operator now leaves the forklift and climbs up onto the running board of the locomotive to use the fixture for power assembly removal. As when removing any EMD power assembly, it is first necessary to break the power assembly loose using a standard tool. If the operator forgets to break the power assembly loose, the internal relief valve will prevent damage to the equipment or injury to the operator should he attempt to lift a cylinder still stuck in the engine. After the assembly has been freed, a power assembly cylinder retaining device is attached and the replacement fixture is moved into position. The mounting plate on the swivel assembly is affixed to the head and the power assembly is removed.

The power assembly is now rotated over the handrail and slightly lowered for transport to a power assembly container. The power assembly is lowered into the container and removed from the swivel head of the fixture. A new assembly is now acquired from a container for replacement into the engine. The new assembly is carried with the fixture back to the locomotive where it is again positioned for installation. When fixture positioning is complete, the assembly is placed back into the engine and the fixture is removed, cleaned, and stored for future use.

The forklift mounted locomotive component replacement fixture has proven to be a safe, effective method of removing EMD power assemblies and locomotive components such as water pumps, aftercoolers, starters, and governors. It provides an excellent alternative for performing this type of work where there is no crane coverage. Even at facilities where cranes are available, this fixture provides an alternative when cranes are performing other tasks.

In summary, this fixture offers an economic alternative to the purchase of new cranes.

IV. LOCOMOTIVE SANDING, FUELING, AND DROP TABLES

Sanding

Locomotive sanding systems generally encompass two operations.

The first is the handling of sand to be placed into storage for later use in the locomotives.

The second operation is sand distribution — removing the sand from storage and transferring it to the locomotive sand box.

Sand handling is generally the most troublesome operation, especially in older facilities where sand elevating drums are gravity-fed from a hopper car. In such facilities, the sand is usually blown into a trackside tower for distribution to the locomotives. Old elevating drums lack the ability to control the speed of the sand as it moves through the delivery piping. In recent years it has been recognized that controlling the speed of the sand can greatly reduce the pipe wear. Doubling the speed at which the sand travels has the effect of quadrupling the wear rate. An ideal speed for sand to travel through a pipe is about 400 fpm. At this speed the sand will continue to move through a piping system; in some cases, a slower speed can stall the sand. Today's sand transporters have controls which can assure the proper material speed. The older elevating drums use a timer to control the material flow. The time is set based on how long it takes to move a drumful of sand through a pipe system at a given pressure (approximately 90 psi). The speed of material is not a consideration because pressurized air and sand are present throughout the pipe when elevating sand.

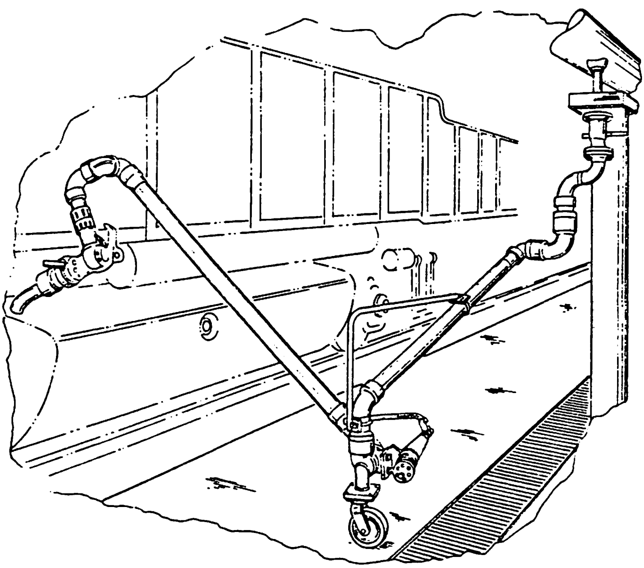
Most modern sand systems send a smaller slug of sand through the pipe. The slug is pushed by a controlled air supply at low volume and low pressure. This method of conveying is known as dense phase.

When large volumes of air at any pressure are used to move sand, this is known as dilute phase. In dilute phase, the speed of material transfer is high, but so is the pipe wear.

In recent years, railroads have contracted to have sand delivered by truck and blown into storage, usually directly into the trackside tower. The obvious advantage is that the maintenance of the sand handling equipment belongs to others. Disadvantages are that you will pay for a full 25 tons of sand whether or not your tower can hold that much. The truck delivers sand at dilute phase and requires a 4-in. fill pipe to the tower. The truck uses a blower which can generate 650 cfm at 15 psi. This air is blown into the truck, and sand is gravity fed from the truck's hoppers to be picked up by the passing air.

With such a system, the air-to-sand volume is great. The air entering the tower must be filtered and vented. The air-to-cloth ratio is dictated by the EPA and/or the local health authorities. Therefore, to meet the requirements, a large dust filter must be used, generally of about 1,500 cfm capacity. The material transfer has a sand blasting effect and high pipe and elbow wear occur. One manufacturer of cast iron elbows makes a vortice elbow which outlasts the piping than 3 to 1, when used in this application.

Each railroad has its own preference for a particular type of sanding equipment. There are sanding cranes, trackside towers, pressurized trackside sand pots, conveyors, single and multiple towers, and other arrangements. When selecting a sand system, consultation with the vendors will help determine the system most suitable for your requirements.



Fueling

Three years ago, the A. T. Moeller Corp. was asked to look at improving the fueling at an existing facility. This facility had an overhead fueling manifold which was equipped with several 15-ft. hose drops located on 19-ft. centers. The problem with the existing fueling arrangement was that the hoses were cumbersome and had potential for physical injury. The goal was to design a device that would eliminate the physical effort and yet be as effective as the hoses.

A device was developed which replaced the existing fuel hose. A fuel loading arm was designed to have the same reach as the hose and yet eliminate the strain of handling heavy hose.

The only option prior to this fuel loading arm was to place the manifold underground and install fueling cranes. The installation of cranes in this instance would have been disruptive and costly.

The retrofit fuel loading arm consists of a primary tube attached to the existing manifold outlets via swivels and a secondary aluminum arm attached to the fueling nozzle. The primary and secondary arms are joined via a swivel joint on a support carriage assembly. The secondary arm is counterbalanced by a torsion spring assembly to carry the load of the secondary arm and nozzle.

The fuel loading arm rotates 360 deg. from the swivel connection at the manifold. The secondary arm rotates 360 deg. from the connection at the support carriage, thus permitting the arm to be extended straight out in any direction.

The retrofit fuel loading arm has been in successful operation at several facilities. A complete facility can be retrofitted in one shift.

Drop Tables

Various types of drop tables are in use today.

The most popular machine uses mechanical jacks to raise and lower the wheel set. Other units in operation use hydraulics and some very old units use a braided belt which travels up and down by belt movement.

The capacity of a single wheel set drop table is determined by the axle load rating of the locomotive being worked on. Today's drop tables are sized to the capacity of modern traction motors, for a total capacity of 100,000 lbs. This capacity is required only when the drop table raises into the wheel set to be removed. After the wheel set is lowered a few inches, the load reduces to that of the wheel set with traction motor, approximately 13,000 lbs. When fitting a wheel set into a locomotive, it is necessary to progress slowly, but once free, a higher speed will reduce cycle time. The older drop tables hoist and lower at 2 fpm throughout their cycle. These machines use machine screw jacks which, due to the level of friction, are inefficient and require greater power. They are not capable of high speed operation.

One major problem with older style drop tables is that the jack screws and nuts self-destruct when contaminated by the debris falling into drop table pits.

A recent development in drop tables addresses this and other problems. A brief list of improvements includes:

a. Covered screws;
b. Two-speed hoisting 2 or 14 fpm;
c. Pre-programmed automatic hoisting and lowering;
d. Automatic track positioning.

The jacks are physically positioned to protect from falling debris and emply a continuous cover that keeps contaminants off the jacks. Ball screw jacks are rated for inch life. They do not wear out. They fatigue when at the end of their inch life cycles. A drop table with four 3-in. ball screw jacks used to change out 2,000 motors per year has a life expectancy of approximately 50 years.

Ball screw jacks are efficient and can be run at high speeds. With a machine designed for two-speed hoisting, the fast speed is 14 fpm with a slow speed of 2 fpm. The primary purpose of hoisting fast is to reduce the hoisting time required when changing a wheel set. This machine employs a programmed logic controller which can be programmed for various hoisting functions. A programmable AC inverter allows for deceleration of the rack drive for precise positioning at the center line of the tracks.

A drop table equipped with machine screws that are properly protected from contamination will have a much longer lifespan.

A major flaw in many drop table designs is that the release areas (where wheel sets are exchanged on the drop table top) are not provided with a means for locking the top at that location. The problem lies in lowering replacement wheel set on the drop table top. Every hard placement causes a shock load which transmits to the jack screw thrust bearings, which affects the bearing life. All new facilities should be equipped with locking bar pockets at the release area.

V.
HAZARDOUS WASTE DISPOSAL

The decade of the 1990s has been characterizes as the "environmental decade" for the United States. New and potentially costly environmental regulations, such as those governing the percentage of liquid to solid in our waste stream, are being implemented.

For example, recent changes to regulations covering the handling of used oil filters in the state of California are causing a review of how oil filters are handled. Disposal costs have increased dramatically. Environmental concerns regarding clean water are dictating immediate change.

Operating in California, Union Pacific Railroad is one of the carriers which are addressing some of these issues. At two of its maintenance shops, machines have been installed for crushing used oil filters. Two goals have been set. First is waste minimization to reduce the cube, thus saving on disposal costs. Second is to reduce oil going into landfills and develop resource recovery programs.

Many maintenance shops in the past have placed used filters on end to allow oil to drip out of them. At the end of a ten to 14 day period, filters were placed in a waste receptacle and hauled to the local landfill.

Procedures such as this are being changed. Some state regulations now consider used oil as a hazardous waste. The possibility of heavy metals in the oil and filters requires new methods of disposal.

A primary concern is for seepage into the fresh water table at the maintenance facility. Regulators check for hazardous waste materials being transferred into streams and rivers through rainfall runoff. One maintenance shop reports that it installs plastic tarps under work and storage areas as a preventive measure.

In some states used oil filters are classified as hazardous waste and may only be disposed of in certain types of landfills. In California, designated landfills are long distances from locomotive maintenance shops. Because hazardous waste is not allowed to leak onto highways, the California Highway patrol requires inspection and certification of containers that transport used filters. Such containers are expensive to purchase and costly to keep certified. At present, there are only a limited number of licensed haulers in this business.

Many landfills charge disposal fees based on the type and volume of waste. One large manufacturer of compactors has recognized this problem and is working to develop machines to reduce oil content and cube size of waste lube oil filters.

The standard machine consists of electric over hydraulic power unit. A 15 horsepower, three-phase motor generates 57,7000 lbs. of packing force. Oil filters are placed in the charge box area. The machine cycles and pushes the filters up a restricted "S" shaped collar. On the collar are two spring adjustable cylinders that operate a restrictor inside the "S" curve. Compaction occurs when filters are compressed against each other. Oil removed during compaction drips through special openings in the ram face and floor of the charge box. This oil then flows into a fifty gallon holding tank under the machine. A special pump then allows the oil to be removed from the tank for shipping to a recycler.

The compacted filters are collected in a roll dump hopper as they fall from the compactor. When the hopper is full, a forklift is used to transport and place the filters into a hazardous waste container.

Because compaction causes a 75% reduction in the volume of disposed filters, an attractive return on investment is quickly achieved.

Marathon Equipment Co. has two new models of compactors on the market. In an effort to increase oil flow from used filters, modifications were made to earlier machines. The floor and side walls of the compactor are now made with special heavy duty bar gratings that have 1/8-in. gaps the full length of the compaction chamber. The restrictor blade is now operated by computer, based on a preset restriction pressure.

A new model is available which precrushes filters in the charge box area. As costs escalate to dispose of filters, this machine will probably be the only one available. At present, it is an expensive machine, but as more information develops on future disposal liabilities, this machine becomes increasingly attractive.

All of us are searching for better and more efficient ways to operate. Costs are escalating even as we strive to be competitive. At the same time, we must provide environmentally responsible solutions for the waste byproducts of our industry. With proper planning and equipment, refuse is a controllable expense.

THE CHICAGO RAILROAD MECHANICAL ASSOCIATION
THE CHICAGO RAILROAD DIESEL CLUB
THE CHICAGO RAILROAD CAR ASSOCIATION

The Chicago Railroad Mechanical Association would like to introduce you to our organization. The Association exists ''For Exchange of Ideas on Railroad Locomotives and Cars'' which forms the basis for meetings that provide an excellent opportunity to learn of new product offerings and maintenance procedures as well as becoming better acquainted with others in the railroad industry.

The Association has 110 sustaining member companies and 600 individual members. Meetings are held on the SECOND MONDAY evening of each month during September through April with an additional ''SPRING DINNER DANCE'' on the FIRST FRIDAY EVENING OF May and a ''GOLF OUTING'' the FIRST FRIDAY of June. The meetings are located at the Union League Club of Chicago at 65 West Jackson Blvd., in the Chicago Loop. Meetings are generally sponsored by one of our member Companies who then make a short presentation on a topic of current interest. Plenty of time is available for shop talk amongst the members.

Sustaining membership dues are $120.00 per year plus $30.00 for each individual from your company. Supply members are assessed $30.00 for dinner and refreshments for each individual attending a meeting.

If you have never been a member of our Club or Clubs and would like to see what we are about first hand, just contact our Secretary, Don Brooks (708-258-9660), and we will be happy to provide you with complimentary tickets for one of our meetings. We'll look forward to seeing you at the next meeting where you will find a friendly informal atmosphere in which to learn more about the railroad industry and its people.

The Board of Directors
The Chicago Railroad
Mechanical Association

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

Wednesday, September 19, 1990
8:30 A.M.

Pre-Convention Presentation Chicago. RR Mech. Assn.

April 9, 1990 Union League Club Chicago, IL

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PERSONAL HISTORY

C. Douglas Corbin

Mr. Corbin was born in N. Kansas City, MO on June 3, 1958. He attended elementary school in Omaha, NE; junior high school in Naperville, IL and high school in Atlanta, GA. Mr. Corbin graduated from the Georgia Institute of Technology in 1980 with a Bachelor's degree in mechanical engineering.

Doug began his railroad career in Atlanta, that same year as a management trainee in the Mechanical department for the Southern Railway System. He traveled around the system spending time training at various locations until October of 1982 when he was promoted to general foreman at the Chattanooga Diesel Shop. In 1987 Doug became assistant superintendent of the Norfolk Southern's System Assembly Shop in Chattanooga, TN. Recently, in early 1990, Doug was transferred to Bellevue, OH as the senior general foreman of Norfolk Southern's Bellevue Locomotive Shop.

Doug and his wife, Ana, have been married nine years and have boy-girl twins three years old. The children keep Doug and Ana very busy and have given great joy to their growing family.

I.
CATERPILLAR POWER IN REMANUFACTURED LOCOMOTIVES

Caterpillar engines have been installed in locomotives since the late 1930's. Worldwide there are over 2100 Cat powered locomotives producing between 350 and 4000 thp. This discussion will concentrate on the 3500 family of engines, a V8, V12, and V16 engines. What is required in an installation? Why Caterpillar power and what are the notable differences with the OEM engines in locomotives?

Caterpillar worked with the Norfolk Southern in 1983 to put the 3512 engine in the first North American locomotive, NS TC10 #100, a remanufactured GP9. After producing three in the railroad shops, two units were done outside at Republic Locomotive Works and the GE Apparatus Shop Cleveland. Other locomotives that have followed along behind the pioneers. In each case both Caterpillar and the remanufacturers, including Generation II Locomotives, Republic Locomotive, Peoria Locomotive Works, and VMV have been refining and building on what had been learned in prior units.

The important lesson that has been learned from the 1960's and the 70's experience is that for the Cat powered locomotive to be able to achieve its potential of availability and reliability, the engine packages must be installed into fully remanufactured locomotives with upgraded and modernized systems. The goal is that all componentry be new or 100% remanufactured. This goes a long way towards ensuring a durable, reliable, serviceable, locomotive. Caterpillar has been working with the remanufacturers to come up with a standardized package for all, with common systems among the three sizes and a well engineered interface to the locomotive systems.

It takes a technology transfer from Cat along with the learning curve of experience for remanufacturers to properly interface the microprocessor based PEEC (Programmable Electronic Engine Control) to the locomotive controls and trainline. A considerable investment of many manhours of stationary and in-train testing under all modes of operation is required to get it right.

Today many hulks start out in poor condition. In many cases equipment has been removed and the frames may be cracked or bent. The unit has to be stripped to the bare frame. The frame is then shot blasted, straightened and reinforced, particularly if it is known to be susceptible to bending.

Mounting pads are prepared to drawing and the package is checked in place for proper alignment and elevation. Most railroads specify the installation of crash blocks. These are welded to the frame, leaving a space for the Cat package to expand thermally.

Because the engine turns at 1800 rpm in notch 8, a new air compressor drive is required. Some have been equipped with a 50 hp Kato AC drive motor with a large flywheel which is bolted directly to a conventional overhauled compressor. Some units have been fitted with a Flottman rotary screw compressor from Germany. The flywheel has to be large enough to keep the compressor running when the voltage dips under fan start-up.

The 3508 V-8 package has an eight-cylinder engine; 3512, a V-12; and 3516 a V-16. As shown in Fig. 1, the packages include the traction alternator, dual auxiliary alternator, couplings, a flexible mounting system, separately packaged safety and engine and excitation control system. These packages put 1000, 1500 and 2100 hp (Fig. 2) respectively into the alternators.

Why sell packages to the remanufacturers?

1) The packages are tested and product supported by Caterpillar.

2) Because the engine is factory mounted on a substantial base which is resiliently mounted to the locomotive frame, flexing of the locomotive frame does not stress the engine and its bearings. Component alignment is maintained and external shock input to the engine components is reduced.

3) Vibration input to the frame and radiated noise are reduced so the package can meet railroad expectations for cab noise levels.

4) The package can be quickly and easily removed and replaced.

5) It is load tested as a complete package using its own PEEC control to ensure performance and efficiency.

6) With a common locomotive interface requirement, PEEC software has now been optimized and standardized.

7) Labor is saved by not having to fabricate new mounts; you just make modifications to the existing EMD mounts.

A. Package weights (See Fig. 3)

Engine weights are nominally less than the original engines, which necessitates reballasting the locomotives. Weight is frequently added to bring the unit up to the amount desired by the specific railroad. Package weights range from 24,000 to 43,00 lbs.

B. Base

The package base is made of deep gusseted I beams connected by multiple thick plate and box section crossmembers. It is designed so all natural frequencies are outside the operating range. The frame is supported by four flexible mount assemblies, one at each corner. The 3516 mount arrangement is custom designed for the application. A pin, connected to the frame, is supported inside a rubber "doughnut". The rear mount is a dual design because of the suspended weight. Mount locations have been selected for even weight distribution while permitting the use of the original EMD mounting pads and holes from a 16 cylinder 645 engine. Only slight modifications are required to the pads.

The 3508 and 3512 frames and mount designs are similar to the 3516 package but use 24 rubber disks in place of the "doughnut" design. Similarly these frame mounts are designed to use the 12 cylinder 645 engine mounting pads. The engine mounting system on the rails is designed to allow for the block thermal growth in width and length.

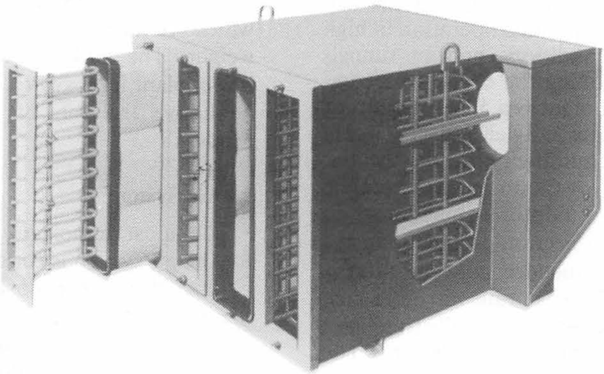
The dual auxiliary alternator is mounted on a rigid platform extension on the front of the package. Pad feet are fitted with vertical and horizontal jacking screws for quick alignment.

The main alternator feet are now being fitted with vertical and horizontal jacking screws which speed up alignment of the two-bearing alternator. The alignment procedure for this alternator is different from the conventional one used today.

Crash blocks and ground body locating bolts are installed to meet the railroad's standards. Adequate clearance needs to be left between the frame and blocks to permit the normal damping action of the mounts. All system connections between the locomotive and engine have to incorporate flexible hoses and ducts to allow for package movement.

C. Engine

The following comments about the



engine systems point up differences from the conventional EMD and GE power that you are familiar with.

1. Cooling System

The cooling system is pressurized up to 7 psi. depending on the cap rating. This permits operation in high ambient conditions and in tunnels without boiling the coolant. Recommended coolant is a 55% solution of low silicilate ethylene glycol which permits shutdown in the winter months. Dowtherm is unacceptable. Corrosion inhibitor is mandatory to avoid heat rejection problems later in life. Recommended concentration is 3% to 6% of borate nitrite, which must be added occasionally to replace that lost through oxidation. The coolant should be replaced every three years. Because of the cost and disposition problems with antifreeze, there are firms that have the equipment to distill off the old coolant and dissolved salts and metals. They return the original antifreeze to you for reuse, which is less costly than buying new.

Plain water with corrosion inhibitor is acceptable for those railroads not wanting to handle antifreeze. Of course it would not allow the unit to be shut down as the temperature gets close to freezing. Typically the antifreeze mixture is saved in drums during major service and then pumped back in.

Another difference is that the fans need to be turned on at higher temperatures. This is because the thermostats only start opening at 180 F and are completely open at 195 F. Up to 180 F the water circulates through the block but does not circulate through the radiators. Therefore fan #1 is set to turn on at approximately 193 F and fan #2 at about 200 F.

Thermostats should be replaced every two to three years.

Most installations have used a modified surge tank from the original locomotive. The Cat engine does not require such a large tank as it is expected the radiators will remain full of coolant most of the time. A 30-gallon tank would be adequate to handle expansion and deaeration, which reduces the size, cost and weight. The tank is fitted with the low coolant level switch which has to be above the top of the cylinder heads.

2. Air System

The most important requirement for the air system is for outside air to be ducted in properly sized ducts to the air cleaners and the engine. This avoids a lack of combustion air caused by excessive pressure drops and high cylinder temperatures which can reduce engine efficiency and shorten life. The maximum restriction allowed on new installation with clean filters in notch 8 loaded is a vacuum of 7 to 10 inches of water.

The smaller 3508 and 12 engines are typically installed with cylindrical factory air cleaners fitted directly to the turbocharger. These seem to last a year if the intake duct is also equipped with fibreglass carbody media. There is a safety element inside the primary filter to protect the engine in case the outer element should get damaged. Air filter elements must be replaced when the restriction reaches 25 to 30 inches of water.

3516 installations have used inertial separators to feed air to the alternator, blowers and engine filters. Most have been fitted with paper media assemblies but one railroad is taking deliver of three units fitted with fibreglass baggies. The 3516 package includes moulded rubber elbows to connect the ductwork to the turbos with minimum restriction.

Cat recommends a latching air restriction indicator be installed across the filter media. This is standard on factory supplied filter arrangements.

3. Lubrication System

The recommended oil is 10W40 or 15W40, CD or CF. The oil change period depends on how hard the locomotive works and the quality or effectiveness of the new oil's additive package.

Oil changes can be based on hours or sampling results. The normal period is 1,000 hours, but branchline service seems to be okay out to 1,500 hours. However, it can be extended only if the oil has not exceeded any of the condemning criteria.

These criteria are based on physical tests and infrared analysis. Briefly, they include:

- — a sputter test for water dilution
- — a litmus test for ethylene glycol
- — a flash test for fuel dilution
- — Infrared analysis to determine whether the oil will exceed 100% of allowable soot, sulphur products and oxidation in the next 92 days; or in other words whether those levels are less than 50% of allowable when tested.

Sump size is 124 gallons on the V-8, increasing to 226 gallons on the 3516. The engines are fitted with an oil cooler that has a bypass valve to prevent damage or oil starvation when the oil is very thick during startups in winter.

Up to now the 3516 has been equipped with an oil prelube pump to supply oil to the main bearings because of the heavy alternator rotor weight. An oil pressure switch is interlocked with the starter to make sure the unit is prelubed before startup. The prelube pump will no longer be fitted as standard with the inclusion of the two-bearing alternator design. However, it will still be available as a custom option.

There is no need for extra oil filtration packages ordered by some railroads other than it might extend the oil change period by increasing the quantity of additive available.

4. Fuel System

The engine has a mechanical fuel pump with an electric fuel pump recommended for purging the lines and filter housing of air after the filters are changed.

Fuel line size must be increased compared to the original installation because the engines depend on circulating fuel flows of two to three times that of the OEM's. The 3516 circulators over 340 gallons per hour. This flow is used to cool the injectors, and inadequate flow can eventually lead to injector seizure. The fuel flow rate is quite dependent on line restriction, so supply and return hoses need to be several sizes larger.

5. Combustion System

Fuel is injected directly into the cylinders by unit injectors which operate as high as 17,400 psi in notch 8. There is no automatic changeout policy on injectors. We recommend that cylinder temperatures be read annually when run on the load bank or self test.

New engine packages are being fitted with K thermocouples in each exhaust port, which allows a test harness with quick connect plugs to be hooked up for monitoring cylinder temperatures. Deviation of more than 100 F from the average of all cylinders could indicate:

- — an injector spray problem
- — incorrect synchronization (too little load), or
- — incorrect injection riming.

Provided the condesation in the fuel tank is not allowed to get into the injectors or dirt to get into the supply lines after the filter, injector life can be up to seven years, which was the case on NS's #100. The injectors were working okay but tip wear had caused the fuel rate and tractive horsepower to increase by about 10% over the seven years.

The recommendation is that units be fitted with fuel line sediment and water traps ahead of the pump. They should have clear bowls to show when they need servicing. These prescreens prevent

- — rapid wear of the pump,
- — plugging of the main fuel filters, and
- — water carryover into the injectors.

There is no soak back turbo pump because the 3516 turbochargers are cooled with both a water and oil supply.

The package does not require mufflers because the turbos do a good job of breaking up the sound. Cab noise has been measured as low as 83 dba in notch 8 loaded but stationary. A rain cap is recommended for the exhaust stack.

Valve clearance needs to be checked and adjusted if necessary at the first 92 days. Afterward it should be checked every 180 days. Valve recession has been minimal on existing units — rarely requiring adjustment.

6. Safety Systems

The package includes a complete safety system with sensors, relays and alarm outputs.

Shutdowns include:

- — Low water level
- — Crankcase overpressure, and
- — Two oil pressure switches, a lower one for the low speed range up to 1150 and a higher setting for the high range above 1150 rpm. Engine speed is monitored and overspeed is prevented by the black monitor module on the right of the safety panel. This box prevents the engine speed from exceeding 114% of notch 8 or 2060 rpm. It cuts off the fuel rack actuator and trips an air dam which shuts off combustion air. The system has to be manually rearmed after it trips.

Remanufacturers include their own annunciator panel to provide system and safety status.

Two power derates are included. A linear water temperature derate will cut back up to 440 hp starting at 210 F through 220F. If the linear derate does not function, there is a step switch derate of 440 hp at 220 F. A linear altitude derate of 300 hp starts at 5,000 ft., continues up through 10,000 ft.

The starters are protected with a moulded cover to meet FRA regulations.

7. Installation Audit

An installation audit of both the mechanical systems, safeties, and electrical performance is a very important step in assuring railroad satisfaction with the finished locomotive. Lessons learned with previous installations have resulted in additional test steps and more detailed installation recommendations. A full audit is required on all new installations and is performed by one or more factory engineers. The goal is to ensure satisfactory engine life and optimum control performance. If any faults are found the remanufacturer has to correct them and retest the system before it can be released to the customer. Final approval and delivery starts the warranty coverage.

D. Electrical System

1. Alternator

All North American installations have used the brushless self-excited Kato alternator which runs at 1800 rpm in notch 8. Typically the V-8 and 12 have been coupled to 700 v alter-

nators for slow speed operation while the 3516's turn a 1250 v alternator. The alternators can produce 6000 amps intermittently which allows the four traction motors to be permenently connected in parallel. The alternator is connected to the engine flywheel with a Cat designed viscous damped rubber element coupling. Alternators being built today incorporate a two-bearing design. The original single bearing design was found to put an excessive load on the back of the engine under certain conditions.

2. Auxiliary Alternator

The dual auxiliary alternator is driven by the 1.33:1 drive at 2400 rpm in notch 8. It is rated at 150 kw at 203 v and 120 Hz. It has a boost circuit to ensure that the air compressor can start when the blowers and fans are operating. The DC generator is rated at 15 kw at 74 v or 200 amps. It is connected to the engine with a Vulkan Tshan flexible coupling with rubber spider drive that reduces gear train wear while absorbing some flexural misalignment.

3. Locomotive PEEC Control System

Caterpillar's PEEC system capability has grown considerably since it was introduced in 1983. Fig. 4 shows the iron necessary for the system. This multiprocessor system monitors engine, alternator, motors, fans, grids and trainline signals and controls engine load, excitation and sanders; and has a built in high adhesion capability.

The block diagram in Fig. 5 shows most of the interconnections. PEEC controls three outputs which are shown in the top of the diagram, a Woodward EG10P actuator to operate the fuel rack, 0-10 amps for alternator excitation and the sander control. Most inputs to PEEC are through potted nonadjustable modules. These modules allow motor current, fan current, grid current, and alternator voltage and current to be read. Fig. 6 shows the six axle version of the wheelslip panel, which allows PEEC to monitor the high and low motor currents while allowing for motor cutout. Engine feedback signals includes a rack position sensor, water temperature sensor and altitude sensor. Locomotive monitoring includes notch code, generator field enable, self test request, dynamic brake level and yard or main line acceleration rate selection. Unique performance parameters for your railroad are programmed in this personality module, which bolts to PEEC.

Originally PEEC was installed on the side of the engine or alternator. Today the PEEC panel is located in the high voltage cabinet which speeds up troubleshooting.

PEEC now has extensive limp home strategies. In many cases it does not even reduce power, deducing component condition from other signals available to it when one signal is lost. Onboard diagnostics, while still less than we would like to see, has evolved into 14 key fault modes. Remanufacturers typically are installing new electrical cabinets for optimum component location. They end up being fairly busy cabinets with all of the conventional relay logic which can make troubleshooting tedious. Several of the remanufacturers now offer offboard CPU systems which can control those systems not operated by PEEC. The illustration shows one typical installation. Remanufacturers have programmed their systems to control:

— Dynamic brake setup and extended range DB contactor control
— Trasnsition contactor control (if fitted for slug cutout)

— Generator field control
— Locomotive contactor logic
— Fan monitoring, control and cycling
— Air compressor monitoring and control, and
— Automatic start-stop control. This last feature is being incorporated on units for one member railroad. Shutdown will occur when the unit has been in neutral after a progammable delay. Restart will occur when the top tank water temperature reaches a programmable level such as 44 F and running until a predetermined level is reached.

In addition remanfacturers offer varying ammounts of performance recording and "snapshot" fault recording capability. At least two of the systems are configured with additional troubleshooting fault free analysis, which combines both PEEC fault annunciation with additional monitored signals and has been proven to reliably permit remanfacturers to troubleshoot over the phone.

A byproduct of the second CPU system is a simplified electrical cabinet which holds sensor modules, terminal strips and a few safety contactors.

E. Performance

There are a number of reasons why railroads have shown interest in Cat engine packages for locomotives. The most important reason is the potential fuel saving. The engine can be shut down year round. Because of the antifreeze, the engine can be shut down in winter for lengthy periods while other engines must remain running to protect the exposed radiators. The engine package is both durable and reliable. The control system and higher amperage alternator allows the elimination of failure-prone vintage circuit boards. Also it provides a cost effective high adhesion control system coupled to the engine control. PEEC software has been adapted for one railroad by modifying acceleration rates and load strategies to eliminate the majority of black smoke during transients between notches particularly in self test. This type of modification can substitute for an air-fuel ratio control and will be examined more in the future to determine the optimum performance tradeoffs to meet potential visual smoke regulations.

Parts and service support for the locomotives are available across North America from Caterpillar dealers working in concert with the remanufacturers. Railroads only need to stock a small quantity of maintenance items because 99% of all parts are available within 48 hours.

1. Fuel Test Summary (See Figs. 7 & 8)

To elaborate on the fuel efficiency of the engine, a head to head fuel test was run in 1989 with a Generation II remanufactured GP20C powered with a 3516 running in consist with a recent railroad-overhauled GP38-2. Trains varied between 2,000 and 4,400 tons and a total of 16 trips were recorded. The test procedure was approved by the railroad research department. Witnesses judged that this very labor intensive test procedure was probably one of the fairest and most accurate field fuel efficiency tests ever run.

Onboard computers monitored notch times and the power produced. Combined with load banking, this ensured optimum performance was maintained on both engines.

2. Load Bank Results (See Fig. 9)

In notch 8 the 3516 produced 3% more tractive horsepower while saving 12+% in fuel or 15 gph. Idle consumption was 56% less and dynamic braking was 61% less than the GP38-2.

3. Overall Test Results (See Fig. 10)

Over six days of operation with 16 trips, the 3516 package saved 21.2% fuel over the GP38-2 which burned 2,380 gallons for nominally the same horsepower hours produced. The tractive horsepower hours per gallon of the 3516 powered unit were more than 25% above those of the GP38-2.

4. Annual Savings (See Fig. 11)

Assuming 330 days per year operation at 20 hours per day, the 3516 would save 35,000 gallons of fuel running at the equivalent test duty cycle. The savings would jump to 47,000 gallons per year if run on the EMD medium duty cycle. Brochures on the 3500 package and the fuel test summary which include additional information are available from Caterpillar.

5. High Adhesion Control

The system regulates both synchronous as well as singleton wheel slips in traction and dynamic braking. Motor wiring recommendations include the capability of sensing and correcting for truck or axle slide while in DB.

Field tests have demonstrated inferred adhesions of between 30-32% on good rail. In one shakedown test with a slug, the pair had an adhesion of only 16%. The slug was found to have leaky conventional axle bearings which were dripping oil onto the wheels and rail head. Even though the slug was in series parallel with the mother unit the control system was still able to obtain 16% which was surprising. The worst axle slip on the slug with oil on the rail head was a random rotation of the slug axles from one to two inches at a time. Adhesion of the RS18 conventional unit with the same leaky slug, it was estimated, would have been in the 0-5% range.

Properly done, Cat powered remanufactured locomotives can provide new-locomotive high adhesion performance with better fuel efficiency in the low and medium horsepower classes at potentially lower cost and improved reliability.

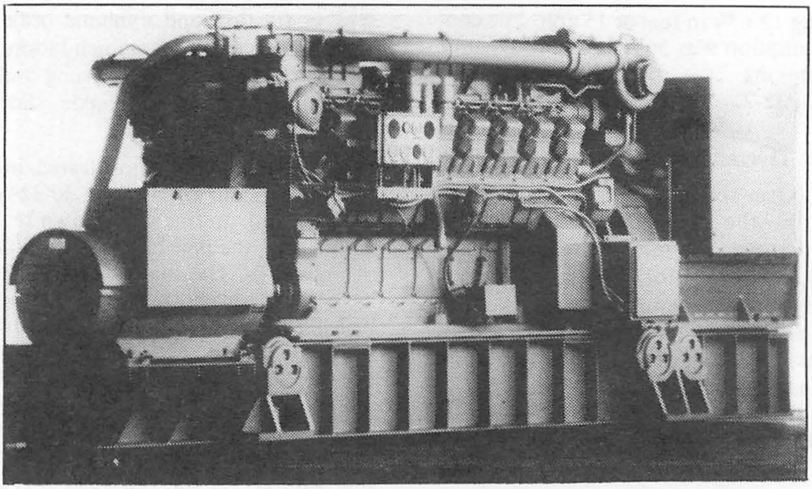


Fig. 1

3500 Family Gross Hp Ratings

at 1800 RPM*

ENGINE	PEEC EQUIPPED		CONVENTIONAL GOVERNOR	
	Mainline	Branchline	Mainline	Branchline
3508 - 8 Cyl.	800	1000	800	975
3512 - 12 Cyl.	1200	1500	1200	1480
3516 - 16 Cyl.	1600	2075	1600	1975

*1300 & 1500 RPM Ratings Available

Fig. 2

Package Weights

ENGINE	ALTERNATOR	AUXILLIARY GENERATOR	BASE	TOTAL
3508 - 10,800	7000 *(700 Volt)*	2500	4000	24,300
3512 - 13,400	7000 *(700 Volt)*	2500	4300	27,200
3516 - 18,600	15,000 *(1250 Volt)*	2500	7000	43,100

Fig. 3

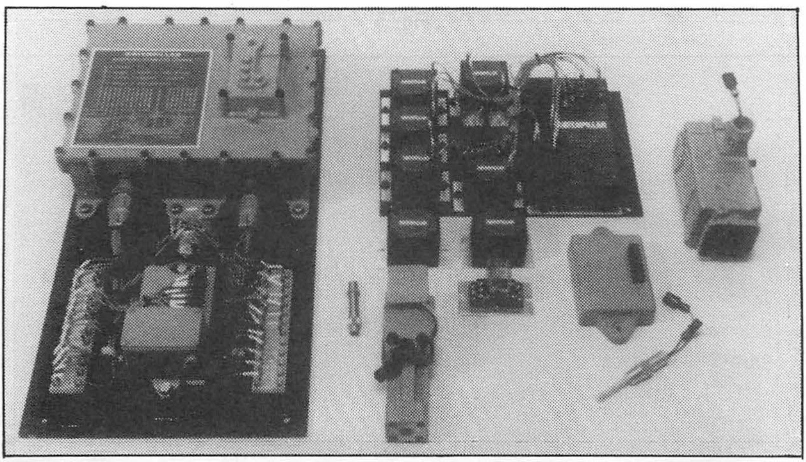
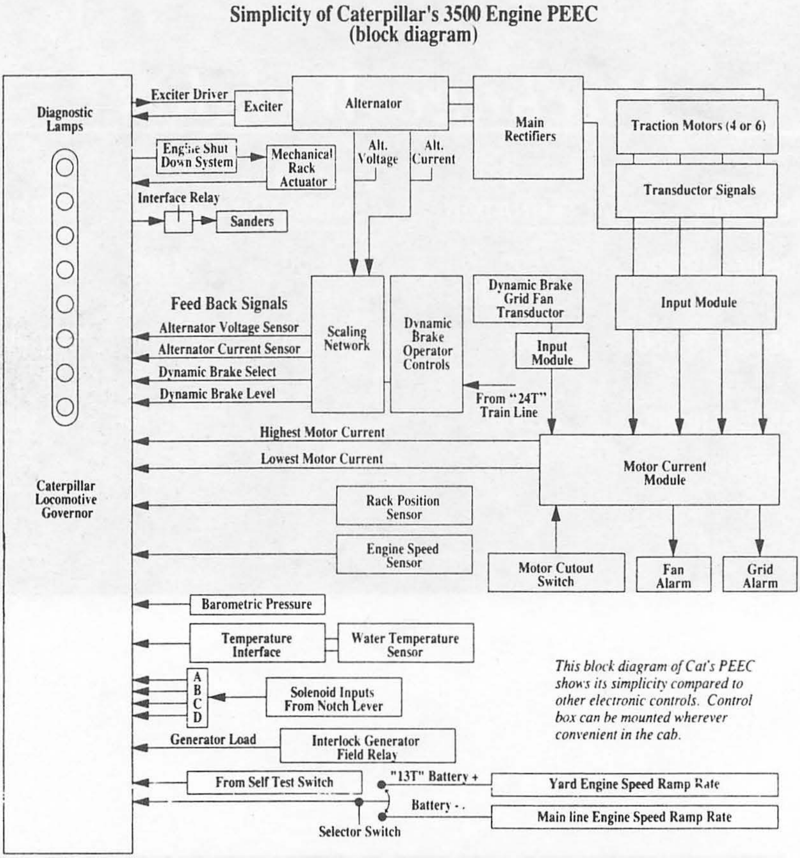


Fig. 4



This block diagram of Cat's PEEC shows its simplicity compared to other electronic controls. Control box can be mounted wherever convenient in the cab.

Fig. 5

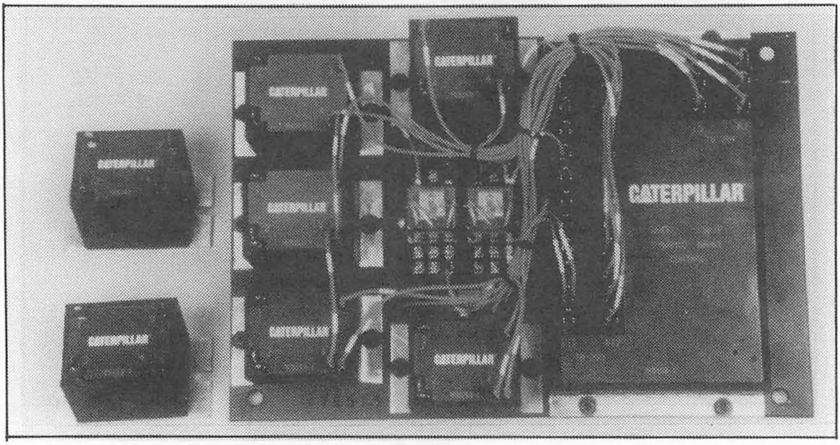


Fig. 6

Fuel Test Summary

3516 Powered GP20C vs. GP38-2 (Rebuilt)

- **Location: Cyprus Mine Track**
  - Babbitt, MN - Silver Bay, MN
- **Tested In Consist - Alternated Positions**
- **Light Train: 2000 Tons**
  Heavy Train: 4400 Tons
- **Trips: 16 Return Trips of 28 miles (or 42 Miles)**
- **Parked Idle At Night**

Fig. 7

Fuel Test Summary

3516 Powered GP20C vs. GP38-2 (Rebuilt)

- **Fuel Source Single Tank Car**
  7.311 lbs/gal @ 60°F
- **All Fuel Pumped Out Of Weighed Barrels**
- **Locomotives Jacked To Same Height Above Unique Fill Spot**
- **Road Performance / kW Hours / Notch Times Recorded On TRACRAIL Onboard Computers**

Fig. 8

Load Bank Results

	3516-GP20C	GP38-2
Notch 8 Performance*	1929 THP	1873 THP
Notch 8 Fuel Rate	104.4 gph	119.2 gph
Idle	2.0 gph	4.5 gph
Dynamic Brake High	5.7 gph	15.5 gph

**To Traction Motors*

Fig. 9

Actual Trip Results

16 Roundtrips of 56 or 84 miles	3516-GP20C	GP38-2	3516 ADVANTAGE SAVINGS	3516 ADVANTAGE %
Fuel Consumed	1,874 gal.	2,379 gal.	505 gal.	-21.2%
Average Gallons per Hour	16.52	20.98	4.46	-21.2%
Tractive Kilowatt-Hours	22,427	22,647	NA	---
Tractive kW-Hours* per Gallon	11,965	9.519	2.45	+25.7%
Tractive Hp-Hours per Gallon	17.074	13.706	3.37	+25.7%

**To Traction Motors*

Fig. 10

Annual Fuel Savings Projection

Based On:
330 Days Operation
20 Hours Operation 4 Hours Parked Idle

DUTY CYCLE	3526-GP20C	Gallons Saved	GP38-2
16 Test Trip / 6 Day Average	130,808 gal.	35,314	166,122 gal.
EMD "Light"	159,011 gal.	36,424	195,435 gal.
EMD "Medium"	247,723 gal.	47,551	295,274 gal.

Fig. 11

II.
THE EMD 710G3A ENGINE

The 16-710G3A engine was introduced in May of 1990 to improve fuel economy and increase engine brake-horsepower to 4100 hp. Several changes were made in the original 710G3 engine to gain fuel efficiency.

A. Aftercooler Changes

The original G3 engine had a standard two-pass aftercooler. The G3A is equipped with a four-pass aftercooler which passes the cooling water through the core four times thereby absorbing more heat from the air. This aftercooler is designed with 16 copper fins per inch which increase the heat conduction rate as well as surface area. The old aftercooler had 11 aluminum fins per inch. Baffles were also added at the top and bottom of the core to prevent air from bypassing around the core. All of these changes have resulted in the air entering the power assemblies being as much as 20 degrees F cooler than with the 710G3 engine, thereby improving the amount of air trapped in the cylinder for combustion.

B. Cylinder Liner Changes

The 710G3A engine uses L11 cylinder liners. This liner is structually identical to the current L10, but ports are redesigned with an 18 degree air swirl pattern. This swirl angle is increased over the G3 engine's 15 degree design. The 18 degree swirl more completely purges exhaust gases from the cylinder by creating an air flow closer to the cylinder wall. By purging these gases we will have a cleaner charge of air for the next cycle. In addition to the above, this liner's port tops are 1/16th of an inch lower in the stroke. This allows a slightly longer power stroke for better engine efficiency.

C. Injector Changes

Airflow has been slightly reduced on the G3A injector tip so as to better atomize the fuel used in the cylinder. A slightly smaller amount of fuel is injected into this cylinder due to the gain in efficiency of the engine overall. Additionally, the pumping element, plunger and bushing are changed to improve injector component commonality across the 710GA engine line.

D. Cooling Fan Changes

The G3A engine is installed in a locomotive with nine-blade cooling fans instead of the eight-blade fans used earlier. More heat absorption at the aftercoolers results in the need to dissipate more heat at the radiators. These fans are still of the two speed design for better cooling control capability. The motor stator has also been improved by the addition of a better varnish treatment to eliminate problems seen earlier in the two speed fan design. This change will eliminate the vibration that caused bars and windings to loosen in the old fan.

E. Engine Timing Change

The 710G3A engine has been returned to top dead center timing from one degree ATC in the 710 G engine to improve fuel efficiency. This change also returns the 710 to the historical TDC timing standard for EMD turbocharged engines, reducing the possibility for shop error during engine timing.

F. Governor Changes

Because of the engine fuel economy improvement and the internal injector change, the governor on the 16-710G3A engine has been balanced at a longer rack setting of .82 inches, versus .78 inches on the 16-710G3.

G. Cylinder Heads

This engine will utilize the tangent flow cylinder head in production models. These heads have revised flow dividers incorporated internally in the casting. These dividers provide more uniform cooling across the fireface of the head. This means less heat distortion difference between the running temperature of the head and the cool non-operating engine. Valves, therefore, have a better chance of sealing under both conditions.

H. Fuel Savings

The 710G3A engine will give an overall fuel savings of 1.5 percent over the 710G3 for the EMD medium rail duty cycle. This is yet another step in EMD's efforts to reach better efficiencies through improvement in engine design. If done at overhaul time, one member road projects the difference between a G3 overhaul and a G3A upgrade could be minimized, if removed parts are reclaimed and reused on non-converted 710G3 engines. Depending on the rebuild practices of the individual railroads, these costs may be higher. You must weigh these costs against the fuel savings to decide if a conversion would be cost effective for your railroad. Future production 710 Engines by EMD will be of the G3A design.

6. Cylinder Cover And Gasket

The cylinder cover is now die cast with locating washers to help center the cover. Some cylinder cover leaks were the result of misalignment between the cover and the jacket. This misalignment allowed the cover seal to make only partial contact with the jacket, thereby permitting oil to seep under the bottom edge. Installation of the cover locator washer will provide correct alignment of the cover and avoid the cover resting against the banjo fuel fitting.

The redesigned cylinder cover features a seal groove designed specifically to hold the silicone seal. The old square neoprene seal became very hard with age, thus allowing for leaks. Also, it was very difficult to remove and clean when applying a new gasket. The new silicone seal presses into place and is easy to remove since it does not harden with age. The soft material allows the gasket to conform to surface irregularities and roughness. The hollow tube design allows greater mechanical compressibility. Finally, the long lasting resilience assures long term sealing.

7. Elimination Of Main Frame Core Plugs

On a 16-cylinder engine, there were nine main frame core plugs at the center of the frame. These have been eliminated by casting a steel pipe in the casing. New core plugs located at the edge of the frame are readily accessible.

8. Eliminating The Air Compressor Drive Shaft

Since the drive shaft from the diesel engine to the air compressor and cooling fan has been eliminated on the Dash 8 locomotive, oil leaks which could occur around the drive shaft have been eliminated. These leaks initiated time consuming repairs so the elimination of the drive shaft was a major accomplishment. An aluminum seal is now used for the crank and enclosure. Also, the side oil drain has been eliminated on the Dash 8 oil pan. The oil drain is now located on the front bottom of the engine. The side oil drain was eliminated because the diesel engine now sits deeper in the deck.

9. Cam Bolt Seals

The cam bolts no longer have rubber sealing washers. A copper washer is now used and it conforms to the frame to make a good solid seal, therefore eliminating the possibility of any rubber seal breaking down and contaminating the lube oil supply.

10. Turbo

Several improvements have been made to the GE turbo to help eliminate leaks. The turbo oil drain now has a Viton gasket which replaced the nitrile gasket. Viton was found to be a much better material than nitrile. The turbo ejector pump and piping were eliminated as was the water discharge header. Instead of three water pipes connecting to the turbo there are now two. The center pipe has been eliminated and replaced by a cover plate.

There is currently an internal air seal passage for the turbo oil seal. The external seal was plugged for fuel economy. The external air came from the compressor in the past. To keep the air compressor from working so hard, this external air supply was eliminated. This helped conserve fuel and also eliminated a potential source of air leaks. There is now a new internal seal air supply passage right in the turbo which supplies adequate seal air at lower notches and idle (Fig. 18).

The turbine end oil flinger is another improvement. The turbine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end oil flinger, or turbine end seal as it is sometime called, prevents oil leakage past the air seal. Previously, oil could leak into the air so this end seal was installed to stop the leakage (Fig. 19).

11. Forward Or Free End Cover

The corner on the engine end cover would leak due to the bolts being spaced too far apart. This situation has been remedied by adding two more bolts to better secure the cover in place.

12. Lube Oil Relief Valve

Another improvement is that the lube oil relief valve is mounted right on the engine. This eliminates joints which are prone to leak.

B. Fuel Leaks

1. Injector Upper Drain Pipe - Eliminate

The injector upper drain pipe (or PEE tube) has been eliminated. This eliminates a source of possible fuel leaks. Fuel is drained from the existing internal hole.

2. Fuel Pump O-ring - Viton

The high pressure fuel pump O-ring is now made of Viton which replaces those made of nitrile. Viton is an excellent seal for fuel oil. The seal has been changed to a larger size and is now square cut to improve sealing, Part No. 115X2525-1. The old nitrile O-ring is still available, so check parts bulletin PB-99 for the proper O-ring.

3. Fuel Filter Housing Seal

The Viton seal replaced a nitrile rubber seal in the fuel filter housing which helps eliminate leaks.

4. Single Piece Banjo Fuel Fitting

The fuel fitting where the two flexible fuel hoses fit into the "T" at the cylinder head has been improved. In the past, there were five joints or connections, now there are three. By eliminating two joints, the possibility of leaks has been reduced and the fitting strengthened and made easier to install.

5. Reduction In Fuel Piping And Fittings

Fuel piping and fittings have been reduced by 30% on the Dash 8 locomotive. A good example of this is the single block regulator/relief/sight glass component. The regulator, relief valve, and sight glass were formerly at three different locations on the engine. By combining them into one unit a considerable amount of piping was eliminated (Fig. 20).

C. Water Leaks

1. Eliminate Head to Liner Seal

The cylinder head-to-liner seal has been eliminated by welding the head and liner together. Portions of the Mechanical Committee's reports for 1988 and 1989 dealt with the design and the rebuilding of the GE EB welded head-to-liner assembly. Please consult those LMOA publications for additional information about this type of power assembly.

2. Different Seals

Seals have been changed in other locations. GE is constantly testing new products and materials for ways to improve its locomotives. As a result of this testing, water discharge seals have been changed to an ethylene propylene material, EPDM. Cylinder head shoulder gaskets have also been improved by replacing Viton gaskets with EPDM gaskets. The intercooler to the forward end cover water seals have been changed from nitrile to EPDM material. This

improved technology will help prevent leakage problems.

3. Fluid Amplifier

The fluid amplifier on the Dash 8 locomotives is a vast improvement over what has been used in the past. A butterfly valve is not used to control the routing of the cooling water which helps reduce the size of the fluid amplifier. Now instead of many bolts and a large gasket, only four bolts and a small gasket are used. Water leaks would sometimes develop around the bolts, but most of these bolts have been eliminated.

D. Conclusion

In conclusion, specific gasket materials are being used in each application for water, fuel and oil leak control. Materials are selected to optimize performance for the fluids being sealed. Also carefully considered is the joint design and whether to use a flat gasket, O-rings or a square seal. The use of cut seals instead of molded seals is another consideration.

In certain cases is has been possible to eliminate a joint altogether, further reducing leakage. Several new materials have been mandated, and GE parts publication PB99 was specifically written to advise the customer of this situation. Gasket kits have been revised to include these latest material changes. GE is field testing a new gasket for lube oil coolers.

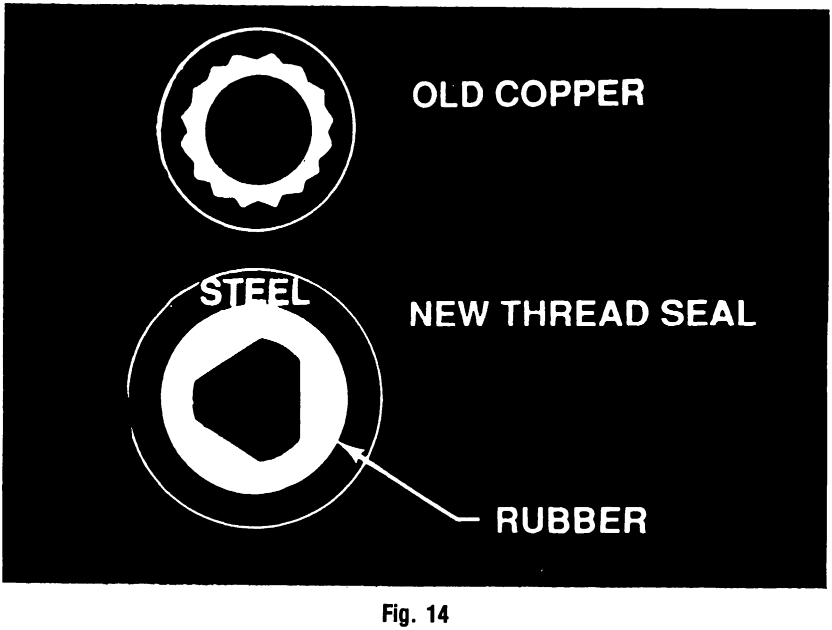

Fig. 14

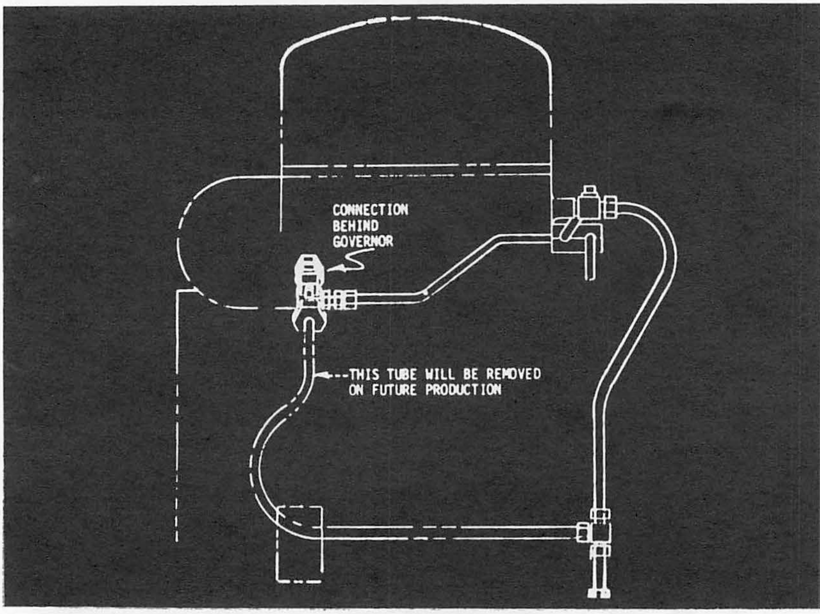
CONNECTION
BEHIND
GOVERNOR
THIS TUBE WILL BE REMOVED
ON FUTURE PRODUCTION

Fig. 15

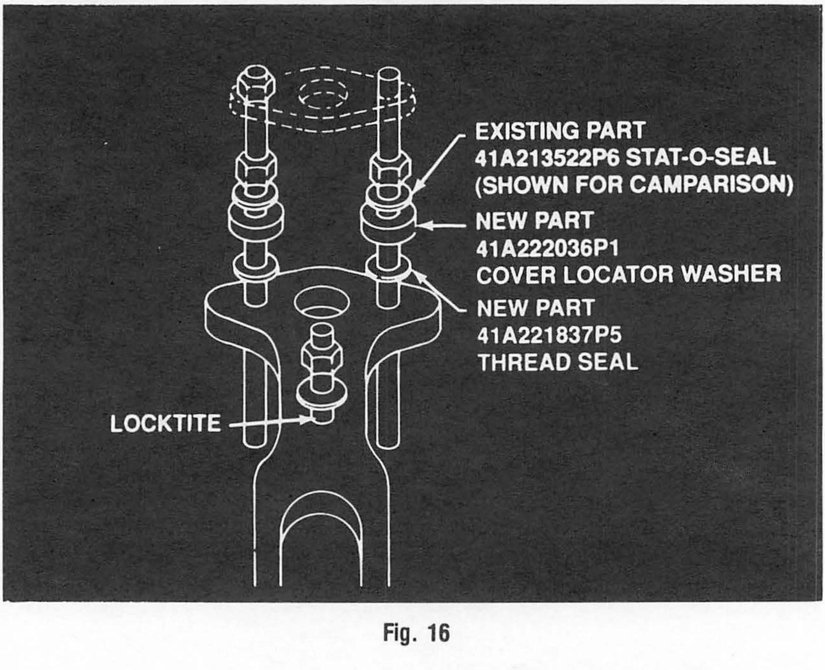
EXISTING PART
41A213522P6 STAT-O-SEAL
(SHOWN FOR CAMPARISON)
NEW PART
41A222036P1
COVER LOCATOR WASHER
NEW PART
41A221837P5
THREAD SEAL
LOCKTITE

Fig. 16

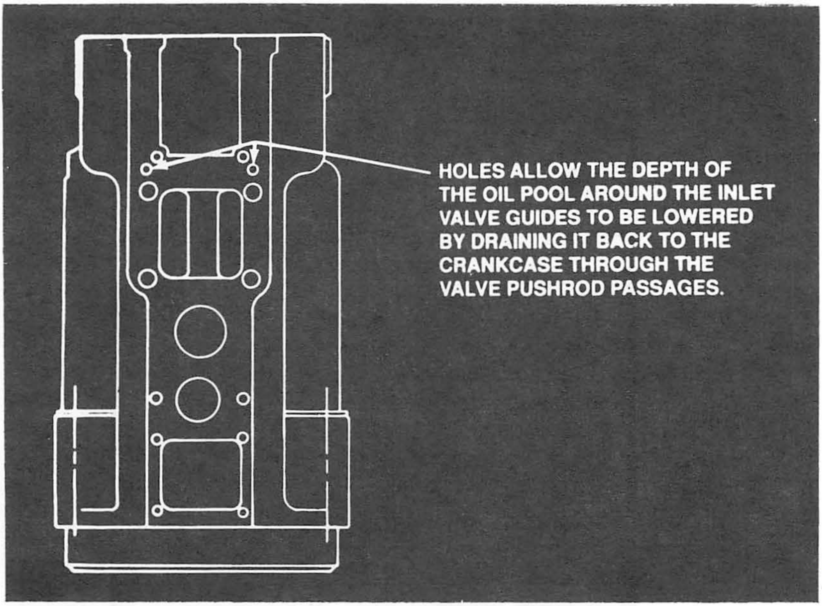
HOLES ALLOW THE DEPTH OF
THE OIL POOL AROUND THE INLET
VALVE GUIDES TO BE LOWERED
BY DRAINING IT BACK TO THE
CRANKCASE THROUGH THE
VALVE PUSHROD PASSAGES.

Fig. 17

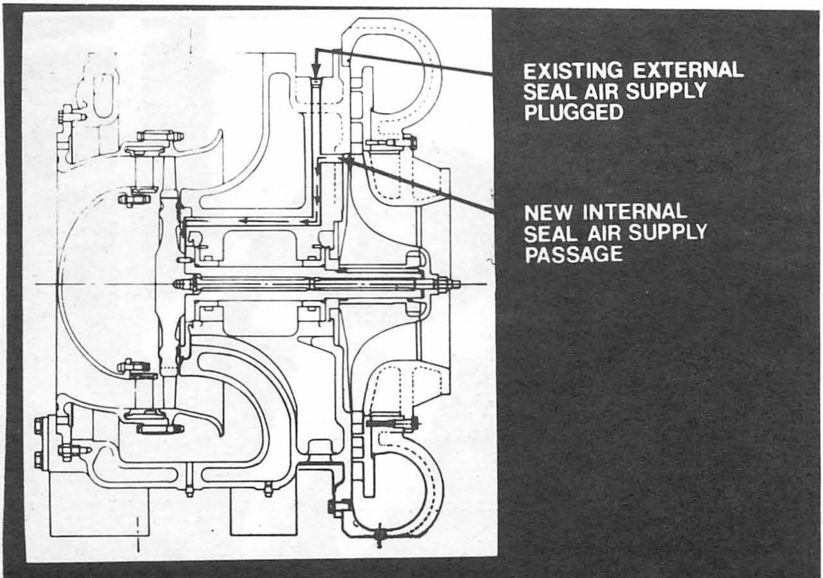
EXISTING EXTERNAL
SEAL AIR SUPPLY
PLUGGED
NEW INTERNAL
SEAL AIR SUPPLY
PASSAGE

Fig. 18

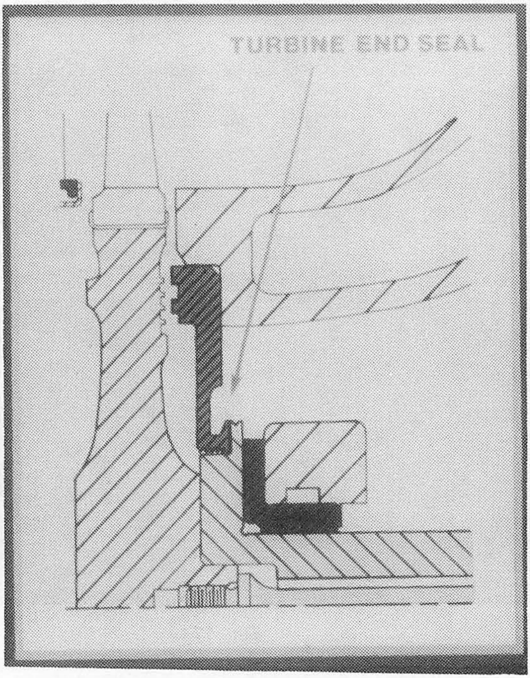

Fig. 19

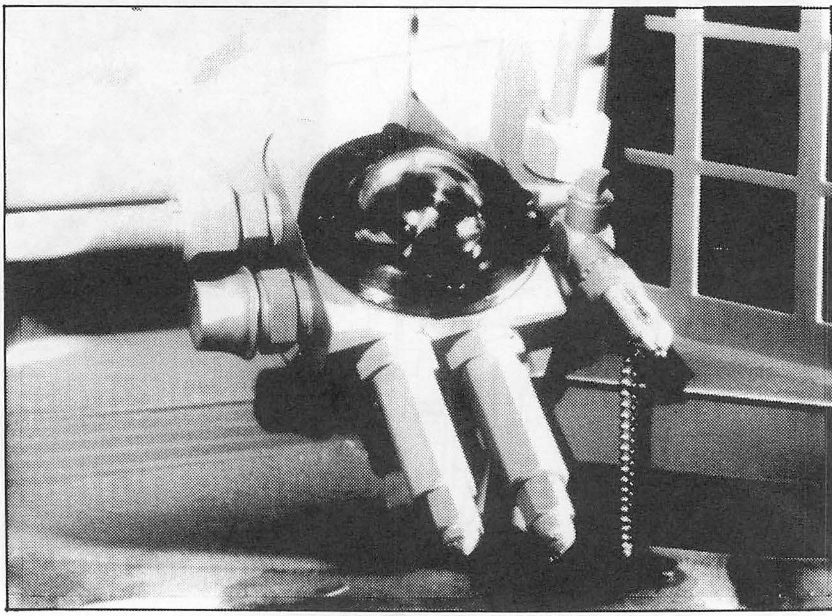

Fig. 20

V.
REBUILD OF THE EMD F3B FUEL INJECTOR

A. Brief history on the difference between the F3B fuel injector and previous EMD injector designs.

1. As EMD fine-tuned its 645F3 engine design in the early 1980's to maximize fuel economy, it begat 645F3A and 645F3B engine generations. Refinements incorporated in these generations included improved turbocharging (creare turbo), modified excitation (LC-113 module), and rebalancing the engine governor from an original balance point of .76 to .78, .80, and eventually .82.
2. These refinements collectively made a slight retarding of fuel injection necessary to reach a maximum fuel economy benefit. Some initial applications of 645F3A engines incorporated a change in engine timing from 0 degrees top dead center, to 2 degrees after top dead center. EMD developed the graduated helix plunger for 645F3A, 645F3B, and other current engine designs to obtain fuel injection retardations and better control of the injection process internally in each injector. Therefore, 645F3A and 645F3B engines equipped with graduated helix injectors are timed at 0 degrees top dead center, in common with previous EMD turbocharged engine designs.

B. Physical differences between the F3B fuel injector and previous EMD injector designs:

1. 1/2" diameter plunger and bushing with transitional helix plunger.
2. Low sac spray tip, for finer combustion, lower smoke, and better combustion.
3. Valve cage reservoir has modified geometry to reduce the phenomenon of "hammering" in high output injectors. The F3B valve cage has a scribed line about its circumference to identify this valve cage from previous designs.

C. Rebuild procedures for injectors in a railroad-operated injector shop

Contents

Injectors returned within the warranty period may not require the complete reconditioning operations that follow. Based on the judgement of the warranty inspectors, it may be possible to use some parts that are normally scrapped, such as the needle valve spring and filters.

1. Disassembly and cleaning

1.1. Disassembly

Disassemble the injector, taking care not to damage any parts.

A. The following parts must be kept together in matched sets:

a. Plunger - bushing assembly - Return to vendor for Utex or re-

coupling end.
3. 645E3A and F3 engines - (.500 inch plunger diameter) - two .010 inch deep by .090 inch wide undercuts, one on each side of the rack control pin.

d. The three different gears may be identified by their difference in diameter.

2.5 Spray tip assembly acceptance inspection

Needle valve type

2.5.1 Identify needle valve design. All non-low sac volume injector tip assemblies are to be replaced by low sac volume tip assemblies. Low sac volume tips may be identified by a 90 degree seat angle on the valve seat and a 0.400 counterbore on the sealing surface end of the tip body. The low sac volume tip is also stamped "L" on the tip end. Also the smaller diameter portion of the neddle valve shank is longer for the low sac volume tip than for the non-low sac design.

2.5.2 After the visual test, all nozzles should be given a slide test. First dip the nozzle assembly in filtered test oil. Holding the nozzle body almost vertically, pull out the needle valve to one third of its engaged length. When released, the valve should slide down to its seat by its own weight.

3. Injector assembly

3.1 In order to facilitate the alignment of all components while torquing at final assembly, rinse injector parts, including any new or reconditioned parts in injector test stand and storage oil. Assemble the filters, filter springs, filter cap gaskets, filter caps and calibration adjustment slide to body assembly. If Detroit Diesel filters are used, be sure to install with the slotted side up. Assemble the calibration adjustment slide so that the gauging face of the slide is flush with the face of the body assembly. Lock slide in this position. **BE SURE** the slide adjusting screw contacts the body before tightening the slide locking screws.

3.2 Clamp body assembly in flushing stand and flush for 15 seconds using specified oil. Injector must be assembled wet. Do not blow parts off.

3.3 Valve opening pressure test

3.3.1 Assemble needle valve, all the stack up parts, seal and nut to test fixture.
Install fixture in injector test stand and connect fuel line after bleeding air from assembly.

3.3.2 With the pressure gauge valve closed, actuate the pump handle with several rapid strokes to cause the valve to function freely. Then actuate the pump handle slowly and observe the opening pressure on the pressure gauge.
The following limits apply:
New & remanufactured injectors - 2800-3400 PSI

While activating pop tester lever at more than one stroke per second, a finely atmoized spray at the tip must result. Rapid closing of the needle valve must produce a sharp "chatter".

3.3.3 If the valve opens without producing a finely atomized spray or the valve seats without producing the sharp "chatter", make several rapid strokes with the pump to dislodge any foreign material from the needle valve seat. If the needle valve fails to function properly, dirt on the seat or a defective seat may be the cause. Mis-alignment can also cause sluggish valve action. To correct mis-alignment, loosen the injector nut and rotate the tip a small amount and repeat Item 3.3.2.

If the valve fails to produce a sharp "chatter" **AND** a finely atomized spray, replace it.

3.3.4 Seat Leakage Test

Operate the hand lever of the nozzle tester until the pointer on the pressure gauge indicates approximately 300 PSI below the actual opening pressure.

The nozzle is considered leakproof it not one drop of oil emerges at the nipple tip within 10 seconds.

3.4 Make certain that the timing mark on the gear tooth is between two timing marks on the rack teeth.

The following torque values apply:

Injector Nuts - 120 ft.-lbs.
Filter Caps - 50 ft.-lbs.

3.4.1 Assemble the injector using whatever new or reconditioned parts are necessary. All remanufactured injectors must have a new low fuel sac volume spray tip assembly.

The seal between the injector body and nut must be lubricated with the test oil to minimize the tendency to twist and shear during assembly and tightening. A Viton seal ring is now commercially available to eliminate the problem of hardening and in-service deterioration.

3.4.2 Apply an identifying code number on the side of the injector body indicating the place of remanufacturing, month and year.

3.4.3 If the injector is not to be tested immediately after assembly, it should have shipping plugs applied and then stored in the proper storage rack.

4. Injector testing

Remanufactured injectors must pass the following tests. Any injector that does not pass the specified tests must be repaired and re-tested.

Equipment - injector test stand (pop tester)

This stand is used to determine:

a) spray and valve chatter
b) freeness of rack movement
c) holding pressure and leakage.

When an injector is installed in the test stand, it must be bled of air by at least ten strokes of the pump before clamping the supply line.

4.1 "Pop" test

4.1.1 Install the injector in the test stand.

4.1.2 Fill the injector with fuel oil and bleed air, but do not connect the fuel line from pump to injector.

4.1.3 Set the injector rack all the way in.

4.1.4 "Pop" the injector with the manual lever, using approximately 40 smooth, even strokes per minute. The needle valve should function the same as required under Item 3.3.3 with regard to spray and chatter. If the valve does not function properly, it could be because of a binding needle due to stack-up tolerance. A partial revolution of the spray tip will usually eliminate the problem. Since dirt can also cause this condition, a vigorous flushing in the "pop" tester will sometimes clear the valve.

4.2 Free rack test

A binding rack can be caused by misalignment due to tolerance stack-ups and can usually be eliminated by loosening the nut and rotating the spray tip.

The rack must move freely and without hesitation over its full range at any position of the injector follower.

This test is especially important in the case of E3B and F3B injectors since the plunger and barrel assembly is less tolerant to clamping distortions.

4.2.1 To be considered satisfactory, the rack must fall its full travel by its own weight when the injector is held horizontally and rotated about its axis

4.2.2 The injector must be installed in the injector test stand, filled with test oil, and have the air bled.

Depress the injector follower with the popping lever to the extent of its full travel and move the rack back and forth through its full travel.

Slowly release the injector follower to its uppermost position while continuously moving the injector rack back and forth. No drag on the injector should be felt at this time.

In practice, the majority of E3B and F3B injectors pass the test requirements of 4.2.1 satisfactorily. However, if the follower is depressed and the plunger is inserted completely in the bushing, the rack binding occurs more often. This condition is one of the leading causes of p&b assembly scoring on the calibrating stand.

This test could be performed in a less operator-dependent way in a specially designed fixture with the injector installed and operated in a horizontal position so that the rack would always move by its own weight at any follower position.

4.3 Holding pressure and leak test

4.3.1 Connect fuel line to injector and apply approximately 50 PSI pressure. Seal ring must be tested for leakage at low pressure (0-50 PSI) due to the fact that at high pressure it will seal and sometimes will not show possible low pressure leakage.

4.3.2 Apply 1800-2000 PSI pressure to the injector. No leakage is permitted at the nut to body seal, filter nut gasket, body plugs, between spray tip and injector nut, or spray tip orifices.

4.3.3 If leakage occurs at the spray tip orifice, reduce the fuel pressure to zero. Disconnect the fuel line, fill injector with fuel, "pop" injector to dislodge any foreign material that may be lodged between the needle valve and body seats and repeat Item 4.3.2.

4.3.4 New or remanufactured injectors should be qualified by limiting the drop from 2000 to 1500 PSI in not less than 30 seconds.

4.4 Injector Calibration

Equipment: Calibrating stand (Bacharach-Yat)

a. The Bacharach stand has a variable speed motor which should be set to run at 900 RPM for standard injectors. Specified oil is used for checking the injectors.
The oil temperature must be between 100 and 105 F and the inlet pressure controlled between 30-35 PSI with the stand running. Before injector output is measured, the injector must be run in the test stand for one test cycle to bring it up to temperature.
Small variations in the manufacture of this equipment result in difference in injector output from the same injector in different calibrating stands. Master injectors should be used to establish the high and low limits for each calibration range. The stands should be checked with the Master injectors of the proper part number each time different part number injectors are tested to be sure that they are maintaining the correct limits.

b. The test oil specified by EMD should be used in the calibrating and injector test stands. This oil has the correct viscosity, (1.78-2.45 centistokes), for the tests to be valid and has rust preventive additives to protect the injectors while they are in storage.

4.4.1 All injectors must be checked and reset as necessary to be within the output limits established for each master injector.
Master injectors are used to establish the output limits for each calibrating stand and to check its repeatability at frequent intervals. Master injector kits are available for each injector range. A kit consists of an injector set at the high limit, an injector set at the low limit, and a storage case.
The rack on the Master injector has been set to give the correct output and then locked and cut off. With normal, careful handling the output should not change for many years of checking unless contaminants are allowed to enter the injector on or off the test stand.

4.4.2 If there is a hard, hydraulic knocking sound, usually intermittent, when the injector is run on the calibrating stand, the flat check valve and/or flat check valve cage should be replaced. If the check valve cage does not have the deeper valve seat reservoir, and does not have an identifying circumferential groove on the outer diameter, discard and replace it with a proper check valve cage.

4.4.3 All standard injectors should be calibrated at 900 RPM if the stand is capable of running at this speed.
Special injectors with smaller orifices should be calibrated only at 800 RPM; 900 RPM operation will induce higher stresses in the

4.4.4 Calibration slide adjustment

Except in rare instances, it will not be necessary to match injector tips to injectors equipped with calibration adjustments in order to meet output specifications. However, all the characteristics governing the fuel output of plunger-bushing assemblies and spray tip assemblies must be closely controlled by the supplier of fuel injection equipment.

Injectors with outputs which cannot be adjusted within specifications will probably require a tip change. To facilitate this, all spray nozzles should be identified according to their fuel output capacity: Low (L), Medium (M), and High (H), as required by EMD's Engineering specifications.

4.4.4.1 Before installing the injector in the calibrating fixture, check the position of the gaging face of the slide. It must be flush with the injector body. If not, adjust it to be flush by loosening the Locking screw and turning the Adjustment screw clockwise to move the slide out, or counter-clockwise to move the slide in. Apply force on the Adjusting screw to be sure it remains in contact with the injector body at all times. Tighten the Lockscrew. Recheck the slide position.

4.4.4.2 Check the injector output. If not within specifications, loosen the Lockscrew and turn the Adjusting screw clockwise to decrease output, or counter-clockwise to increase output. It is not necessary to remove the injector from the calibrator to make this adjustment.

4.4.5 Operate the high and low limit Master injectors for three test cycles each to purge the air in the system and warm up the Master injectors. Thereafter, the averages of five additional test cycles of each Master injector shall be established as output limits of the given injector type for that test stand.

D. Rebuild procedures for injectors in a vendor injector shop

Contents

Injectors received for remanufacturing shall be fully remanufactured, (not requalified), with their components meeting all the visual, dimensional and functional requirements defined herein.

The raw materials out of which the components are made are assumed to be qualified by prior usage and shall not be inspected for material content.

1. Disassembly and cleaning

1.1 Disassembly

Fully disassemble the injector and all sub-assemblies taking care not to damage any of the parts.

The following parts should be scrapped at disassembly:

a. Body to nut seal ring

b. Copper gaskets
c. Filters
d. Needle valve spring
e. Flat check valve
f. Spray tip assembly

1.2 Cleaning

Clean all parts thoroughly of carbon, lacquer and dirt. Use care so that surface finishes and dimensions are not affected.

2. Parts inspection

2.1 Bodies

a. Inspect for burrs, metal slivers, scratches, damaged threads and obstructed passages.
b. Make sure the body and all passages are clean.

2.2 Plunger and bushing

The purpose of initial visual inspection is to separate and reject all the parts which cannot be repaired economically in the processes described in subsequent production steps.
This decision is made on the basis of intimate knowledge of all production steps, as well as the knowledge of, and experience with EMD parts requirements.

2.2.1 Plunger condition classification	**Action**
— Deep abrasions that cannot be corrected effectively	* Reject plunger and bushing
— Deep erosions that cannot be corrected effectively	* Reject plunger and bushing
— Moderately deep abrasions or erosions	* Reject plunger only
— Scoring (seizures)	* Reject plunger and bushing
— Plated or otherwise modified plungers	* Reject plunger only
— Chipped fuel metering edges in operating regions (See ETS 102, paragraph 6.2.)	* Reject plunger only
— Excessive chips or other defects on the plunger shank or head	* Reject plunger only

* The condition of the bushing I.D. is generally a mirror image of its plunger O.D., but to a lesser extent.

2.2.2 Bushing condition classification	Action
— Excessively chipped shoulders	* Reject barrel only
— Excessively damaged face, which cannot be corrected effectively	* Reject barrel only

2.2.3 Parts categorization and disposition

As a part of initial core inspection for visual defects, all EMD p&b's must be separated by part numbers.
According to the results of the visual inspection, record the quantities in the appropriate areas of "P&B Core Initial Inspection" sheet.

2.3 Nut

(See under C, 2.3.)

2.4 Control rack and gear

(See under C, 2.4.)

2.5 Hydraulic stack components

Reject:
- Check valve
- Needle valve spring
- Any check valve cage without the identifying circumferential groove

Save for further remanufacturing; at customer's option:
- Spacer
- New design check valve cage
- Spring cage
- Valve spring seat

2.6 Filter cap

Inspect for cracked or damaged threads, fuel line seats, gasket surfaces and hexagon head condition. Reject any parts that cannot be restored effectively.

2.7 Follower assembly

Inspect for excessive wear at tappet contact, damaged stop pin or spring, gouges, cracks and erosion. Reject any parts that cannot be restored effectively.

2.8 Follower spring

Reject springs which are broken, bent, eroded, collapsed, corroded, cracked or worn.

2.9 Gear retainer

Inspect for scoring, burrs, cracks or other damage. Reject unacceptable parts.

2.10 Spill deflector

Inspect for erosion and damage. Reject any that exhibit either of these conditions.

2.11 Filter springs

Reject if broken, cracked, bent, eroded, corroded or collapsed.

2.12 Nozzle assembly

Reject and replace with new nozzle assembly.

3. Component remanufacturing

3.1 Bodies

Lap the body sealing surface to produce a smooth, even surface. No nicks or scratches are permitted in this area.

3.2 Plunger and bushing

3.2.1 Plunger shank and bushing O.D. must be refinished to produce a uniform visual appearance.

3.2.2 Bushing sealing surface shall be reconditioned in such a way to appear uniform and flat within 3 light bands when checked with the optical flat. It also mush remain square with the bushing axis.

3.2.3 All plunger O.D's and bushing bores must be measured and categorized according to the size of subsequent operations.

3.2.4 All plungers and bushings must have their mating diameters refinished to conform to the same dimensional specifications for size, roundness and taper as new parts.

3.2.5 Specified surface finish and texture must be maintained on mating surfaces of plungers and bushings. This requirement is of special importance for F3B injector application. Due to comparatively higher lateral pressures, (as a result of higher injection pressures), the plunger and bushing surface texture must be such to provide for adequate lubrication of the assembly, thus preventing localized heat build-up and consequent scoring.

3.2.6 All plungers and bushings must be fitted selectively for specified diametral clearance. With the plunger inserted in its bushing, in working position, the clearance must be within specifications for all sections of the assembly. Prior to fitting, all of the parts, as well as the measuring equipment, must be temperature stabilized. Touching or holding the plungers in the area to be measured and fitted should be avoided. Very little heat will expand the plunger enough to alter the gage readings and give inconsistent clearances. One must bear in mind that the total tolerance for diametral clearance is only 30 millionths of an inch.

3.2.7 All p&b assemblies must be subjected to a hydraulic test to confirm their fit to specified clearances. The amount of leakage past the clearance fit must correlate with the predetermined clearance/leakage relationship.

The test is designed also to test for the integrity of the sealing effectiveness of the bushing "shoulder". The test assures the compliance of p&b assembly with the "holding pressure" requirements of Section C, 4.3.4. Strict cleanliness and temperature control are essential for meaningful results of this operation. Precautions outlined in 3.2.6 apply.

3.2.8 Given the various manufacture origins of parts received from the field, it is essential that all the performance related fuel output characteristic be inspected on all assemblies.

The travel of the plunger during which both ports are closed and the injection occurs is known as the "effective stroke" of the plunger. An effective stroke measurement will show the net effect of the dimensions and tolerances presented in Fig. 21 that influence fuel delivery. A specially designed fixture is used to check all parts for effective stroke. Any part found out of specifications must be disassembled and parts rematched to other counterparts.

3.2.9 Prior to part marking and packaging, all parts must be submitted for final visual inspection and plunger freeness test.

The plunger must slide freely of its own weight through the complete length of the bushing when held at an angle of 45 degrees. Plunger free fall is to start with the plunger positioned at sufficent depth so that both helix edges are entered in the bushing inside diameter as presented in Fig. 22.

In any radial position of the plunger, there should be no binding, stickiness or hesitation of movement after the plunger starts its free fall movement. This test must be performed with the plunger in three different radial positions.

3.3 Nut

(See under C, 2.3.)

3.4 Control rack and gear

(See under C, 2.4.)

3.5 Hydraulic stack components

All hydraulic stack components must have opposed sealing surfaces restored by a process capable of maintaining them parallel, and correcting the out-of-parallelism condition as needed. Also the sealing surfaces must be flat within two light bands when checked under monochromatic light. Minimum rebuild height cannot be under new part specifications by more than .001.

a. Spring cage

Sealing surfaces must be completely refinished. Spalling from needle valve contact on used parts must not exceed .001 in depth. Minimum rebuild height must be complied with. No corrosion or damage is permissible.

b. Check valve cage

Sealing surfaces must be completely refinished. Spalling from needle valve spring contact must not exceed .001 in depth. No corrosion or damage is permissible. Minimum rebuild height must be complied with. Fuel duct must have adequate chamber depth.

c. Spacer
Sealing surfaces must be completely refinished. Minimum rebuild height must be complied with.

d. Spring seat
This may be reused after inspection for damage, corrosion or wear.

3.6 Filter cap

All filter caps must have the conical sealing surface refinished to new surface finish specifications.

3.7 Follower assembly

The tappet contact surface must be refinished to remove any imperfections. The follower length measured between the plunger contacting surface and the tappet contacting surface must be maintained within specificationa.

4. Injector assembly

(See under C, 3.)

5. Injector testing

(See under C, 4.)

6. The concept of matched injector rebuild kits

Manufacturers and rebuilders of fuel injection equipment generally develop their part specifications by reverse engineering of original parts. Given the differences between various manufacturers in their manufacturing capabilities, product knowledge and product acceptance criteria based on their various reverse engineering efforts, p&b's do not always reproduce O.E.M. specifications accurately. Consequently, tolerances as well as nominal values of fuel output related characteristics are often out of original equipment specifications.

Remanufacturers receive p&b's of various origins from the field. For the remanufacturing operation to be economically sound, as many as possible p&b's must be refitted, irrespective of their origins to meet clearance specifications.

It is natural that the performance related fuel output characteristics are affected by this mixing and matching of various parts. Even assuming that the nozzle flow capacity meets original specifications, it cannot be expected that one of these p&b assemblies taken at random and assembled with any random nozzle of given capacity would meet the fuel output requirements for the injector in question. This is why the adjustability range of the calibrating slide is not always sufficient to compensate for the disparity of the p&b characteristics.

EMD practice is to calibrate its injectors at the full load setting. Some manufacturers offer matched kits containing high fuel output capacity nozzles and low fuel output p&b's to meet the full load output only; no check is made of the idle fuel output because the manufacturer has never published idle fuel output specifications.

This procedure eliminates all the plunger and bushing assemblies that exceed fuel delivery specifications by a wider than acceptable margin. It also


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assures the user that the required full load fuel output will be produced with the rebuilt injector on the test stand at final assembly and test operation. The effect of such a process is illustrated in Fig. 23.

It must be noted that the reduction in fuel output under full load conditions by a low flow tip (as a result of orifice restriction) is not duplicated at idle operation because of the considerably lower rate of fuel delivery by the plunger and the associated much lower injection pressures. The same effect is true for the high flow nozzles, except that idle output is lower. Therefore, the fuel output at idle reflects more closely the geometric effective stroke whereas the full load effective stroke is modified more or less by the injection pressure conditions.

For these reasons, the compensation obtained at full load with the high and low flow nozzles does not occur at idle. Therefore, this matching practice results in an idle range greater than experienced with the normal calibration practice. When combined with various manufacturers differences in helis angle tolerances, the effective stroke range at idle will be even greater which may become a problem with pending fuel exhaust emissions constraints.

Because the process of matching components for full load fuel delivery has much to offer with respect to efficiency of injector rebuilding, further development work could be done to control the idle fuel delivery.

The effective stroke should be measured both at full load and idle.

Any p&b assembly taken with any random flow capacity nozzle must always produce the required fuel output at full load.

Also, the p&b assemblies should be classified for effective stroke at idle. The range of effective stroke at idle could be divided into three categories - low, medium and high. With those designations, the injector rebuilder would select the kits with p&b's of one idle classification for each engine set of injectors. The matched kit then would give full load full output at the first assembly and test of the injector. It also would give a closer controlled idle fuel output range on the engine for optimum regularity and exhaust emissions.

The value of idle output matching becomes even more important with regard to controlling idle emissions and lube oil dilution and its associated problems with highly charged engines having high turn down ratios, which is the ratio of full load fuel output to idle output.

Control of idle fuel output has been actively pursued within the fuel injection industry since the days of Baldwin-Lima-Hamilton and Alco Locomotive Engines.

With the prospect of tighter environmental controls and in the interest of obtaining peak engine efficiency through all operating ranges, it would be desirable for EMD to specify procedures and limits for fuel output at idle. Such a specification would make the concept of a truly matched injector rebuild kit possible.

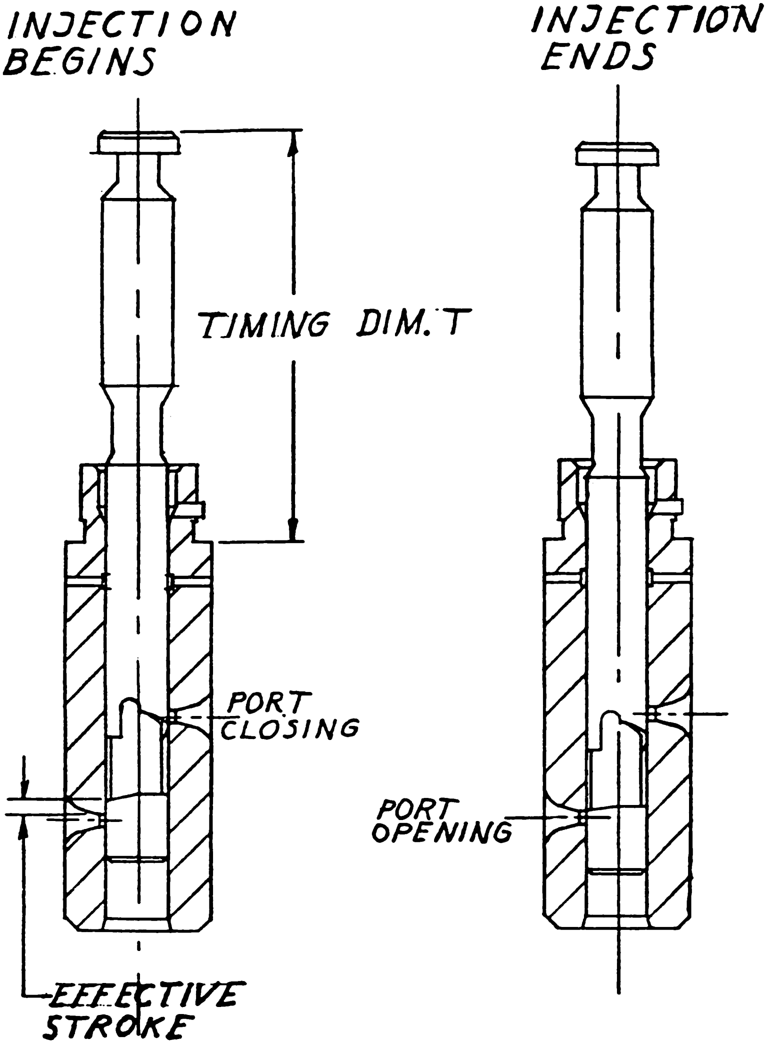
INJECTION BEGINS
INJECTION ENDS
TIMING DIM. T
PORT CLOSING
PORT OPENING
EFFECTIVE STROKE

Fig. 21

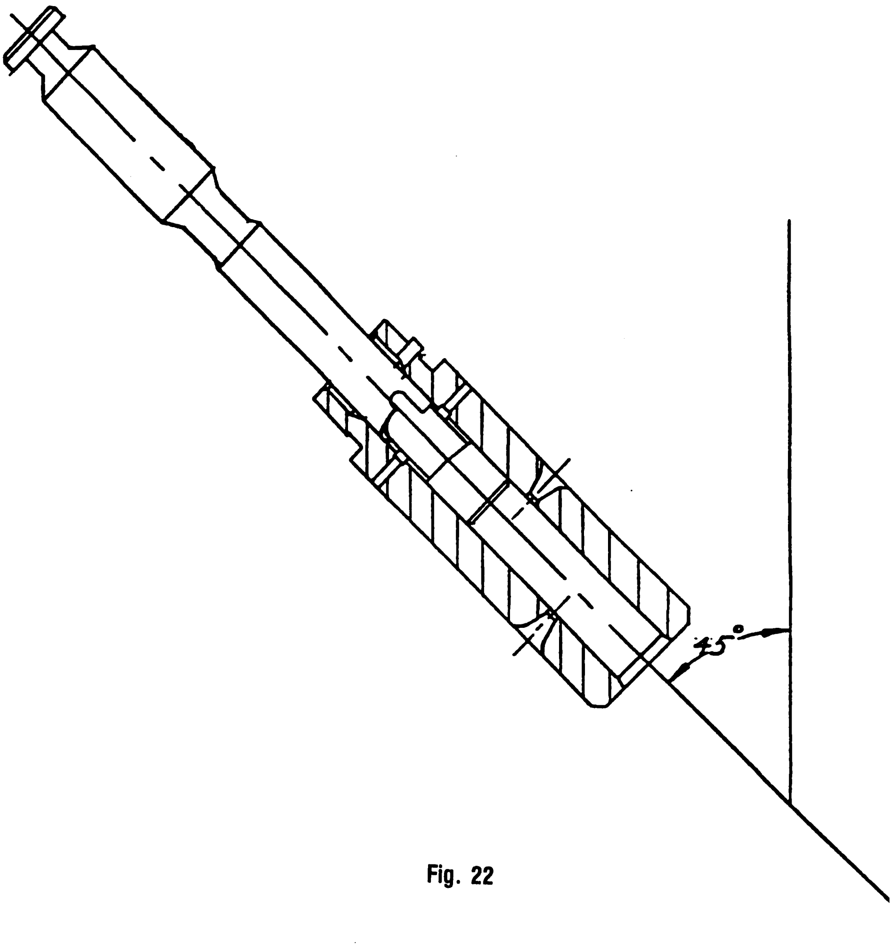

Fig. 22

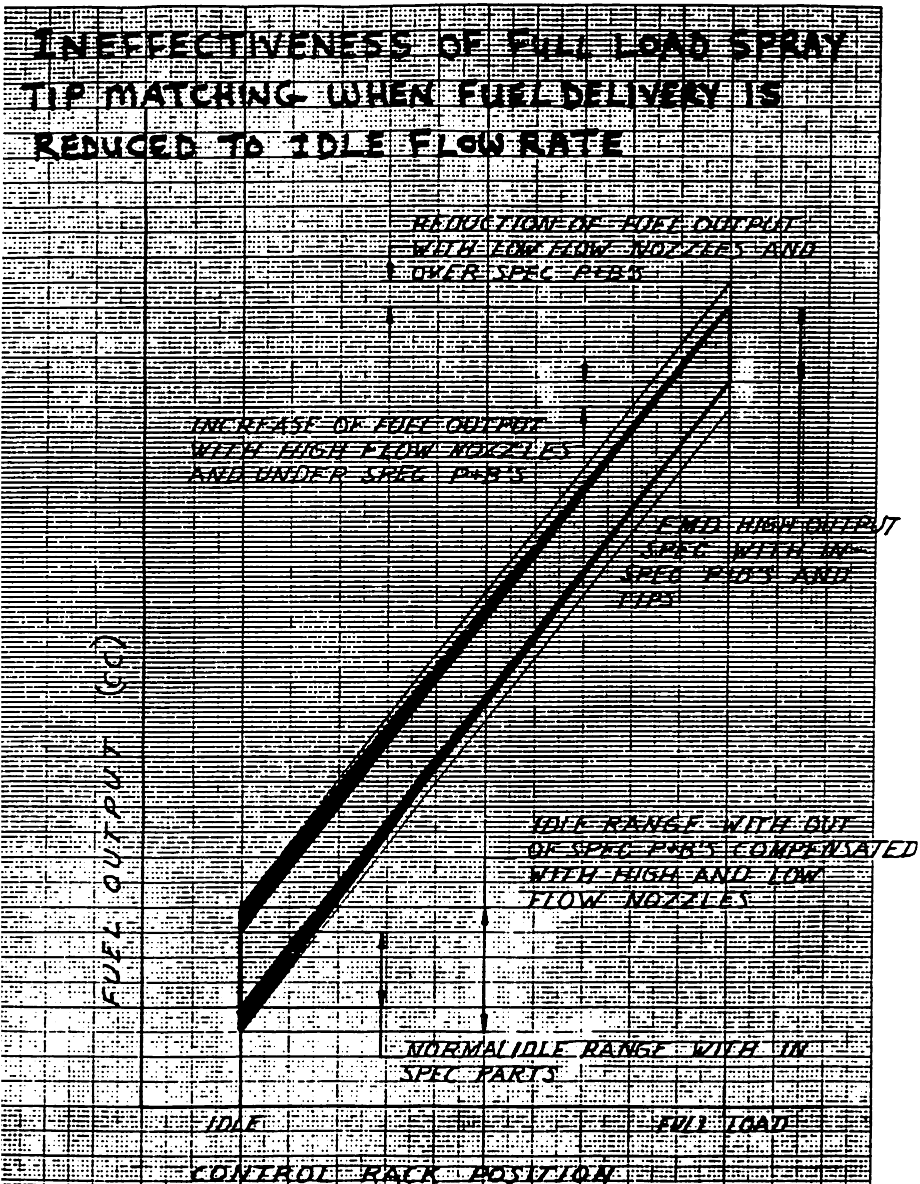
INEFFECTIVENESS OF FULL LOAD SPRAY TIP MATCHING WHEN FUEL DELIVERY IS REDUCED TO IDLE FLOW RATE
REDUCTION OF FUEL OUTPUT WITH LOW FLOW NOZZLES AND OVER SPEC P+B'S
INCREASE OF FUEL OUTPUT WITH HIGH FLOW NOZZLES AND UNDER SPEC P+B'S
END HIGH OUTPUT SPEC WITH IN-SPEC P+B'S AND TIPS
IDLE RANGE WITH OUT OF SPEC P+B'S COMPENSATED WITH HIGH AND LOW FLOW NOZZLES
NORMAL IDLE RANGE WITH IN SPEC PARTS
FUEL OUTPUT (CC)
IDLE
FULL LOAD
CONTROL RACK POSITION

Fig. 23

WHAT'S YOUR PROBLEM PANEL SESSION

MODERATOR: Charles A. Miller, Regional Executive of LMOA, and Manager-Loco. Planning, Standards & Programs-Service Design, Union Pacific Railroad.

Moderator: We'll begin with the questions from the box. Please introduce yourselves when you ask or respond to a question. The first question is directed at the Fuel and Lube Committee.

Question: Do you see any long-term affect from the rail or flange lube that will require environmental clean-up and are these costs, if any, projected in the savings?

Glen Peters - Santa Fe Railway - I don't know if there's any projected clean-up costs from the on-board lubricators, except in the locomotive itself. I do foresee some clean-up problems on the track side lubricators. To the best of my knowledge, none of these economics have been factored into the savings.

Moderator: Before we continue with questions from the box (and there are many), I would like to ask anyone in the audience to come up to the microphone now and present a question or two and when time permits we will go back to the box for other questions. This is your session. The experts are here. The Committee Chairmen are here and the people who wrote the papers are here. So please, introduce yourself.

Moderator: Here's one that was in the box. Our Dash 8 locomotives are having increasing problems with the motor-driven air compressor drive motors failing as a result of locked compressor or single phasing when a contactor fails. All other motors on the Dash 8's are protected thermally and through the computer for excess cycling and locked rotor. The compressor is not so protected. What is GE planning to do to provide compressor motor protection?

John Chessario - General Electric Field Support Specialist - The person asking the question states that this is an increasing problem, however I do not believe this is the case. Our data base indicates only five failures last year between three customers, so out of a fleet of over one thousand we have less than one half of one percent failure rate. The microprocessor protects the motor by logging a fault for excessive cycling and taking the air compressor off line. The air compressor motor also has protection in the form of a speed sensor. If an attempt is made to start the air compressor and no speed is detected within 3 seconds the microprocessor will log a fault and take the air compressor off line. If the engine speed is at 330-440 RPM, a second attempt will be made with the engine speed at 580 RPM or higher. If the motor again fails to start, the computer will log another fault and take the compressor off line. This strategy prevents the motor from running whenever a problem exists with starting the motor, such as a single phase or locked rotor condition, but will still allow the unit to load. If the CDC2 contactor is welded the computer will not only log a fault but also prevent the Auxiliary Alternator from starting to protect the air compressor from overspeeding (since this contactor doubles the motor speed proportional to engine speed). These faults are resettable by the level 1 operator and allow the unit to load. If the operator continues to reset the faults without rectifying the air compressor starting problem he can cause undue damage to the motor.

Moderator: Thank you, John. I hope that the person who wrote the question received the response he was looking for.

Question: We still see lots of 55 gallon drums coming to the railroad with chemicals. Are the vendors getting more responsive to using refillable containers, versus making the railroad get rid of drums at their own expense?

Glen Peters — Santa Fe Railway - Well, in Santa Fe's case, we found most of the vendors were very responsive to providing larger vessels and are more than willing to dispense with the drums. It appears to me that the industry is responding.

Moderator: Any of the suppliers feel that they can tell us what they're doing in that regard? What do we have to look forward to in the future?

Doug Corbin - Norfolk Southern -We've found very little reluctance from the suppliers to use the large containers. Probably the biggest drawback is getting the equipment in place to utilize the containers. Once you've got the material there in them, you've got to set up pumps and stand-by places to keep these containers. In a lot of cases you've got to build a dyke-type system in case this large 500 gallon container ruptures, you've got to have something to catch it. So really the slow part of the process is getting your facility ready to handle these bulk containers and we found very little reluctance on the supplier's part. The slow part is getting yourself ready for it. So you might keep that in mind.

Moderator: Thank you Doug. Any more comments on the containerization and disposal of same?

Question: This question is directed to the New Developments Committee. The electronic fuel gauge is the topic and there's a series of questions. Are any railroads currently using electronic fuel gauges in large numbers? What success or problems are being experienced by those railroads? If successful, is the railroad changing their locomotive fueling schedules or locations? Ben, would you give us a shot at that, please?

Ben Smith - NJT - I personally don't know what the major carriers are doing as far as electronic fuel monitoring equipment. I believe that Amtrak is using some of that equipment on their locomotives that operate over the Transcontinental operation. As from our perspective (the commuter railroads), we basically have a servicing requirement that brings our locomotives across the fuel station, at the maximum, every third day. We use mechanical devices at this point in time. One reason they are not utilized on our railroad is the cost of installation and the initial cost to purchase the equipment. Economics at this point dictate that we (from a commuter perspective) not apply it to our equipment. I'd like to open the floor up and ask some of the major carriers what they do.

Jack Hunt - Illinois Central - We have equipped either two or four of our locomotives with the fuel sensing device. Only one failure was reported so far (a sensor failed). Other than that, they work fine.

Ben Smith - NJT - I'd also like to add that one of the things that we're going to be doing in next year's committee sessions is to look at peripheral equipment that can be incorporated with the micro-processor units on the locomotive and integrating that equipment with the major manufacturers' new series locomotives and seeing if some of that peripheral equipment can't be incorporated in the data base and kept on board the locomotive and

become an integral part of the locomotive cab operating station.

Moderator: Thank you, Ben. Are there any more comments on the electronic fuel gauge?

Question: Should not the thrust of the AAR in the emissions area be to push for a regulation based on ton miles? This would create the fairest competitive environment for land freight.

Moderator: Dick Cataldi, I think this one might be aimed directly at you.

Dick Cataldi - AAR - We're pushing for this approach right now in California (they're meeting today). They will be coming up with a more logical approach, rather than grams per brake horse power hour or specific fuel or equipment modifications. It's easire to talk about it conceptually than to actually put it into practice, though. It will take a long time to put a proposal together for any regulatory agency. If we do get the pre-emption from the Feds on the Clean Air Act, then we'll have more time to contemplate it for EPA. But, yes, I certainly agree that this is the approach we should be taking and it is the approach we're taking.

Moderator: Thank you Dick. Any more on this subject?

Question: On the subject of diesel emissions. How did the FRA develop their acceptable limits and aren't they questionable by virtue of no alignment by other entities?

Bill Harris - Norfolk Southern - I suspect that question is aimed at the FRA worker exposure regulations which state no exhaust emissions are allowed in the locomotive cab. FRA has an informal set of limits which were adopted from OSHA limits. So while it hasn't been formally promulgated, they do rely on the OSHA limits.

Moderator: Are there any other comments?

Question: Here's a question directed towards the locomotive builders. Have any tests been conducted by the OEM's on the impact of multi-viscosity lube oils on turbo charger hydrodynamic bearings and will the lower viscosities support and center the rotating assemblies during start up and at lower operating temperatures? May we have a comment, please?

Dave Scott - Manager of Engine Development - EMD - Our lube oil test procedure (and I'll ask someone from Chevron to make a comment about the discipline with which qualifications of multi-vis lube oils have been undertaken) is to qualify the entire locomotive engine and system for use with whatever candidate oils are under evaluation. Of course, I can only speak with any certainty to the products in the marketplace provided by EMD that are installed on EMD engines. Since we don't supply turbo chargers in all cases, I would say that we don't make any warranty (expressed or implied) about the qualification of that equipment for any lube oil (multi-vis or any other kind). Thank you.

Eli Shamah - Oronite Additives -In all the field testing that we have done with the multigrade oils, covering several million miles, we have not had any turbocharger problems. These tests were carried out in both GE and EMD locomotives in heavy duty service.

The other point I wanted to make is that although a multi-vis oil is thinner than a single grade oil at low temperatures, this is not true at other temperatures. For example, an SAE 20W-40 multi-vis oil is blended to the same viscosity as a single grade SAE 40 oil at 100°C. Multi-vis oil will be

thinner than the single grade oil at temperatures below 100°C, but it will be thicker than the single grade oil at higher temperatures. Current multi-vis oils do not thin down at low temperatures, they actually thicken, but at a lower rate than single grade oils. So even accounting for some shear with multi-vis oils, a properly formulated SAE 20W-40 oil will provide the same bearing lubrication as a single grade SAE 40 oil.

Moderator: Thank you. I hope the answer was suitable for the gentleman who wrote the question.

Question: Again, dedicated to the Fuel & Lube Committee - With the 20W-40 multi-grade oils becoming more accepted is their compatibility problem with the 20W-40 oils from different suppliers who use different additives?

Gene Neuwirth - Shell Additives -We've conducted some studies with the two additive products and the two VI improvers that are currently being used in the marketplace (the Shell package DIVI and the Oronite Texaco DIVI) and have gone from 80% of one to 20% of the other and then reversed the concentration from 20% of one to 80% of the other and have seen no deleterious effects in any laboratory testing that we've done. We've not done it in engines, but we would not suspect that that would be a problem. We've never seen the problem in single grades and wouldn't expect to see it in multi grades.

Moderator: Gene, are there any compatibility problems, studies, etc. with straight weight oils?

Gene Neuwirth - We've done that, as well, without any problems.

Moderator: All right, it's time for you to get up and come to the microphone. Let's have something that's on your mind. Any questions, please?

Brian Brooks: Good morning, my name is Brian Brooks. I'm from V-Line in Australia. I hope you understand me. You might need an interpreter along the line.

Moderator: Thank you for joining us, Brian.

Brian Brooks: I've got three questions. My first question is aimed at the New Developments Committee on heating, ventilating and air conditioning. I'm just wondering if anyone has experience with roof mounted, packaged air-conditioning units in this country. I noticed that there were none shown on the slides.

Ben Smith - NJT - Presently, I know there's two railroads testing these units and both railroads are passenger operations. Presently, New Jersey Transit is testing two prototype roof-mounted cooling systems and so is Amtrak. We showed a slide yesterday of an installation on locomotive 357, which was at one of the Amtrak installations. Presently, the unit that we're testing is a Carrier unit. It's a 30,000 BTU unit, but it operates at 480 volts, three phase, because on our locomotives we have a head-end power package that gives us a constant voltage and frequency output source, which the freight railroads are not really privileged to. HEP provides heating and lighting on our cars. We've had some problems with both units and we've had to take the units off. There was not enough air flow coming out of the units, plus both had some leakage on the recovery drip pan. The unit went back to the manufacturer for servicing and correction. We also have smaller, RV type air conditioning units that run off a similar power source and they seem to be doing

quite well and they're probably less than one-third the BTU output that the larger units are capable of putting out. They do quite well in our electric locomotives.

Brian Brooks - V/Line - We have some experience with roof mounted, packaged air conditioning units. We find them quite good. They are rated at 7 kilowatt capacity. The roof mounted is quite good, because you can do minor repairs on the roof just by entering the lift hatches. We also run some under floor units, but we found that the roof mounted ones are superior in terms of being able to work on them far more readily. Thank you for that.

Brian Brooks - V/Line - My second question is on high adhesion bogies. We currently run 25 EMD locomotives which weigh approximately 124 metric tons. Our ton is 2,200 pounds and I think your ton is 2,000 pounds. These locomotives run three axle bogies which use D-43 traction motors which are among EMD's lightest traction motor. They're used for high speed running, and are basically like a D-87 traction motor using narrower case and thus are a half ton lighter. On the high adhesion bogie, we have a lot of hunting problems, especially at lower speed on tangent track. When we get to curves, everything seems to be okay. The bogies have had this characteristic ever since new. I'm just wondering has anybody experienced problems with the high adhesion bogie with hunting problems and what have they done to correct it?

Ben Smith - NJT - I know in the US industry, as far as high speed opertion, Amtrak did a lot of studies and tests on the corridor operation as well as on parallel routes. One of the things that they recommended was a change in wheel taper; changing from conventional 1 and 20 wheel taper to 1 and 40 wheel taper. Also, they increased periodic maintenance and added dampening shock absorbers. They went to laterals as well as vertical snubbers and also horizontal snubber shocks. I think they're available from EMD on their standard Blomberg trucks. One of the things we did at New Jersey Transit is we took the standard Blomberg M, which has rubber, bolster load pads and we went back to low profile elliptical springs for ride quality. We found that the rubber mounted pads didn't provide the same ride quality that the elliptical Blomberg did in past generation locomotives, and the new low profile elliptical spring operation that we adapted on all our bogies right now seem to be doing quite well and provide a better ride quality and better truck stability. I'd like to open the floor to some of our friends from Amtrak because I know they've done quite a bit of testing and they've worked with us on stability tests on acceptance of our new electric locomotives. Dave, can you help us?

Dave Goehring - Amtrak - I believe the gentleman from Australia was referring to a three axle truck. Essentially, we lost the battle at Amtrak. The particular Hyatt HTC truck that we received on our original SDP40s in the 1970s is no longer acceptable in our high-speed service. That was not so much from hunting as it was from lateral forces that were being imposed on the rail and Amtrak felt this was not acceptable for high-speed service. So Amtrak went to the two-axle truck. We still operate a three-axle, General Electric designed truck in the Northeast corridor, but it's restricted to 85 MPH. So I really can't give you a lot of help from Amtrak's point of view. I know Joe Schmidt was with Amtrak during this period of time. He's sitting (here in

the audience). Possibly Joe has something he'd like to add to this.

Joe Schmidt - Retired - I think Dave really summarized it quite well. On the three-axle truck (SDP40), it was determined that on certain degrees of curvature on certain railroads, the high rail tended to turn over. This was, of course, for passenger train operation completely unacceptable. You freight guys have different standards than we do when we're carrying people. The consequence of these tests were that the SDP40s were remanufactured and they came out as F40PHRs which is using a two-axle truck and is the basis of the current Amtrak F40 locomotive. The General Electric E60 truck situation was somewhat different in that it was found, initially, at high speed qualification runs of 100 MPH literally the locomotive squatted down between the rails, meaning that both rails were displaced laterally. It was one of the most remarkable high speed derailments, I guess, anyone ever experienced. Right, Dave? There was absolutely no damage to equipment and there was no pileup. All they had to do was go out and rebuild the track. The finding was that at high speeds and especially when accelerating, there was high frictional forces between the truck and the frame, so that the buff load was in effect causing the truck to bind. It did not re-center itself when the truck had taken an offset when entering a curve. When you came out of the curve, you were still accelerating. The truck didn't straighten out. And so, finally, by a combination of putting very low friction materials at those wear and rubbing points and also with the expensive addition of yaw dampers and vertical and lateral dampers, the locomotive was able to continue in Amtrak service. But as Dave pointed out already, restricted in high speed operation. And the maintenance of those low-friction surfaces (all teflon coated) became a very big, important maintenance factor for Wilmington to take care of. That's about it.

Joe Slezinger - Train Tronix - To address the gentleman from Australia's problem, I think notwithstanding all that's been said so far, Ben's comments about putting fixes on the trucks are probably what would need to be done. We're talking here now about a locomotive that's the weight of a four-axle American locomotive that's running on six axles, which has different three-axle trucks. Everything is a tuned system where it hunts, so some studies would have to be made and some dampers would have to be applied. That would probably be the best fix, I would think.

Moderator: Thank you, Joe.

Colin Cathan - Via Rail - We're running a fleet of 59 F-40PHs between Montreal and Toronto and we're running them at 95 MPH. Unfortunately, we run them on somebody else's railroad and so there are limitations as to what we can do based on what they will allow us to do to a very large extent. We're running them with 1 in 40 taper and with the locomotives as originally supplied, the CN insists that we turn the wheels every 20,000 miles for stability reasons. What we are doing at the present time, is going through a program of changing out the yaw dampers and with that they're going to allow us 40,000 miles between turning. By way of comparison, the LRC allows us 50,000 miles between turning. Thank you.

Glen Peters — Santa Fe - Back in the mid '70s, the Santa Fe ran a 79 MPH freight operation with SD-45-2s and I do not remember the taper we had on the wheels. But in response to crew complaints for rough riding, we elected to skim the wheels every 92 days. The flanges were nowhere near condemnable, but we found when we took that little bit of curvature out of the taper, the crew complaints disappeared. This might be something you'd want to consider.

Moderator: Thank you, Glen.

Dave Goehring - Amtrak - Glen, I think the Santa Fe was using the zero taper at that time. Amtrak ran locomotive tests in conjunction with your locomotives at that time and I believe Santa Fe was using the zero taper.

Moderator: Thank you, Dave. Brian, I hope this discussion has been of some assistance to you, Incidentally, I must tell you, at this point, Brian, that in our book that goes out at the end of the year, this will be all written down for you.

Moderator: Your next question, sir.

Brian Brooks - V/Line - My last question is that we've been running the D-43 traction motor for approximately four to five years now, and we've been promised that at the end of this year or maybe early next year, we'll have a maintenance instruction for it. My question now is aimed at an EMD representative. There's a rumor currently flying around Australia that EMD is not going to produce maintenance instructions to the old standard. They're not going to be as comprehensive as they have been in the past because of the concern that's around about pirates copying and reproducing EMD items and selling them at a lower price because they don't have to go through all the development and everything. We've found that the MIs that we've received to date have been excellent and have helped us considerably, especially as we're so far from America. I'm just wondering, is that correct? Is it true that the MIs may be less comprehensive in the future. Would anyone like to comment?

Ralph Robinson - General Service Manager - EMD - No it's not true. We still intend to produce MIs. The D-43 traction motor is used extensively in Australia and not too many other locations, and in terms of MIs and being current on MIs, that's one of the ones we haven't had up to date in the way we had wanted to. It is not our intention to limit the information in the MIs in any respect to inhibit our customers from maintaining the components. That's the intent of the MI and we intend to continue doing that. No question.

One comment about your previous question on trucks. I think almost all the responses were addressing high-speed hunting on trucks, and your question was on low-speed hunting problem. High-speed hunting has been an issue and a question that's been addressed in many ways; yaw dampers and profiles and what not have been a key part of that. Your question is a different question that, I think, most of the folks answered. We'll talk to you about that after the meeting here today.

Brian Brooks - Thank you very much.

Question: Here are two questions from the box both regarding GG roller bearings. An abnormal number of Timken class GG roller bearing hotboxes have occurred. What can be done to correct this situation? Maybe someone from Timken can help us with that one or perhaps Brenco would like to respond. The second part of that question can probably be answered by some of the railroads involved. Is there any economic reason to convert from Hyatt boxes to GG bearings? Gentlemen, this is your session.

Glen Peters - Sante Fe - Our big impetus was to take one more recurring maintenance item away from the service pit and that was done by going to GG bearings. There was a significant manpower saving by simply not having to perform inspections.

Dave Goehring - Amtrak - That question may have been submitted by someone from our company who is not present. Amtrak is currently converting several locomotives from the oil box to the cartridge type bearing. We've never had really any defects in the bearings, but we have had locomotives set off because they've tripped hot box detectors and after the inspection is made we found very little wrong with the bearing. I've talked with Timken about this while I was here this week. They claim it's a seal problem and that they have developed a new seal which I am anxiously waiting for. We've had disruption of passenger trains and locomotives set off in the middle of the hills of Wyoming, Colorado, New Mexico and wherever because of tripping hot box detectors. It turns out there's really nothing wrong with the bearings at all. The locmotives are still safe to operate, but railroad policy dictates that they be set off. So it's been a burden to Amtrak and an inconvenience to our passengers to have to deal with this problem.

Moderator: Thank you, Dave.

Question: I'd like to know the current status of the Amtrak F69PH-AC locmotives. Are they still in testing? Are they in service? What's the experience been to date?

Jim Spiegel - EMD - The F69 locomotives are in a revenue service test program. They are presently operating on Amtrak's train to San Francisco and they'll be travelling around the United States over the next 15 to 20 days with our test car, gathering data and also visiting many key cities around the country.

Moderator: Thank you, Jim.

Joe Schmidt - Retired - Amtrak - Would either or both of the builders give us a brief summary of what action they have taken and what investigations are underway at looking at alternative fuels back at their own development (engine development) centers?

Dave Scott - Manager-Engine Development - EMD - EMD has had a number of programs over the last fifteen years to look at some alternative fuels. We've even built a couple of locomotives (a small group of locomotives) capable of running on methanol; those units were shipped overseas. In the United States, the thrust toward alternate fuels took a couple of different passes. One was toward lower cuts of existing distillate fuels or heavy fuels. We also looked at more radical alternatives, for this marketplace at least (liquified or compressed natural gas or methanol or something like neat methanol as a fuel).

We have qualified for other applications use of some heavier grades with more sulphur content and higher viscosities. There hasn't been a significant impact in the locomotive market because generally they're very poor for idle operation and in marine or standby or baseload operations where the ancillary equipment that goes along with handling heavy fuels is capable of being handled. Heavy fuels, for instance, need the same amount of equipment adjacent to the engine as the engine occupies. The centrifuges and heating equipment that go along with heavy fuels are a room the size of the engine room normally in a marine installation. So that

doesn't lend itself very well to mobile equipment like locomotives. The underlying economic force for qualifying or looking deeply into an alternative fuel has not been there. The Burlington Northern has had a very public stance on liquified natural gas and I leave it to them if they wish to make a comment on that. There has to be some economic reason for looking into an alternate fuel. If the Environmental Protection Agency makes an economic reason, then I would say that development programs along that line would have to respond to that set of boundary conditions as soon as they're known. We know that we are going to be regulated and that, in general, the EPA response to a cost-effectiveness criteria and looking at very far afield activities like a radically different alternate fuel generally doesn't respond to that as the first cut of a strategy to limit emissions in an engine activity. They are more relevant when one talks about twenty years down the road in emissions regulations as the trucks are today with their 94 emissions regulations. So we have no fundamentally active alternate fuel programs at EMD, although we have investigated in the past several different alternatives, including natural gas, a dual fuel and methanol.

Moderator: Thank you very much.

Andy Hillhouse - General Electric - Alternative Fuels - We are still looking at them and we're still in our lab working with coal slurries and things of that nature. Our fuel and lube man had to leave early. I don't know all the data on it, but we are looking at alternative fuels all the time.

Moderator: Thank you, Andy.

Joe Schmidt - Retired - Just a follow-up question. It seems apparent, at this point, that EPA is not particularly driven by any economic cost benefit evaluation. If I overstate the case, Dick, correct me.

And so, I really was thinking more in terms of the situation developing out there in California and we can't really wait until we are looking at regulations and then have the builders begin to investigate how to cope with the emissions problem.

I'll ask a very specific question. For example, what are the real difficulties with using a glow plug or a pre-combustion chamber in the engines very similar to what we have today, thinking always in terms of the possibility of retrofit, for example.

Dave Scott - Manager-Engine Development - EMD - You lost me in the dust when you talked about pre-combustion chamber. Generally, the world has moved away from pre-cup engines because they are relatively dirty diesel cycle engines. If you're talking about sustaining combustion for alternative fuels, for instance, natural gas or methanol, those must respond again to an underlying economic question about what is the good strategy for this industry to answer the emissions regulations that are coming.

In California, they don't exist in total isolation from the world. There are political agendas involved and certainly a lot of things hit the press that are public domain about outlaw-diesel fuel in the south coast air quality management district's area or something like that. As we hopefully get federal pre-emption of emission regulations as a feature of the 1990 Clean Air Act, those kind of questions will need to respond to cost benefit.

I'll make an observation here too. In a marketplace with twenty odd thousand existing products and the current production rate produces on the order of about four or five hundred new products a year, the focus isn't going to be on what we produce in LaGrange as a new locomotive to alter the amount of emissions going into the atmosphere in the United States. I mean, you're talking about a retrofit question and what you can do economically to change the tons of oxides of nitrogen and the tons of particulate matter per year.

With respect to the EPA, if things follow pattern, we expect that a rule-making phase of the legislation will ensue as soon as agreement is reached in Washington about the basic features of the legislation. And during the rule-making phase, I would encourage the industry groups and railroads to be active, but constructive in your positions with the Environmental Protection Agency. Because history has shown, I think, that only a positive relationship can be at all productive. General Motors, of course, is an extremely high profile organization when it comes to the Clean Air Act. We have a tremendous amount, as a corporation, at stake in how our relationship goes forward positively. We build in this railroad industry on that kind of experience.

And we have been very active. We sit with the Locomotive Emissions Advisory Committee in Southern California. One of my subordinates is there today. We are a non-voting member on that activity and have overseen a great deal of the preparations of that report, which we believe will come back as a relatively well-reasoned piece of work.

So while alternate fuel activity isn't a high priority at this moment, we have investigated the major alternate fuels in the past and have characterized them and know them as to what they are. And anything beyond that, really has to respond to whatever we're trying to accomplish. There isn't room in this market, fundamentally, to have a lot of extra development programs. The fundamental underlying question is there are not enough locomotives sold in the United States to justify that sort of thing, so we have to be very careful about where we put our resources. And when we understand where we're headed and are participating in a positive relationship with the forces of regulation, we'll see very clearly what strategy will evolve. But I doubt seriously our first strategy will be alternate fuels but that's just my personal opinion. I don't know what the EPA is going to do.

Moderator: Thank you. It seems to me with the price of fuels going up, we, the industry, must push and shove where we have to.

Moderator: Here's a question for the New Developments Committee. Can the recommended availability, reliability and durability methods be duty cycle specific? There was a paper given by the New Developments Committee. Ben, can you help with that, please?

Ben Smith - NJT - I'm going to call on Jim Hogan who presented the paper. Unfortunately, the author of that paper is not present and she's probably the best one to answer that question.

Jim Hogan - Caterpillar - Yesterday afternoon, we went back to our committee and discussed specific recommendations on what availability, durability and reliability should be and try to advise the industry on which way to go. We have to do a lot of committee work on that and I don't think we know today what would be, I guess, an overall view of what railroads would like to see. What we did talk about yesterday in committee is coming up with a survey to the industry and ask for your recommendations. Their procedures could tell us what type of standards would be good for each individual railroad and we'll try to come up with a consensus. We also decided to work with a couple of trade publications and maybe print our paper for the industry to look at it and make recommendations back to members of the New Developments Committee. I think we have to some research before we really know where the industry is going. Thank you.

Moderator: Thank you.

Question: What is the feasibility of retrofitting an electric-driven air compressor on older locomotives?

Luzern Richter - Manager of Traction Systems Development - EMD - It is practical to retrofit an electrically-driven air compressor to the older locomotives? There are a couple of things that you have to consider. One is the power source. If you have locomotives with D-14 companion alternators, for example, the chances are, probably not. You need to do something with that companion alternator to upgrade its power capability. If you have an Amtrak locomotive, for example, and you have a head-end power source, you might consider using that alternative power source for supplying the power. Physically speaking, the electrically-driven air compressor should fit in an EMD locomotive in a similar location to where the current mechanically-driven compressor fits, so space should not be a major issue. The main thing, as I say, would be the power source to drive it and if you have an older locomotive with a D14, you may have a serious problem there depending on what the rest of your auxiliary loads are.

Moderator: Thank you.

Andy Hillhouse - General Electic - Physically, it could fit in just about any unit. From the power source is where the problem would lie as to whether you have the right source to drive the air compressor motor. Basically, I think it's the same as what EMD is saying. Physically, it looks like it would fit.

Tom Leary - Union Pacific - Are you implying though that there's a possibility that a CA5 generator may have enough power capability to drive a motor-driven compressor?

Luzern Richter - EMD - Again, Tom, there is a possibility that the CA5 would work. We would want to very specifically look at the application. I could presume you were looking at SD-40-2s but we would specifically want to work with you, look at application, and then make our recommendation based on what's there now.

Moderator: Thank you. We have time for several questions.

Question: Larry Gilles - Clyde Engineering - I'm a Service Engineer for EMD. I have one question and one answer. My question has to do with what one of my customers read in last year's LMOA minutes concerning an SD50 dynamic brake testing panel. I spoke with somebody yesterday following the Modern Tooling update relative to this panel and was told it got off to a bit of a dropkick start but has since been improved. Has anyone had any experience with it? Does it work? And can you give me the address of the builders because I've written twice to the address in the book and have received no answer.

Moderator: Is the Chairman of the Diesel Electrical Committee, Don Gezon, here. Can he address that for us, please?

Don Gezon — Grand Trunk Western - It's because of those kinds of questions that I have Tom Leary sitting up there for me. He has experience with SD50s. In fact, we had a conversation this morning, but it did not involve a dynamic brake testing panel. So Tom, please try and field this one, if you can.

Tom Leary - Union Pacific - I'm not aware of what type of panel you're talking about. I do know when testing dynamic brakes, the only method to actually test a dynamic brake for functioning is to operate the locomotive under its own motion, above 25 MPH and apply the dynamic brake and see if you get results. Otherwise, stationary type testing is limited only to assuring that the control system functions correctly, shifts the dynamic brake correctly and produces the brake call signals, etcetera and field current. But in actual practice, you must actually move the locomotive to fully test the dynamic brake. I'm not aware of any type of system that short cuts that, but I sure would be interested if somebody does have some way to test dynamic brakes thoroughly without having to move the locomotive.

Mr. Gilles - It's written up in last year's minutes (page 228). Sorry to do that to you. They gave me a little bit of an explanation of what it actually does, but they seem to have gone underground since. The second part of my standup is in defense of when Brian Brooks of V-Line was up here. I happen to be the lucky Service Engineer who is preparing the MI for the D-43 traction motor. And to the best of our ability at Clyde, we'll make the deadline that we've set. But I'm here at pressent and my notes are way back in Australia. Thank you very much for having us here.

Moderator: Thank you.

Question: When diesel exhaust emission in cabs were reported and units tested, were they the same reported units? The second part of the question is as follows: Dismissing watering eyes and breathing problems as transitory or of little consequence, doesn't this belie our knowledge of the insidious effect? I will turn this over to Glen Peters and I will also give you the 47 other cards to go with it when we're done here.

Glen Peters - Sante Fe - Bill Harris left about three minutes ago. As I remember in discussing this with Bill, he took a random sample or a random sample was taken over quite a number of locomotives to get a feel for how this was distributed. The watering eyes and odor problem, I don't think the medical profession has really come down and correlated that to be carcinogous in itself. There are other fractions in the exhaust smoke that is thought to be carcinogous, but it is not the same fractions that cause the watering eyes.

Moderator: Okay, Glen, thank you. The questions in the box were very good. We had quite a few of them. The questions from the floor were adequate. I hope that we answered some of your questions in this session. It is your session, We hope to do a better job next year. I'd like to turn it back over to our President, Don Hudgens.

President Don Hudgens: Thank you Charlie. I just have a few closing remarks. First of all, I would like all of the Past Presidents, Vice Presidents, Regional Executives, Committee Chairmen and Committee Vice Chairmen to meet in the Counsel Room immediately following the luncheon today. We want to have a short meeting. I know all of us have planes to catch, so I hope it will be real short. Like Charlie mentioned earlier, the questions that were asked here today and the responses were recorded and Ron Pondel will be transcribing them. He'll be sending each person that made a response or asked a question, a transcript for your corrections. He will ask for a deadline to get the transcripts back and I hope you all comply, because he's going to go with what you said if he doesn't hear back from you. I hope we get the publication out this year before the end of the year. I would like to thank all of our advertisers for the support that they give us. They really make our publication possible and everyone here certainly appreciates their support. I guess that pretty well winds up the LMOA Convention for this year. I would like to thank everyone for being here. I would like a show of hands. Is everyone happy with being in Atlanta? Are there any people that are unhappy with it? (NOTE: A majority of hands were raised indicating their approval of meeting in Atlanta). This is the first time we've met outside of Chicago and it was proposed a few years ago that we meet periodically in other cities. I will talk to the RSA board members about the possibility of some future meeting date to be held in some other city. Right now, we're lined up for the next three years in Chicago. So again, I guess that's all we have for this session. We'll meet again next year, September 15-18th at the Chicato Hilton Towers. Thank you.