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Official Discussion Record of 48th Annual Meeting

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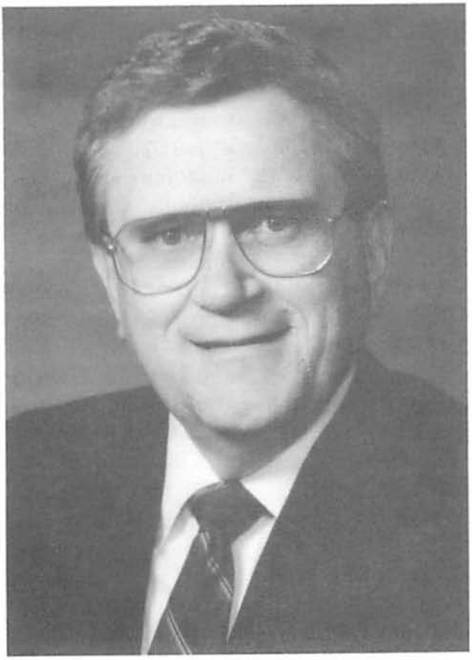
MONDAY MORNING SESSION
September 22, 1986



DALE H. PROPP
PRESIDENT
Chief Mechanical Officer
Burlington Northern Railroad
Springfield, MO

MONDAY MORNING SESSION

September 22, 1986

The joint meeting of the Coordinated Mechanical Associations comprised of the Air Brake Association, the Car Department Officers Association, the Locomotive Maintenance Officers Association and the Railway Fuel and Operating Officers Association with the Railway Supply Association convened at 9:00 A.M. in the International Ballroom of the Chicago Hilton & Towers, Chicago, Illinois with Mr. A. L. Jones, President of the Air Brake Association presiding as Chairman.

CHAIRMAN JONES: I would like at this time to call the 1986 Joint Session of the Coordinated Associations to order.

On behalf of the Officers and Directors of the Associations represented here this morning I want to welcome you all to Chicago and this 1986 Annual Technical Conference.

We are pleased to have with us this morning, Dr. Royal Speidel, Minister for the Chicago Temple, First United Methodist Church. Will you please rise for the invocation.

DR. SPEIDEL: Before we take care of the invoking of God's grace upon us, I would like to simply say it is good to stand before you people and be with you. It is a great feeling because I think of the wholesomeness, the greatness, when I think of railroads.

I was raised out in North Dakota as a youngster when the railroads were like blood vessels running through the body, bringing life, and I just had the greatest respect and admiration and good feeling about you people and about your work.

If any of you are interested in a particular church during these next four days, there is a Roman Catholic Church, Old St. Mary's, and a few blocks from here is Christ the King Lutheran Church. There is a non-denominational church, called Central Church. There is Grace Episcopal Church, and there is Loop Synagogue, and then I come from the United Methodist Church called Chicago Temple at Clark and Washington.

If any of you brought your spouses with you and you're interested in sightseeing, we have what is considered the highest chapel in the world. Our church chapel is 568 feet high. We have daily tours of the church at two o'clock if any of you are interested.

Let us join together in prayer.

Almighty God, thank you so much for these people gathered here today and for their dedication to their work. May these days be fruitful, give wisdom to speakers, give guidance to leaders and organizers.

May this be a great time of sharing ideas and of awarding one another. And as God may bless the work and meetings, may there also be relaxation. Provide Your goodness that these days can note grace in great proportion.

Bless each person here so this can be a great time together.

In Jesus Name; Amen.

MR. MURPHY: Thank you, Dr. Speidel. Good morning ladies and gentlemen, I am Dick Murphy, Director Field Maintenance Operations for Trailer Train Company and this year's President of the Car Department Officers Association.

Chairman Jones has asked me to collaborate with him this morning as we will also do a little later on in our respective Associations' Joint Session.

I would like to introduce the President of each Association at this time, asking them to rise and be recognized. Starting on my extreme left . . .

Mr. A. L. Jones, Engineer Air Brake Maintenance, Union Pacific Railroad, whom you have already met, and President of the Air Brake Association.

Mr. D. H. Propp, Chief Mechanical Officer, Burlington Northern, and President of the Locomotive Maintenance Officers Association.

Mr. D. R. Yerkes, General Road Foreman System, Conrail, and President of the Railway Fuel and Operating Officers Association.

And finally, the individual representing a very important part of this meeting . . .

Mr. T. E. Schofield, President, Unity Railway Equipment, and President of the Railway Supply Association.

We have with us this morning as our keynote speaker Mr. James A. Zito.

Mr. Zito was born in Melrose Park, Illinois and attended Elmhurst College. He began his railroad career on the Chicago North Western in 1944, as a yard clerk at Proviso Yard, Chicago. Since that time he has served in positions of increasing responsibilty within the operating and maintenance departments, some of which include: Assistant Trainmaster; Trainmaster; Division Superintendent; Assistant General Manager; Assistant Chief Engineer Maintenace; and Vice President- Operations.

On September 1, 1979, Mr. Zito was elected Senior Vice President - Operations, the position he currently holds.

He is a member of several railroad organizations and committees including the Railroad Superintendents Association; The American Railway Engineering Association; and is Chairman of the Operating - Transporation General Committee of the Association of American Railroads.

Mr. Zito is also chairman of the Energy Research Committee of the AAR, as well as Chairman of the High Productivity Integral Train Committee.

I have saved the best for last. I don't want his gray hairs to fool you. This fellow has children, aged eight and two years, and Antonio, nine months old.

Ladies and gentlemen, it is my pleasure to present Mr. James A. Zito.

ADDRESS BY JAMES A. ZITO

"The Changing Role of Employees on a New-Technological Environment"

MR. ZITO: Thank you, Dick. I appreciate the opportunity to be here, and am honored to keynote your coordinated associations meeting. With my background as a transportation officer, I must admit that there was once a time when I didn't work as closely with the mechanical department as I should have. I recall . . . quite a few times when I regarded the rip track people as just aggravations when they kept calling for a pull or that it seemed that guys at the diesel shop were simply put on earth to cause me aggravation.

Those were times when our various departments acted as though we had the luxury of working independently of each other. The situation is very different today. Let me illustrate why we need to be more concerned with communication, cooperation, and involvement. This morning, 100 trucks left New York City bound for Los Angeles. In addition to a support system of dispatchers, supervisors, and mechanics, these trucks require a constant crew of 100 to 200 operators to complete the coast-to-coast trip. Sounds pretty inefficient, doesn't it? Yet, these trucks, manned by one or two people each, are beating us in time, service and cost — and every day they are capturing more of our business. How can this be happening when they have a constant crew of 100 to 200 operators for only 100 trailers?

Well, this is not so surprising when you consider that a train moving the same 100 trailers would take twice as many train service employees as truck drivers, with each rail employee receiving a wage and benefits package 50% greater than that of the average truck driver. As you are all painfully aware, the truckers' share of intercity freight revenue has increased by 150% in the last 10 years, at the expense of the rail industry.

I give this example not to blast the unions or our competition, but to point out the urgency of the situation. Railroads are in a fight for their lives at this very moment. It is our challenge as railroad management to cut costs while improving service. To meet this challenge — and to survive — we need to do three things. We need to incorporate the latest technology, streamline our organizational systems, and motivate each and every employee to constantly seek to improve their performance and, in this talk I'm going to tell you why I think the people here and the disciplines you represent must take an even more active role in insuring the complete flow of improvement from technology organized into proper systems and applied with the active cooperation of people. First, a few words about the three areas.

Technology is the brightest area of the three. Because that is the area that provides the giant leaps in productivity. In reviewing the agenda topics for the next three days, I am immensely impressed by the technological breakthroughs made by the railroad industry and its suppliers in recent years. From computerized dispatching to high productivity integral trains, our current operations represent a huge leap from our operations prior to the Staggers Act of 1980. Research continues to progress in the areas of locomotive efficiency, alternative energy sources, and computer applications ranging from train performance simulators to operating cost analysis programs. Many of you are personally involved in projects that are on the cutting edge of these advances within the industry. I applaud your creative efforts, and challenge you to continue to reach out in your science.

The second area I mentioned, systems, can be described as the methods we use to channel our resources and information. Railroad systems are changing rapidly in response to advances in technology as well as to the everchanging business climate. Some examples of system changes would include computer aided dispatching, computerized billing and crew calling, and advanced train control systems.

JAMES A. ZITO
Sr. Vice President - Operations
Chicago & North Western Transp. Co.

While systems are necessary to harness technological change to our advantage, they are also necessary to effectively combine the efforts of our people. When we think of employee systems, we tend to think mostly of rigid guidelines regarding hiring, promotion, transfer, and discipline. But employee systems that are flexible allow for greater management discretion while giving the employee greater freedom to perform his job effectively. Ron Cuchna, the North Western's Vice President of Labor Relations, will be discussing what we feel is one such system tomorrow morning.

The third area I wish to discuss is people. Regardless of the rate of technological advancement, the rail industry will always need people, and people will continue to be our most versatile asset. Our technology and systems are products of our people. Even more than that, though, people have a characteristic that makes it almost impossible for them to resist using their minds to improve their own working environment. I believe people have a desire to participate in decisions affecting their jobs. They want to become involved — and not just be an extension of a machine. By believing this principle, and by acting on it, I also believe we can achieve major improvements and success far beyond what we have accomplished so far in our industry.

Why do I say this? Because I don't think we've done a particularly good job in getting the majority of our people to give their ideas and to get actively involved in improving our companies.

Think back over your own work history. Weren't there times when you thought that you had a good idea about changing the work or a work process to make it better? How many of you brought up your ideas to your supervisor expecting some sort of acceptance and recognition — maybe even a promotion? Unfortunately, many of us were told, "Go back to work and do what you're paid for, I'll make the decisions around here!" After hearing that, how did you feel about bringing up ideas to that supervisor again? Probably not very enthused. Obviously, some of you persevered and moved on to bigger and better things. That's why you're here today. But others with good ideas to share decided to simply do what they were told — not more, and possibly even less. They still have good ideas, and think creatively about their jobs. They just don't share it with their employer.

Now, let's think about our current situation. We as supervisors today, do we truly listen to our people; do we regularly ask for their thoughts about their job arrangement? Or have you fallen into the pattern of some of our former supervisors, who didn't have the time to listen? People should be the most important resource of any organization, and oftentimes all it takes is a willingness of management to listen to start them contributing ideas.

The interrelationship of technology, systems, and people should be of great concern to everyone in this room. You may have highly motivated employees working with the most efficient systems, but if your product happens to be buggy-whips — you're not going to survive. On the other hand, you can give your shop foreman a personal computer to increase his productivity but without systems support, training, and motivation on his part, the computer will gather dust in the corner.

Perhaps many of you have been involved in the development of technology or systems that should have worked perfectly but for some reason never achieved its full potential as planned. When this happens you might ask yourself, how was it introduced to the people? Were they included in the development stage to get them involved from the beginning? Or was it just given to them by the boss after decisions had been made, perhaps with the mention that it should reduce several jobs in their department? Resistance to change is a very natural, human reaction, especially when the change is imposed on us. But by preparing the employee for the change and getting him involved in the process, you can lessen the shock and make him feel more like a participant than a victim. This in turn increases acceptance of the changes and, decreases the lag time required for the improvement to reach full efficiency.

Unfortunately, I speak from experience. I know of some instances where we could have done a much better job of introduction of a new technology. But perhaps we're starting to learn. Recently, we've purchased some state-of-the-art SD-60 locomotives from EMD. We've been sending teams of our contract employees to EMD to learn about the locomotive system directly from the manufacturer. In effect, we are getting our machinists and electricians — and even some locomotive engineers — involved from the beginning because they are the customers of EMD. They are the ones who will be involved with the product on a daily basis. Allowing them to go to EMD to exchange ideas with EMD employees about these new locomotives was a real morale booster for our people. One was quoted as saying that it was the best thing the North Western had ever done. By letting him go to the manufacturer as the Company's representative to learn and help in the design of future generations of locomotives, he became involved, and in so doing, became more valuable to his employer, and himself.

I know all of this sounds very logical. And, actually, I wonder why more of that kind of activity doesn't occur. People want to get involved. Management needs their involvement to improve productivity. But why hasn't it happened more? I guess there is no easy answer to that question. There are contributing factors, to be sure — poor union-management relations, competitive pressure, internal organizational pressure, lack of resources, poor interpersonal skills, to name a few.

But to get everyone involved — to achieve an attitude of equality of contribution — we must change our corporate culture. Railroads are steeped in tradition and most of us are proud of that tradition. But some of our traditional management styles have no place in any modern industry, and especially, not in an industry that is fighting for its survival. But to change the culture of a company requires a massive effort on the part of everyone, especially the management! Some question if we should be so committed to change. I don't. Because I'm absolutely sure of one thing. Unless we do things diffferently, unless we all pull together, within our companies and within our industry, there is only one certainty — we will continue to shrink as an industry.

In fact, we must change dramatically in all dimensions — technology, system, and — most critically — with how we deal with our people in installing new technology and systems.

Companies that have achieved or are achieving excellence embrace the following principles:

1. Promote a climate of open communications which demands attentive listening and candid discussion in an atmosphere of mutual respect.

2. Encourage and recognize innovation and teamwork.

3. Use open communication as a means of bridging organizational levels, resolving departmental differences, and addressing individual concerns.

4. Give every employee the right to know the requirements of his or her position, and the right to inquire as to the validity.

5. Recognize the dual role of everyone in the company as both a customer and a supplier.

6. Expect that every person will strive to meet the requirements of internal customers and make his or her requirements clear to internal suppliers.

7. Expect that every person will continually strive to know the right thing to do and to do it right the first time.

I'm happy to see that a number of railroads and suppliers have instituted programs to improve their ability to tap into the creativity of all their people. I'm pleased to say that the North Western is one of those. We have made a total commitment to improving our culture by instituting a process called our total quality improvement system.

For our quality improvement system to succeed, or any major change in how we deal with our people, we believe that total commitment from the top is of paramount importance. Perhaps some of you are familiar with past programs that were aimed mainly at the workers, or perhaps the first-line supervisors, or even lower management. These programs were doomed to failure from the start because the underlying message from upper management was "here, you get involved in this because you need it, and I don't." Everyone looks for signals from their boss. If he suggests that you get involved in a program that isn't worthy of his time, what does that say to you? You generally will feel that you have the option of participating or not participating. And, if your boss doesn't get involved, it's likely you won't. That's why it's so important to get everyone personally involved from the top down if you want to change your corporate culture.

I know it's not going to be easy, because, for example, I have a 42 year-old management style to change if I'm going to live up to the new standards set by our total quality improvement system. As I mentioned, change is difficult, but I am committed to making that change. I know that improvement only occurs when we keep trying, day after day, until ultimately we develop positive new habits to help us manage more effectively.

And, really, that comment captures the most significant concept in our system. That the biggest changes will be asked of our officers, and, again, we understand that changing will be tough. As in my case, we're asking people to change years of habit and experience, to unlearn some management styles that seemed to have worked successfully for them throughout their careers.

I wish I could say I've reached the point where new methods have become habit with me. I'm not there yet, and I guess very few of our officers are either. Our duty is to keep making a conscious effort until we all become so comfortable with new management and communication styles that they become natural.

Now, early on in this talk, I mentioned the interrelationship of three factors of productivity. I'd like to go back and show why I said that I feel the people in this room must take a leadership role in insuring that any new technology introduction has the organizational systems, and particularly, the people systems, built into the total package.

Let's look back to those new SD - 60's I mentioned. By the way, have any of you had the experience of going to EMD at La Grange recently when they were working on a new order of locomotives? I did. I went there recently and saw a number of those beautiful finished SD - 60's gleaming under the lights — all the paint bright and fresh — not a scratch — not a speck of dirt. What a sight!

But then I thought, what if we just put those works of art into service without any support systems or any training of our people — (of course we're not) — but what would happen if we did? How would they look and how would they be running in a few years? What a crime it would be! A crime to the dedicated people who built these great machines — (and I met a number of those people at EMD — and they are dedicated!) — a crime to our stockholders, whose money we used to purchase the units. And a crime to our employees who would struggle to figure out how to service and maintain the SD - 60's.

I guess it sounds foolish to imagine that we would send out one million plus dollars engines without training people or setting up the support systems — or does it?

Have we, in our industry, ever done things like that? Have we ever introduced a new technology and then discovered, months later, that some poor mechanic on the third shift never was given spec sheets or an electrician never had a schematic of a new circuit?

Have we had failures of equipment? Things that you worked your tails off to perfect, yet things that got ruined, because, if the truth were known, the people who had to use the equipment or maintain the equipment were never given the knowledge or systems to do their job right or the opportunity to give their ideas on improvements?

You know, I think that if those dedicated workers at EMD felt our company would mistreat their units, they'd like to come and share their thoughts about what kind of lousy operation we had. Obviously, they couldn't do it. They really couldn't tell our management how important it is to make sure that that particular new technology must have the support systems and the profile programs necessary to gain maximum advantage.

They couldn't — but you can in your companies. And you uniquely can. And you must if your technologies are to achieve their potential! No one knows what you know! No one knows what's needed like you know!

Your job is only partially done when you come up with the great ideas I see on your conference agenda, or when a technology has been perfected. You must also monitor the creation of the support systems. You must also define the skills needed by the people, and insist that those skills are developed within the people. You must insist that the users have ways to share their ideas. Don't let your technologies be eroded. Insist on completion of this equation. Technology, through systems, through people to completion. You must, because your technologies offer the great hope for our industry. Your new innovations can bring about the mega-leaps in productivity we need. But none of that can fully occur unless you insist on the systems and the people involvement that is necessary.

Thank you.

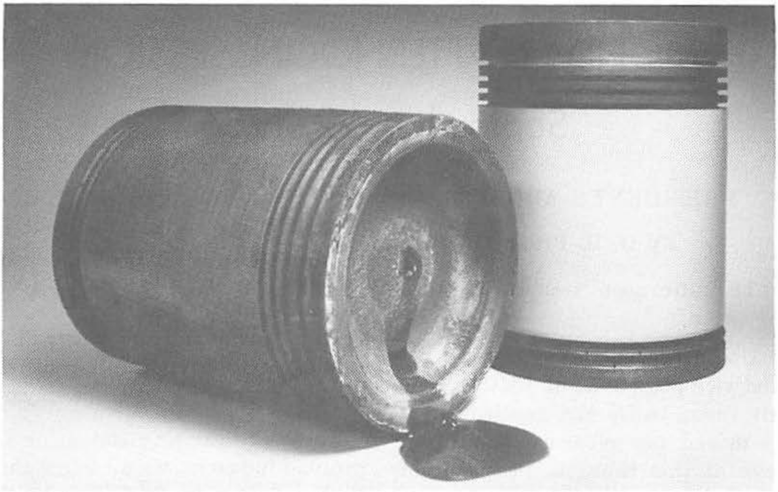
CHAIRMAN JONES: Thank you Mr. Zito for a very interesting and timely address.

On behalf of the Air Brake Association and all the other Associations here convened, I wish to present you with this plaque in recognition; a very small thanks for your effort here this morning.

(The plaque was presented to Mr. Zito)

MR. ZITO: Thank you very much.

CHAIRMAN JONES: In closing this meeting I want to thank everyone for attending. At this time we will adjourn and go to our respective meeting rooms.



MONDAY AFTERNOON SESSION

September 22, 1986

PRESIDENT'S ADDRESS

By D. H. Propp

The afternoon session is called to order.

Distinguished past presidents and vice presidents of LMOA, good afternoon ladies and gentlemen. It is indeed my pleasure and privilege at this time, as President of LMOA, to welcome each of you here. You members of LMOA, affiliate members, railroad officials, government officials and visitors. A special welcome to those persons who are attending from foreign countries.

As you know, LMOA's international membership now consists of six countries, other than the North American continent, countries of Canada, Mexico and the United States. Those countries are Australia, Denmark, England, India, New Zealand and South Africa. We thank them for their interest in LMOA.

After nearly 30 years with the railroad industry and a like number of years with LMOA, it is gratifying for me to have this opportunity to reminisce a bit and share some of my feelings and express my appreciation to those persons who have preceeded us. It is wonderful to see the number of people who have turned out for this occasion. It appears that the membership for the total RSA is beyond 1,500 so far for the convention and tomorrow you will be getting a full report on that. So that is gratifying in these days.

These are exciting times for the railroad industry, we all know that. Railroaders and supply people. We can't afford to miss one beat in that old song of ours, "I've Been Working on the Railroad," because if we do miss one beat, and get ourselves out of step and out of rhythm, we're going to miss out on the competetive edge. Worst of all, we may find ourselves putting a different emphasis on the title and saying, "I Had Been Working on the Railroad," or "I Used to Work on the Railroad." To paraphrase the words of John F. Kennedy a while ago, now is the time for us as management, labor and supply teams, to ask, not what the railroad industry can do for me, but what can I do for the industry? We need to think about that and remember it well. The technical expertise that is gathered in the associations here assemblied, and the LMOA committees, have in the past and will continue in the future, to exhibit innovative ideas sc productivity gains, we must incorporate the ingredient of quality. Our LMOA theme, which you have seen in the foyer, which you will remember was pulled from the hat of a magician last year, it reads "$E=MC^2$." This formula was taken from Einstein's theory of relativity, all things being relative, but it is really only the acrynym for our slogan "Excellence in Maintenance Culture Committed to the Bottom Line." Productivity with quality is the only way the industry can meet the challenges in competition with the rubber-tired truck. And if we don't meet that challenge, we better all learn how to drive a truck. Only quality of locomotive components and parts, quality of engines, quality of products that we put in them, excellence in personal attitudes and attitudes on maintenance, better ideas, innovative thinking will achieve the reliability needed for the competetive edge. We should remember the slogans "Excellence is Attitude" or Wayne Ewing's slogan "Can Do." Remember that positive thinking will mean success. You know all of us can be a Ralph Nader or a Jane Fonda for the industry and support our cause. Go out and promote it, we need that. This LMOA group has the exper-

Don Ward, left, newly elected president of LMOA, shown accepting the gavel from fellow-worker and outgoing president, Dale Propp. Both with the Burlington Northern and located in Springfield, MO at the time of the photo.

tise and the responsibility to provide the excellence and the maintenance culture that is committed to the bottom line.

As an industry and as an LMOA association, we must challenge everything that we do. Question important to the well-being of our railroad.

The key to higher achievement has always been improved methods. Work smarter, not harder. We've heard that before. But with these what we do. Don't be satisfied with the status quo. Labor agreements of the '40's are inadequate for the '80's, and we are approaching the '90's. If laws and regulations are outdated and inaccurate, let's not procrastinate for years before we make a change. Challenge ourselves to improve lubricating oils for locomotives. Don't be afraid to address a fifth generation oil. Research longer filter life. And let not price dictate quality, but rather look at the bottom line for longevity. New tools must and can be developed. Satelite communication is here, but we still need improved fuel measurement systems. The new air conditioned cabooses are wonderful. They're called blinkies or fred. And fred is an acrynym for something like "rear end devices." The implementation of the cabooseless era is here and a huge benefit to our industry. We must, and need, to continue these approaches. Without resistance to the technical changes. There are some people that still resist the cabooseless alternative. We must not allow that to happen. One fellow explained that to me, he said if you ride up and down in an elevator, years ago there used to be an operator there to handle it — today we push the button and the technology takes care of us. If we're not afraid of an elevator, then we should not be afraid of the technology on the end of a train. We need to examine remanufacturing. Refining, regrinding, and only be satisfied with first quality. And the best cost to the bottom line, which is our slogan for this year. With the possible exception of surfboards equipped with cargo racks, the railroad industry is still the number one fuel efficient mode of transportation. We ought to let the world know about that.

Don't let them forget it. This group can make a difference to the one whom all of us must call our boss. And that is our customer. You know, without the quality and the reliability, we can't attract the new customer or the old one. You have to have the engines that will pull the trains on time. You got to have the people in maintenance dedicated to the perfection that is so necessary to meet that competition. Your LMOA has made significant changes this past year, which will streamline the organization for the future. We've made some cost adjustments necessary to keep ourselves, our structure, of the organization within the realm of the new society. Railroad personnel and suppliers in concert participate as members and

chairmen of the hardworking technical committees which provide the ideas and the valuable information for all of us to absorb and digest. These committees can only function with the support of management from railroad and the RSA groups. While the future committees of our LMOA may shrink some in size and number, you can be assured that the quality will remain intact and even improve.

As president of LMOA, I have closely worked and deeply appreciated the hard work of Joe and Lou Koerner. Joe and Lou are planning to retire at this time next year and, at this time, Joe will you stand? Lou isn't here, she is down working, but I would like for you to stand and join in giving him a warm welcome.

(Applause)

Joe and Lou have been dedicated to this organization for years and we are really going to be sorry and miss them a lot in years to come. A special thanks must be given to the host railroads and the railroad clubs that participated in the convention meetings this year. In Montreal we had a good session sponsored by the Canadian Pacific and the Canadian National. In Omaha, the UP has always sponsored us, the Norfolk Western at

Past President and Chairman of the Board Darrell Walker, left, presents Dale Propp with the General Desk Set, emblematic of life members in LMOA, on completion of his term as president of the association. 1st Vice President Dave Goehring, center, smiles his approval.

Roanoke and at Huntington the Southern Southwestern Club, in Kansas City the Southwestern Railway Club and, of course, in Chicago the Diesel Club. These organizations have always done what is so necessary to keep the vital statistics of this organization. We appreciate Marty and Don of Power Parts, for their continued support as always. We know that they will continue to work with this group.

In closing, the LMOA team performed admirably I feel this year in 1986. I know this can be attested by each of you as you listen to the rest of the convention. I want to thank you for a highly successful year and I know that succeeding officers will pick up the challenge to carry on the traditions of the past. I am proud to be a member of LMOA and have for years, and value the friendships and relationships that I have gained through this organization very highly. It's going to be an honor for me tomorrow to pass the gavel on to a collegue of mine on Burlington Northern that probably will become the youngest president of LMOA in the history of LMOA. Normally we make it only at the time that you are about ready to retire. But Don is going to be one of those that supercedes. Needless

Past President Tom Harley, left, is shown presenting Dale Propp with the coveted Past President's Pin. Looking on in admiration, center, is 3rd Vice President Bill Brown.

to say, I am not going to retire. I am moving from the Ozarks to the mountains of Colorado, but I do intend to continue on in Darrell's position and the past president's jobs for the years to come because I know that this organization offers a lot to all of us on the railroad.

So again I say thanks for everything this year and I look forward to our continued association.

Thank you.

(Applause)

Now I would like for all of you to stand please and, at this time, I would like for you to bow your heads for a moment of silence for those members and friends of LMOA that have departed during this past year.

(Silence)

Thank you. You may be seated.

Dale Propp, right, receives his bound copy of the 1986 LMOA Publication from Darrell Walker, as Jack Kuhns, retired LMOA Vice President, looks on in the center.

TUESDAY AFTERNOON SESSION
September 23, 1986

PRESIDENT PROPP: I encourage everyone to come on in and take a seat. We will start our afternoon session.

Good afternoon, ladies and gentlemen. Welcome back to the afternoon session and the Diesel Mechanical Committee meeting. I will give you a couple of more minutes to take a seat and then we will begin the afternoon session with a short business meeting. I have some very important tasks to do and that is to turn the gavel over to the next president of our fine organization.

At this time I would like to ask Don Ward, our first vice president at the moment, to stand please.

I know this guy real well. I've known him since merger about 1980, and a little bit before that. The last couple of years I've worked very closely with him. We're collegues together in the same area. Don has high qualities and he is going to be a good leader for this organization. As I said yesterday, he is probably the youngest LMOA president ever. So it is with a lot of pride and gratification that I can pass this gavel to Don and I wish you a lot of luck in all of the responsibilities that go with the job. Don, congratulations.

(Applause)

ACCEPTANCE SPEECH

By D. L. Ward

Thank you very much Dale. Ladies and gentlemen I accept your nomination as president of Locomotive Maintenance Officers Association and I look forward to serving this great organization during the coming year. This marks my fourteenth year in LMOA. In 1972, I started with the Frisco Railroad in August, and in September I joined the LMOA and almost immediately was put on a committee. So my whole railroad career has been spent and corresponds with my time in LMOA. For those of you who were here last year, you remember when Dale accepted the gavel he had a magician that put on a little show and came up with the theme for this year that we are working on right now. Unfortunately, Dale is being transferred to Denver but he will still be my boss through October 1, so I am not going to try to outdo him and get him upset at this point. I will say to you that for 1987, we have picked a theme that I hope will carry on with the theme that Dale came up with last year, that of Excellence and Maintenance Culture Committed to the Bottom Line. Our theme for 1987, carrying right along that line, will be Productivity Along With Quality, the Mainte-

nance Officers Ultimate Goal. All of our directions during this coming year will be directed toward that theme. The LMOA organization faces many challenges. Those challenges are horrendous that we are facing in the coming years. The LMOA, just like the railroads that we work for, must constantly strive to make this organization more productive, at the same time, we cannot sacrifice the quality of service that we perform and have been performing for so many years to the maintenance officer.

There lies ahead of us many important decisions. Some of them we have already made. They have been pretty tough decisions to make but we've got more to make. We are going to have to look at the new world of downsizing or realigning our technical committees to make them more directed at helping you, the maintenance officer, increase your productivity. We have some tough decisions to make in that area. We also need, as an organization, to develop some kind of a five year plan, so that we know what direction we are going in for the next five years with the changing environment in the railroad industry.

Finally, the toughest decision for me and the one I hate to see the most is during the next year we are going to have to find a replacement for Joe and Lou Koerner. I can assure you it is going to be very tough and I don't look forward to that decision one bit. I know the rest of the officers do not either. If there was any way, I wish we could talk Joe and Lou into staying another 30 or 40 years. It would make it a lot easier on all of us.

In conclusion, I, along with all of your LMOA officers, accept the challenges that lie ahead for us. I look forward to a great year for your Locomotive Maintenance Officers Association.

Joe and Lou Koerner photographed at the April 1, 1987 meeting of the Coordinated Associations, the Union League, Chicago, Illinois.

Darrell Walker, right, is shown receiving his copy of the bound proceedings from Past President Tom Harley. Bill Brown, center, witnessing the exchange.

President Don Ward left, is shown presenting the General Desk Set to Jack Kuhns in recognition of Jack's years of outstanding service to LMOA. Beaming on in the center is 4th Vice President Paul Hoerath.

Paul Hoerath, center, is shown receiving his LMOA blazer in recognition of his promotion to the vice presidential ranks of LMOA. Assisting him into his jacket is President Don Ward, left, and Past President Dale Propp.

Newly elected Vice President Don Hudgens is shown receiving his LMOA blazer. Helping Don into his blazer is left Don Ward, and on the right 1st Vice President Dave Goehring.

PRE-CONVENTION

PRESENTATIONS

INDEX

ATTENTION EVERYONE COMING TO THE MEETING!

REGISTRATION FEE AT ANNUAL MEETING $25.00 PER MEMBER

LADIES FREE

Our registration desk, located in the Lower Lobby of the Conrad Hilton, Chicago, will be open Sunday, beginning at 12 noon. Come in Sunday afternoon, register, and enjoy this special opportunity to visit with our officers and your other friends. THIS WILL SAVE YOU VALUABLE TIME ON MONDAY MORNING. KEEP YOU OUT OF THE REGISTRATION RUSH. **BRING YOUR WIFE WITH YOU.** She will enjoy the special entertainment planned for her!

SPECIAL INSTRUCTIONS

1. **STUDY these reports closely.**
2. **SEND OR BRING written questions to the Committee Chairmen.**
3. **BRING THIS BOOK TO EVERY SESSION OF THE ANNUAL MEETING! There are no extra copies.**
4. **BRING your 1987 LMOA Membership Card for identification in registering.**

ALL RAILROAD MEMBERS! The ground rules of this Annual Meeting require:
"THAT ALL SUPPLY COMPANY HOSPITALITY SUITES MUST BE CLOSED TO AND OFF LIMITS TO ALL RAILROAD PERSONNEL WHILE THE MEETINGS ARE IN PROGRESS."
Please do not embarrass your Supply Company friends by calling at their suites while the meetings are in progress; it will cause them:

1. **To remind you of this ground rule.**

   or

2. **To lose their reservation at this meeting, and to forfeit their right to attend future meetings.**

ALL SUPPLY COMPANY MEMBERS: Your strict observance of the above rule is absolutely necessary, will be greatly appreciated.
You are urged to attend the meetings because:

1. **Your** product might be discussed.
2. You might be in position to answer a question that is asked.
3. You need to know what **our** problems are, in some cases, they are **your** problems also.

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D. L. WARD
PRESIDENT
Assistant General Foreman-Locos.
Burlington Northern Railroad
Springfield, MO 65802

MEMBERSHIP THRU THE YEARS

	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

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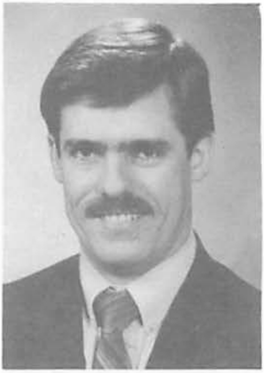

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1941 — J. C. MILLER (Deceased), M. M., N. Y. C. & St. L. R.R.

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1949 — J. W. HAWTHORNE (Deceased), Asst. Vice-Pres.-Equipment, Seaboard Coast Line R.R.

1950 — G. E. BENNET (Deceased), Vice-Pres. - Gen. Purchasing Agent, C. & E. I. Railway

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1954 & 1955 — F. D. SINEATH, Retired Chief of Motive Power, Seaboard Coast Line RR., 1061 Nelson Ave., Jacksonville, Fla. 32205

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1960 — W. E. LEHR, Retired Chief Mechanical Officer, Pennsylvania R.R., 313 Hayden Street, Sayre, Penn. 18840

1961 — O. L. HOPE, Retired Asst. Chief Mechanical Officer, Missouri Pacific R.R.

1962 — R. E. HARRISON (Deceased), Manager Maintenance Planning & Control, Southern Pacific Co.

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1964 — H. N. CHASTAIN, Retired Gen. Manager - Mechanical, A. T. & S. F. Ry., Chicago, Ill.

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1968 — G. F. BACHMAN, Retired Chief Mechanical Officer, Elgin Joliet & Eastern Ry., 612 E. Bevan Drive, Joliet, IL 60431

1969 — T. W. BELLHOUSE (Deceased), Supt. Mechanical Dept., S. P. Co. - St. L. S. W. Ry., Houston, Texas

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1971 — G. W. NIEMEYER (Deceased), Mechanical Superintendent, Texas & Pacific Railway

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1973 — W. F. DADD, Retired Chief Mechanical Officer, Chessie System, 37 Carolina Shores Drive, Calabash, NC 28459

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1975 — L. H. BOOTH, Retired Assistant C.M.O. - Locomotive, Chessie System, 906 13th Ave., Huntington, W. Va. 25701

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1978 — E. E. DENT, Retired Superintendent Motive Power, Missouri Pacific Railroad. 33 Deerfield Lane, Creve Coeur, MO 63141

1979 — E. T. HARLEY, Vice President - Equipment, Trailer Train Co., 101 N. Wacker Dr., Chicago, IL 60606

1980 — JAMES H. LONG, Retired Manager Locomotive Dept., Chessie System, 5454 Cleander Drive, Cincinnati, OH 45238

1981 — R. G. CLEVENGER, Retired General Electrical Foreman, Atchison, Topeka & Santa Fe Rwy., 4133 W. Wilson No. 164, Banning, CA 92220

PAST PRESIDENTS

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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 R.R., 688 J. E. George Blvd., Omaha, NE 68132
1985 — D. M. WALKER, Diesel Superintendent, Norfolk Southern Corporation, 99 Spring Street, Atlanta, GA 30303
1986 — DALE H. PROPP, Chief Mechanical Officer, Burlington Northern Railroad, 1331 17th Street, Denver, CO 80202

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Union Pacific Railroad Co.
Omaha, Nebraska

LMOA wishes to express its thanks to Union Pacific Railroad for again hosting Pre-convention Presentation in Omaha.

Our Fuel and Lubricants Committee's presentation was well received in what we trust was a mutually beneficial experience.

Our thanks again to Mr. J. F. McDonough and others responsible for and participating in this activity.

Monday, September 14, 1987

2:15 P.M.

REPORT OF THE COMMITTEE ON FUEL AND LUBRICANTS

Pre-Convention Presentation: Omaha, NE

April 29, 1987 Red Lion Inn Omaha, NE

K. A. BRINKER, Chairman
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1987 TOPIC:

IMPROVED PRODUCTS THROUGH TECHNOLOGY

PERSONAL HISTORY

KEITH A. BRINKER

Mr. Brinker was born in Greensburg, Pennsylvania on July 20, 1957. He attended public schools in Norvelt and Mt. Pleasant, Pennsylvania and graduated from the University of Pittsburgh in 1979 with a Bachelor of Science in Chemistry.

He began his railroad career with the Chessie System Railroads in 1979 as a Chemist-Spectrographer in the Test Department assigned to the Russell, Kentucky laboratory. In 1981, he was promoted to Test and Environmental Specialist in Cincinnati, Ohio. He returned to Russell, Kentucky in 1983 as Test and Environmental Supervisor. In 1985, he was promoted to Assistant Chief Chemist at the Huntington, West Virginia laboratory.

With the formation of CSX Rail Transport in 1986, he is presently working in the Waycross, Georgia laboratory as Chief Chemist.

He and his wife, Charlene, enjoy bicycling, dancing, plays and travel.

I.

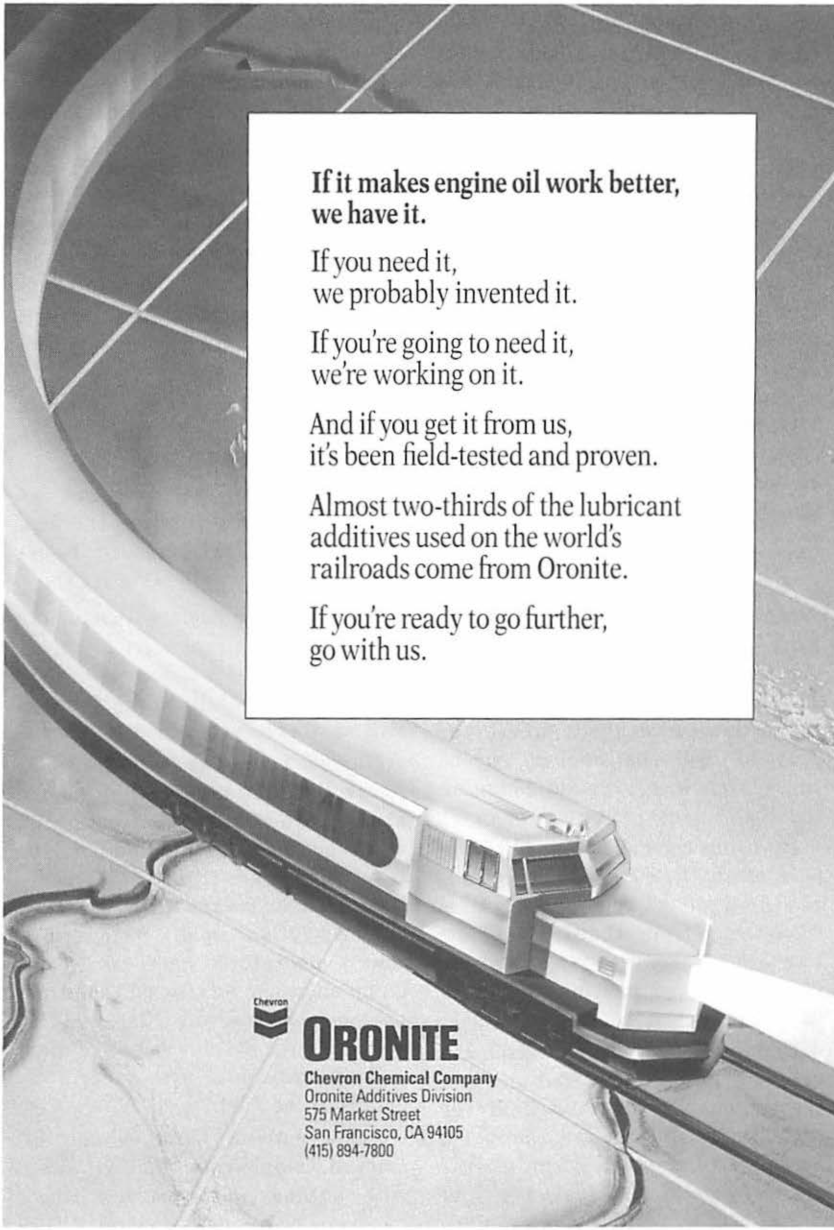
COMMON FUEL ADDITIVES AND THEIR EFFECTIVENESS

Railroads are major users of diesel fuel in the United States. They used more than three billion gallons of No. 2 diesel fuel in 1985, so they have a large stake in the products covered by the term "middle distillates". These are hydrocarbons boiling (approximately) in the 350 to 650°F range (Figure 1). Selective cuts are made on crude oil during refining which remove about 30 - 32% as middle distillates.

The products recovered are naphtha, kerosene and light and heavy gas oil (Figure 2). What remains after the atmospheric distillation is reduced crude from which lubricating oils and other products are made by further processing. To extend the middle distillate supply, residual products are processed in a catalytic cracker to produce more gasoline and middle distillates. The high oil prices during the 1970's encouraged many refiners to upgrade their plants to convert low quality and less expensive crudes. In addition, as the demand for middle distillates has increased, some refiners have added thermally cracked stock to the middle distillate pool.

No. 2 diesel fuel is a blend of straight run distillates (light and medium) and cracked stock (Figure 3). These components are blended to impart the desired performance qualities needed by equipment users and manufacturers. Railroad fuel contains a blend of straight run and catalytically cracked stocks which are mixtures of paraffins, aromatics and lesser amounts of cyclic paraffins and unsaturates called olefins.

The use of heavier, lower quality crudes and the use of cracked stocks in No. 2 diesel fuel affect its performance. Additives are fre-


If it makes engine oil work better, we have it.
If you need it, we probably invented it.
If you're going to need it, we're working on it.
And if you get it from us, it's been field-tested and proven.
Almost two-thirds of the lubricant additives used on the world's railroads come from Oronite.
If you're ready to go further, go with us.
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ORONITE
Chevron Chemical Company
Oronite Additives Division
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quently used by refiners to improve the performance of diesel fuel so it will meet the ASTM No. 2 diesel fuel specifications and provide satisfactory operation in railroad locomotives. Some common additives used in railroad diesel fuel are listed in Table 1.

Additive treatment levels can reach 0.2% of the total fuel. Even though additives improve the performance of railroad diesel fuel, problems have been encountered where further additive treatment of the railroad fuel was required. Two problems, one a low temperature fuel problem, the other a fuel stability problem, are discussed in this paper.

Case I:

A Southwest railroad experienced low temperature fuel problems when locomotives started stalling due to plugged fuel filters. The locomotives were returned to the maintenance shops where the problem was determined to be caused by wax crystals plugging the fuel filters (Figure 4).

By using the cold filter plugging point test (CFPP test), this railroad determined that wax crystals separating from the fuel at low temperatures were plugging the fuel filters and causing the problem (Figure 5).

Using the same test method, the railroad determined that a wax crystal modifer or flow improver could help solve the wax problem. Since wax crystals form at the cloud point of the fuel, the wax crystal modifier can nucleate more, smaller wax crystals or the wax crystal modifier can be incorporated into the wax crystal to inhibit its growth and modify its shape. The smaller wax crystals flow in suspension and improve filter operability (Figure 6). The responsiveness of fuels to wax crystal modifiers depends primarily on:

1. Composition of the wax, generally indicated by the distillation range of the fuel (ASTM D86).
2. Volume of cracked components as measured by the aniline point. (ASTM D611)
3. Amount of wax present as measured by filtering the wax out at a temperature below the cloud point. (IP309183)

Broad boiling fuels with 20-80% points, having a range greater than 100°F and 95% points above 625°F, are generally quite responsive to wax crystal modifiers.

Narrow boiling fuels with a narrower distribution of boiling points also have a narrow distribution of wax molecular weights and are less responsive to wax crystal modifiers. These waxes tend to come out of solution rapidly over a narrow temperature range and can dump so much wax so quickly that the wax crystal modifier can be overwhelmed. Special blends of wax crystal modifiers are needed to handle these fuels.

Fuels with a high volume of cracked components, that is, fuels with aniline points of less than

145°F are generally responsive to treatment with wax crystal modifiers.

Fuels with a low wax content (less than 9%) are treatable. A lower wax content will obviously require less wax crystal modifier since the wax crystal modifier is incorporated into the wax crystal as it is formed.

To investigate the filter plugging problem, No. 2 diesel fuel was blended with (1) kerosene, (2) a mixture of kerosene plus a wax crystal modifier, and (3) a wax crystal modifier. These samples, along with No. 2 diesel fuel, were evaluated for pour point and cold filter plugging point (See Table 2). All three of the treated samples met the railroad's cold temperature requirements of -15° pour point and a 0°F cold filter plugging point.

To evaluate the cost of the three possible solutions a price of $0.80 per gallon was used for No. 2 diesel fuel. Although fuel prices dropped dramatically last year, they are not expected to remain at these low levels for any extended period of time. Therefore, the value of $0.80 per gallon of diesel fuel was used for planning purposes. Comparing the cost of the three possible solutions, the use of kerosene is the most expensive with an additional cost of 4.9 cents a gallon. The next most expensive is the combination of kerosene and a wax crystal modifier with an additional cost of 2.9 cents a gallon. The wax crystal modifier required an additional cost of 0.5 cents per gallon of diesel fuel. (See Table 3) The higher cost of using kerosene is caused mainly by the premium price charged for the product.

The BTU loss associated with the use of kerosene contributes 1 to 2 cents to the cost of winterizing the fuel. This additional cost is considered small when it is weighed against not having the locomotive available for service because of a plugged fuel filter.

Some fuel blends will not respond to wax crystal modifiers. Therefore, kerosene must be added to meet the railroad low temperature properties of -15°F pour point and 0°F CFPP/wax cloud. The choice between the use of kerosene or a wax crystal modifier is made on the basis of cost and whether or not the fuel will respond to a wax crystal modifier.

In October, the Southwest railroad mentioned above collects samples from the refiners of its No. 2 diesel fuel to determine the level of wax crystal modifier or the level of kerosene needed. Starting in December, diesel fuel at every fueling point is monitored every two weeks to make sure it continues to provide the desired cold temperature performance.

At the same time the wax crystal modifier was added to diesel fuel, fuel heaters were added to the locomotives. Prior to using the low temperature additive and fuel heaters, every winter 200 to 300

locomotives had to be towed into the maintenance shops because of plugged fuel filters. This problem appears to have been solved.

Case II:

A major Southeastern railroad also investigated the use of pour point depressants in its No. 2 diesel fuel. It determined that either a pour point depressant or fuel heaters would virtually eliminate locomotive failures due to filter plugging at temperatures around -10°F. Locomotives operating in colder climates where low temperatures are experienced for longer periods are fitted with fuel heaters. The railroad uses a mixture of one gallon isopropyl alcohol to 1000 gallons of No. 2 diesel fuel to prevent fuel filter plugging from ice crystals.

Case III:

Another problem caused by unstable fuel is fuel system deposits that can plug fuel filters and injectors.

Fuel stability is a measure of the fuel's resistance to degrade. Fuel degradation is caused by polymerization (oxidation) and breakdown of hydrocarbons that result in sludge formation.

By stabilizing the fuel, fuel filter life can be extended by minimizing filter plugging. Fuel that is free of sludge and gums eliminates injector sticking, clogged injector nozzles, and clogged fuel lines. Diesel fuel stabilizers, containing dispersants and antioxidants, have the capability to disperse sludges and gums already present in the fuel. Stabilized fuel, free of sludges and gums, insures more complete (cleaner) combustion of the fuel. This, in turn, means reduced carbon deposits on injectors, combustion chambers, valves, piston rings and eductor tubes. Cleaner fuel combustion will minimize unburned fuel and blowby contaminants that affect viscosity and reduce the use life of lubricating oil.

Fuel degradation may occur in today's market due to refinery process changes and mixing of fuels. Some railroads are not aware that they are using unstable fuel because fuel stability is not one of the No. 2 diesel fuel specifications and therefore, they do not test for fuel stability.

A Chicago based railroad ran a 90 day field trial evaluation of a fuel stabilizer. The test involved four GP40 locomotives operating on a captive route. The four locomotives were divided into two engine consists. One locomotive in each consist operated on untreated No. 2 diesel fuel, while the other locomotive ran on diesel fuel treated with 125 ppm of the fuel stabilizer. Both of the two-engine consists made one round trip of approximately 165 miles on the captive route, seven times a week for the duration of the field trial. Each locomotive was monitored weekly for primary fuel filter pressure, fuel stability, filter life extension, injector performance and lube oil composition. The locomotives were prepared for the test in the following manner:

1. Injectors were calibrated.
2. Eductor tubes were weighed and photographed.
3. Lubricating oil was changed.
4. Top decks were cleaned and photographed.
5. New primary and spin-on fuel filters were installed.

Weekly fuel samples were collected from the treated and untreated locomotives. These fuel samples were evaluated in the accelerated heat stability test at 300°F for 90 minutes and the fuel was filtered through a circular filter pad. The fuel samples were also filtered unheated. These filter pads were given a rating (see Appendix 1). Fuels with filter pad ratings greater than seven are considered poor or unstable as outlined in Appendix 1. The graphs for the locomotives operating on treated fuel (Figures 7 and 8) and the graphs for the locomotives operating on untreated fuel (Figures 9 and 10) illustrate the difference in fuel stability between the treated fuel and untreated fuel. The locomotives with untreated fuel had higher pad ratings than those that had been treated with the fuel stabilizer. The results show that fuel treated with a fuel stabilizer reduces harmful sludge that can plug filters and injectors.

Filter pressure readings: Filter pressures from the primary filters were monitored by means of a pressure transducer (0 to 15 psi) wired to a data logger (Figure 11) that recorded pressure changes across the filter. The back pressure was probably the result of insolubles from unstable fuel being trapped on the surface of the filter pleats and restricting the flow of fuel through the filter. As fuel instability increases, the pressure changes across the fuel filter. Other fuel contaminants such as dirt and rust could contribute to the pressure increase across the fuel filter.

The filter pressure test was terminated when the filters using untreated fuel experienced filter bypass or filter failure. The primary fuel filters of the locomotives operating on untreated fuel plugged after 9 and 10 weeks of service respectively (see Figure 12). The primary fuel filters on the locomotives using treated fuel continued to operate through the entire test trial (see Figure 13).

Effect of fuel stabilizers on engine components: Stabilized fuel, free of sludge and oxidation products, may produce a cleaner locomotive that can help decrease costly maintenance procedures. When the fuel is free of sludge and oxidation products, combustion is more complete, producing less soot and carbon deposits. Lower soot concentrations can reduce ring belt deposits, thereby allowing the rings to form a better seal which reduces blowby products and helps produce a cleaner locomotive.

Effect on eductor tubes: Soot accumulation on locomotive eductor tubes can be used to judge whether a fuel stabilizer helps a locomotive run cleaner. Eductor tubes are connected to the oil separator through an elbow assembly in the exhaust stack, mounted on the turbo charger housing. The exhaust gases in the stack create a suction in the eductor tube, which draws up vapors from the engine through the separator element.

Prior to the mini-field test, the eductor tubes were cleaned and photographed. Upon completion of the test, the eductor tubes were removed and photographed again.

The photographs of the eductor tube from locomotive A, running on treated fuel, are presented in Figures 14 (before) and Figure 15 (after) respectively. The eductor tube from locomotive A was weighted before and after the field test and found to have a 17 gram weight increase. Likewise, the photographs of the eductor tube from locomotive C, operating on untreated fuel, are presented in Figures 16 (before) and 17 (after). The eductor tube from locomotive C was also weighted and found to have a 63 gram weight increase during the field test.

Effect on top deck components: Prior to field test, the top decks of the locomotives were cleaned with solvent and photographed. After the test was completed, the locomotive top decks were photographed again. The photograph of the top deck and rocker arms of locomotive A (treated fuel), prior to the field test, is presented in Figure 18. The photographs of the top deck cover and rocker arm assembly from locomotive A, after the field test, are located in Figure 19 and Figure 20 respectively. The photographs, before the field test, on the top deck and camshaft of locomotive C, which ran on untreated fuel, are presented in Figures 21 and 22 (before the field test) respectively. The photographs of the top deck and camshaft, after the field test, are located in Figures 23 and 24 respectively. Although the photographs suggest that the fuel stabilizer can help a locomotive run cleaner due to the short duration of the field test, further testing should be done to verify this observation.

Other factors that could contribute to engine deposits in the eductor tubes or top deck area are: 1) excessively worn engine components, 2) locomotives not operating at proper design efficiency, and 3) low operating temperatures.

Fuel stabilizers may improve the performance of low quality fuels. The cost of fuel treatment must be weighed against the benefits of reduced maintenance and downtime. In some cases, as above, fuel treatment can be expensive. The 125 ppm level used in this field trial represents a treatment cost of 0.2¢ per gallon.

Final comments: Most of the diesel fuel used by the railroads

is of good quality. However, if due to supply shortages or favorable pricing, lower quality fuel is used on a routine basis, then deposits and operational problems can occur. To handle the problems of lower fuel quality, additives can be one solution. Another solution may be shorter maintenance intervals.

APPENDIX 1

ACCELERATED HEAT STABILITY TEST

(300 degrees Fahrenheit, 90 minutes)

This accelerated aging test was developed to obtain storage stability information and evaluate the severe conditions a diesel fuel encounters. It is used to evaluate the relative stability of many distillate fuels and the relative effectiveness of fuel additives.

Materials:

Constant temperature oil bath, set at 300° Fahrenheit ±2° Fahrenheit
2 x 2 cm pyrex test tubes
500 ml suction flask
Millipore pyrex filter holder
Vacuum source
No. 1 Whatman filter paper, dia. 4.7 - 5.5 cm
Heptane
100 ml disposable beakers

Standard set of filter paper ratings (See preparation of standard filter papers)

Procedure:

Measure 50 ml of the oil sample in a 100 ml disposable beaker. (Note) Place two No. 1 Whatman filter papers on the Millipore pyrex filtering apparatus. Two filter papers are used so that the sediment being collected is uniformly dispersed on the top filter paper. Suction is applied only after the addition of the 50 ml of oil sample to the filtration apparatus. Wash the filter paper with 50 ml of heptane, let it air dry, then remove the filter paper. The top filter paper is rated by comparing it to the standard set of filter papers, numbered 1 to 20. This is the unheated, untreated, "blank" filter paper. The bottom filter paper is discarded.

Measure a second 50 ml of the oil sample in a 100 ml disposable beaker, then pour it into a pyrex test tube. Also at this time, measure 50 ml of any various dosages of treated oil samples and place them in pyrex test tubes.

Place the pyrex test tubes with the oil samples into the oil bath, preheated to 300 degrees Fahrenheit.

Remove the test tubes from the oil bath after exactly 90 minutes. Allow the samples to cool at room temperature. Cooling should be gradual. Fast cooling may lead to inaccurate results. Filtration should be finished within a short time after the sample reaches room temperature. Long standing before filtration can change results.

Each 50 ml oil sample is poured into the Millipore pyrex filtering apparatus for filtration, using two No. 1 Whatman filter papers. Suction is applied only after sample has been added.

Wash the filter paper with 50 ml of heptane, let it air dry, then remove the filter paper. The top filter paper is rated by comparing it to the standard set of filter papers. The bottom filter paper is discarded.

The filter paper ratings are determined and compared to the "blank" filter paper rating to evaluate the degree of degradation. A passing rating in this test is usually a filter paper rating of 7 or lower. Some oil companies have set their limits at a filter paper rating of 4 to 5 maximum.

Note:

This procedure cannot be performed on samples containing a visible amount of water. Samples should be filtered prior to testing if a large amount of sediment is present. Filter through No. 1 Whatman, this removes any materials other than those formed by aging.

Preparation of Standard Filter Papers:

One-half gram of Norit A is suspended in 2500 ml of n-heptane with good agitation. (Norit A is a finely ground activated charcoal manufactured by the Pfanstiehl Laboratories, Inc., Waukegan, IL.) Various quantities of this suspension are withdrawn, diluted with heptane and filtered through No. 1 Whatman filter papers. The filter papers were sprayed with Grumbacher charcoal fixative to prevent the loss of Norit A in handling. (The charcoal fixative is available in most art stores.)

The following pads were prepared:

Number	Volume of Suspension in ml	Amount of Norit A in mg. on filter paper
1	0	0
2	0.2	0.04
3	0.6	0.12
4	1.0	0.2
5	1.5	0.3
6	2.0	0.4
7	2.5	0.5
8	3.0	0.6
9	3.5	0.7
10	4.0	0.8
11	5.0	1.0
12	6.0	1.2
13	7.0	1.4
14	8.0	1.6
15	9.0	1.8
16	10.0	2.0
17	20.0	4.0
18	30.0	6.0
19	40.0	8.0
20	50.0	10.0

Reference:

Technifax - Procedures for Evaluating the Stability of Distillate Fuel Oils, July 1976, Petroleum Division TF9 Refinery Chemicals.

TABLE 1
COMMON FUEL ADDITIVES

Identity	Function
Corrosion inhibitor	Prevent corrosion of fuel system parts
Antioxidant	Stabilize fuels to prevent gum formation
Color stabilizer	Prevent color degradation of fuel during storage
Flow improver and pour point depressant	Alter wax crystal growth pattern to allow operation at lower temperatures
Dispersant	Reduce fuel system deposits by dispersing gummy, insoluble residues
Cetane improver	Improve ignition quality of fuel by increasing cetane number
Fuel system biocide	Decrease sludge and slime which causes filter plugging by inhibiting bacterial growth
Combustion catalyst	Reduce exhaust smoke

Diesel fuels usually do not require all of the above additives.

TABLE 2

	Pour Point	CFPP/Wax Cloud
A) No. 2 Diesel Fuel	0°F	+10°F
B) 60% No. 2 Diesel Fuel 40% Kerosene	—15°F	0°F
C) 80% No. 2 Diesel Fuel 20% Kerosene Wax Crystal Modifier	—15°F	0°F
D) No. 2 Diesel Fuel Wax Crystal Modifier	—15°F	0°F

TABLE 3

A)	No. 2 Diesel Fuel ($0.80 x 50,000,000 gals.)			$40,000,000
B)	60% No. 2 Diesel Fuel 40% Kerosene 2% BTU Loss ($0.832 x 50,000,000)			$41,600,000 832,000
			Total	$42,432,000
	Cost Per Gallon	$0.049		
C)	80% No. 2 Diesel Fuel 20% Kerosene Wax Crystal Modifiers 1% BTU Loss ($0.821 x 50,000,000)			$41,050,000 410,500
			Total	$41,460,500
	Cost Per Gallon	$0.029		
D)	No. 2 Diesel Fuel Wax Crystal Modifier ($0.805 x 50,000,000)			$40,250,000
	Cost Per Gallon	$0.005		

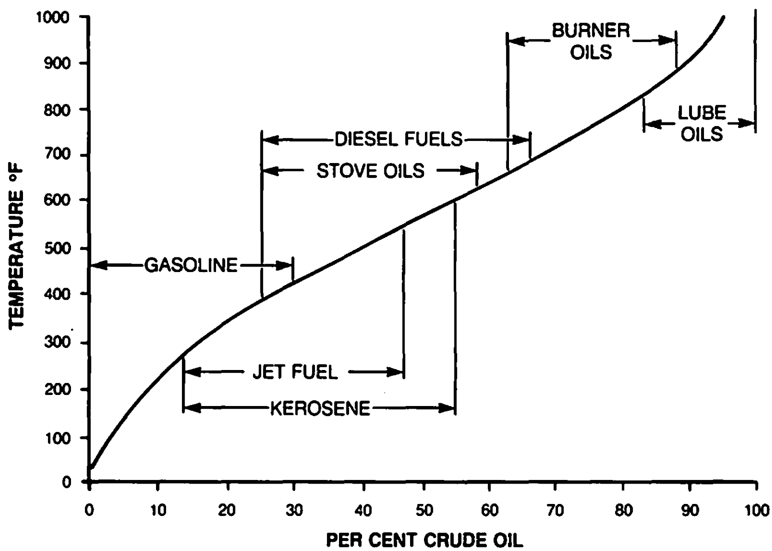


FIGURE 1

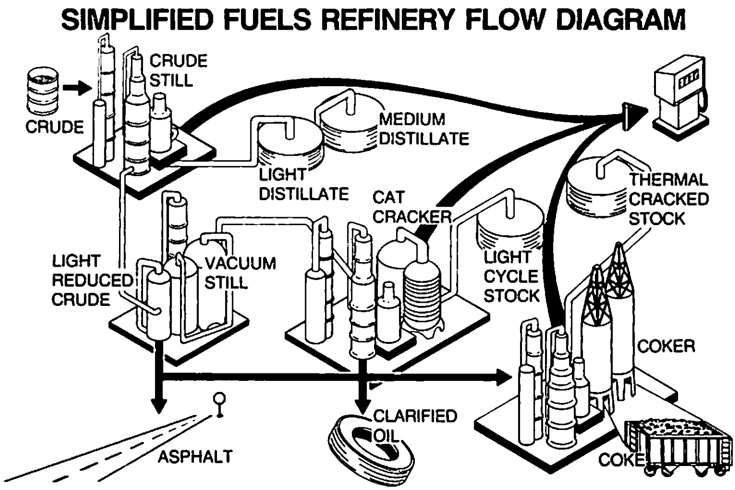


FIGURE 2

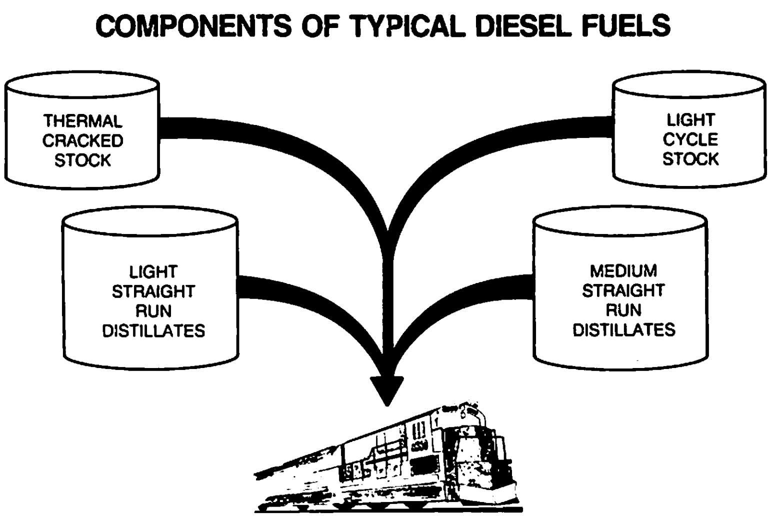
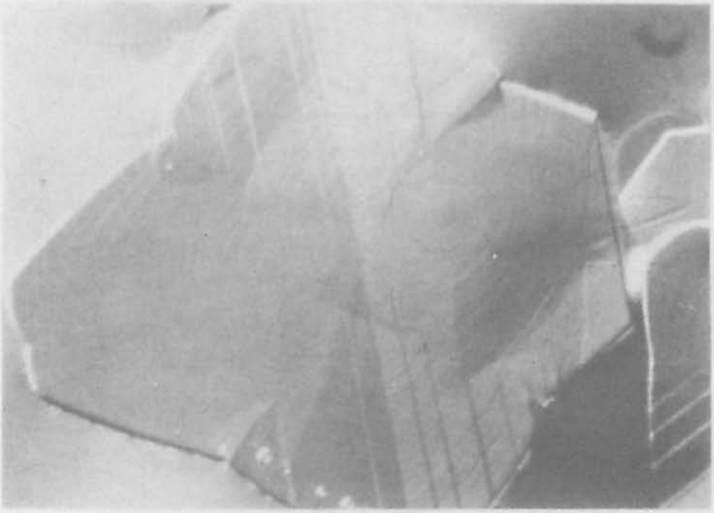


FIGURE 3

LARGE WAX CRYSTALS DEVELOP IN UNTREATED FUELS



- ≈0.5 mm Long
- Block Narrow Transfer Lines
- Block Filters

FIGURE 4

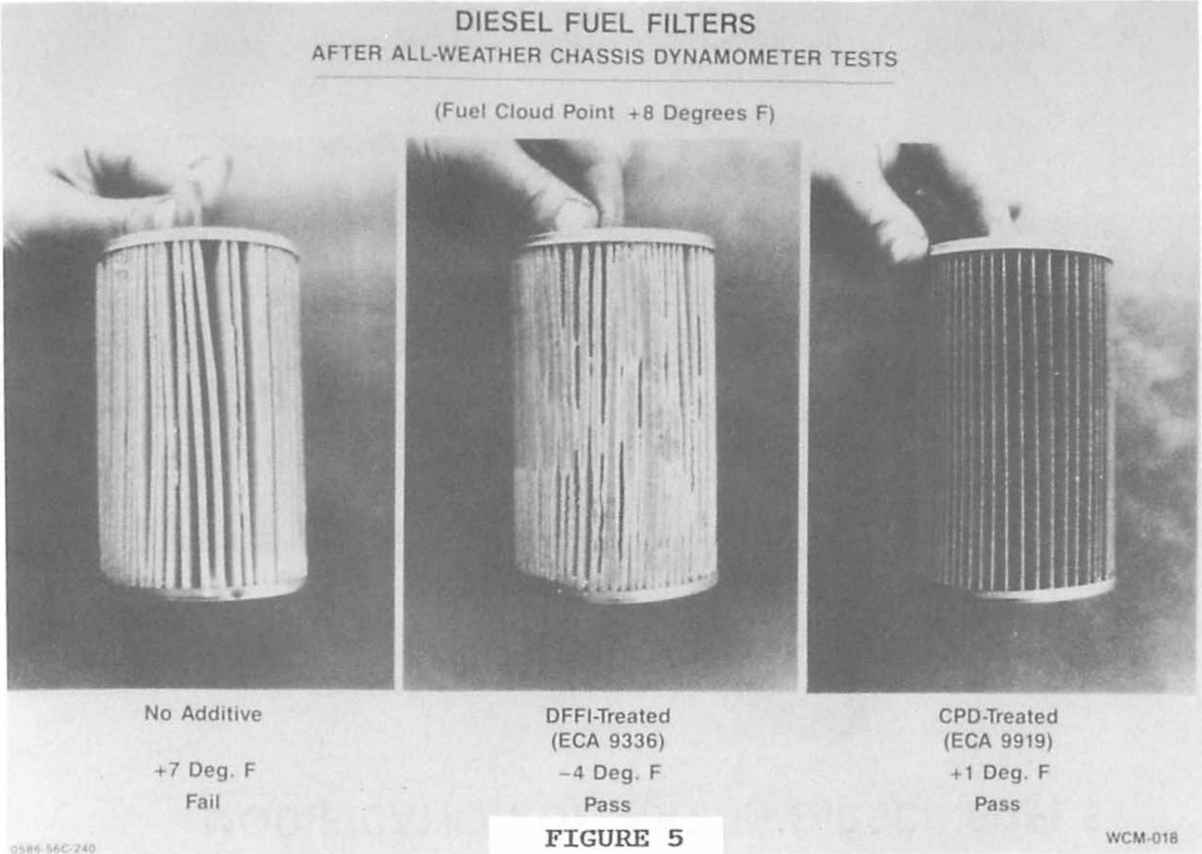

DIESEL FUEL FILTERS
AFTER ALL-WEATHER CHASSIS DYNAMOMETER TESTS
(Fuel Cloud Point +8 Degrees F)
No Additive
+7 Deg. F
Fail
DFFI-Treated
(ECA 9336)
-4 Deg. F
Pass
CPD-Treated
(ECA 9919)
+1 Deg. F
Pass
0586-56C-240
WCM-018

FIGURE 5

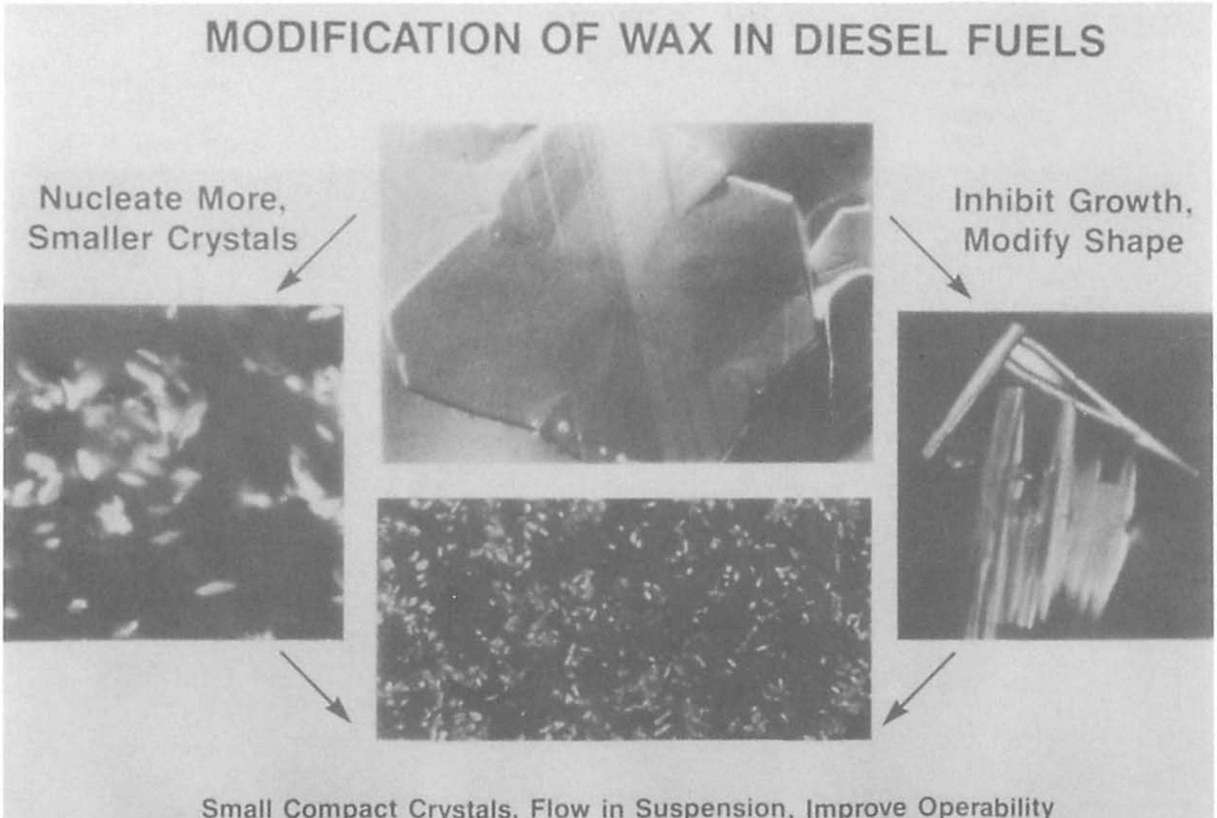

MODIFICATION OF WAX IN DIESEL FUELS
Nucleate More, Smaller Crystals
Inhibit Growth, Modify Shape
Small Compact Crystals, Flow in Suspension, Improve Operability

FIGURE 6

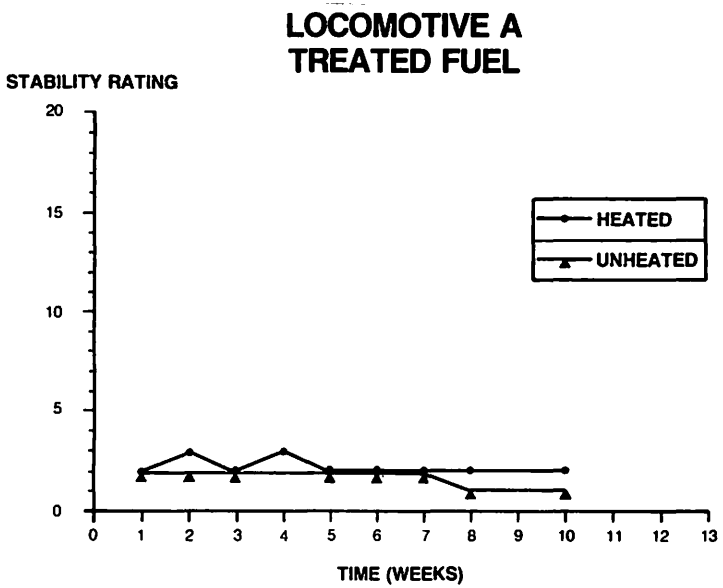


FIGURE 7

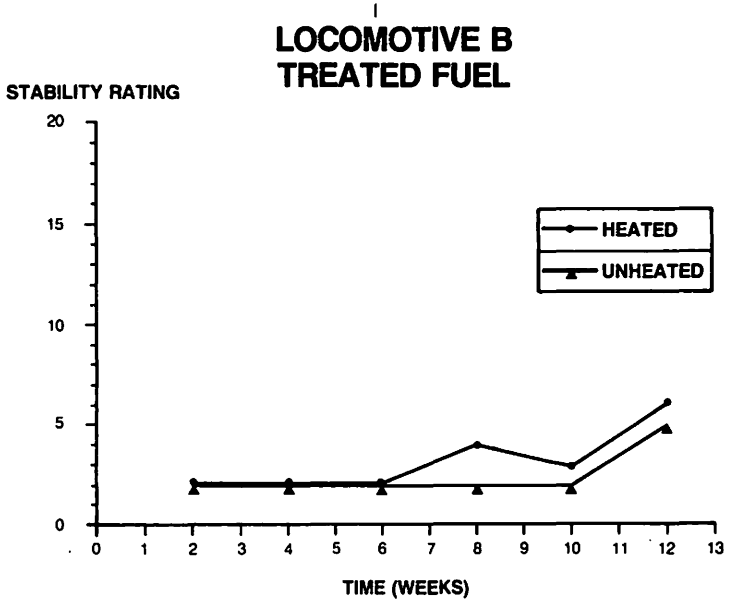


FIGURE 8

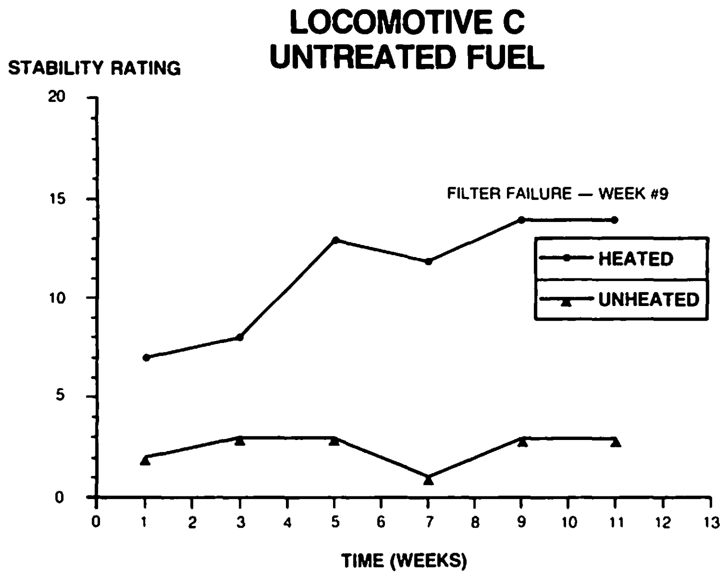


FIGURE 9

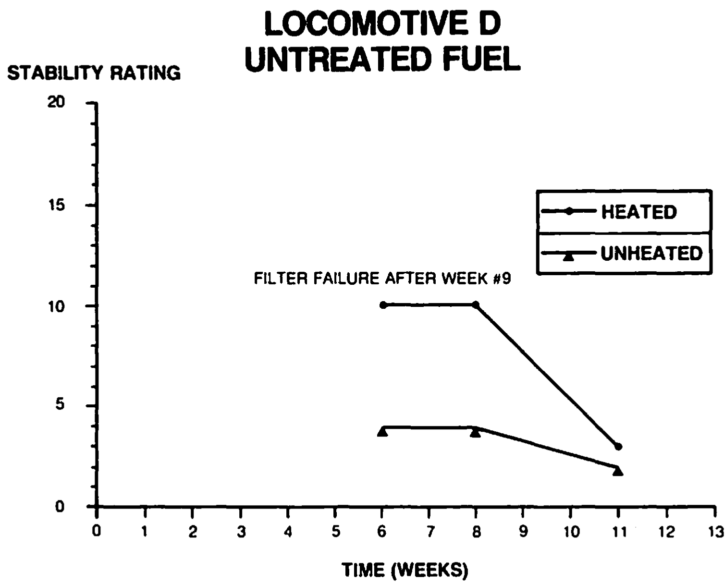


FIGURE 10

FIGURE 11

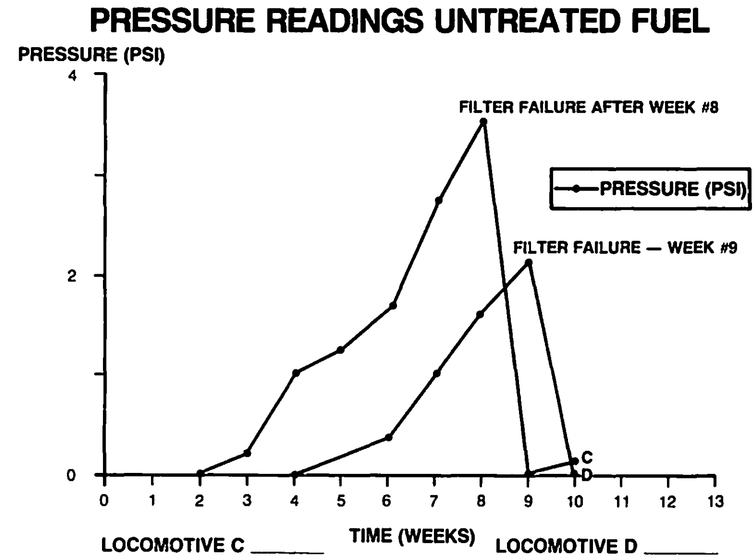


FIGURE 12

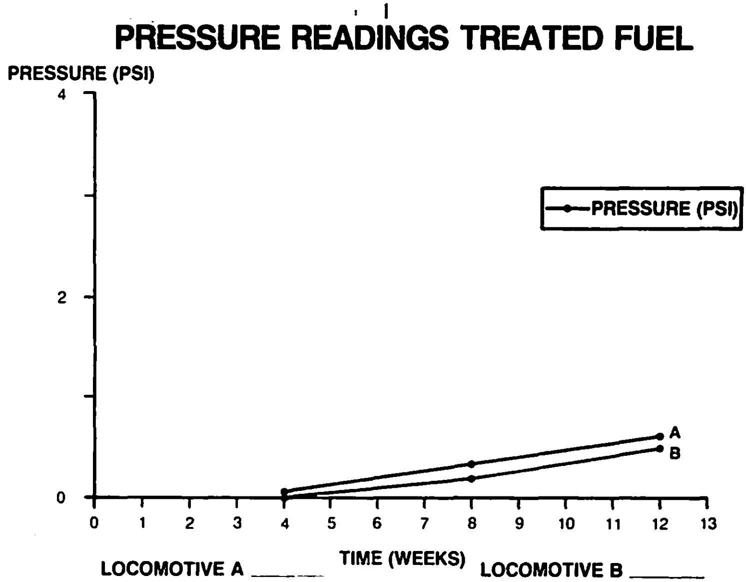


FIGURE 13

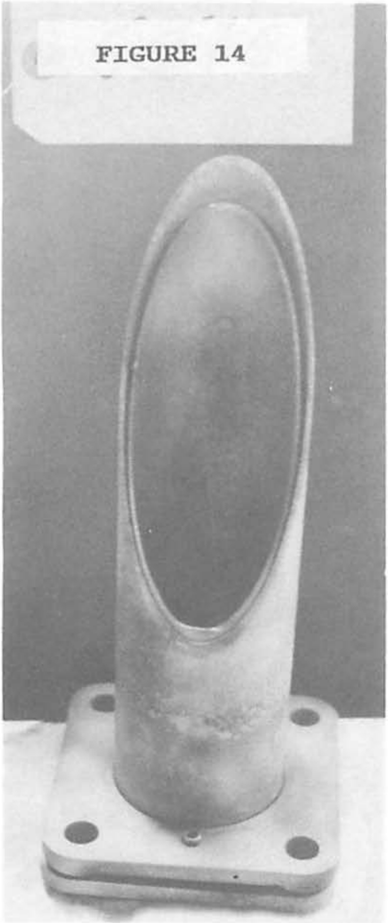


FIGURE 14

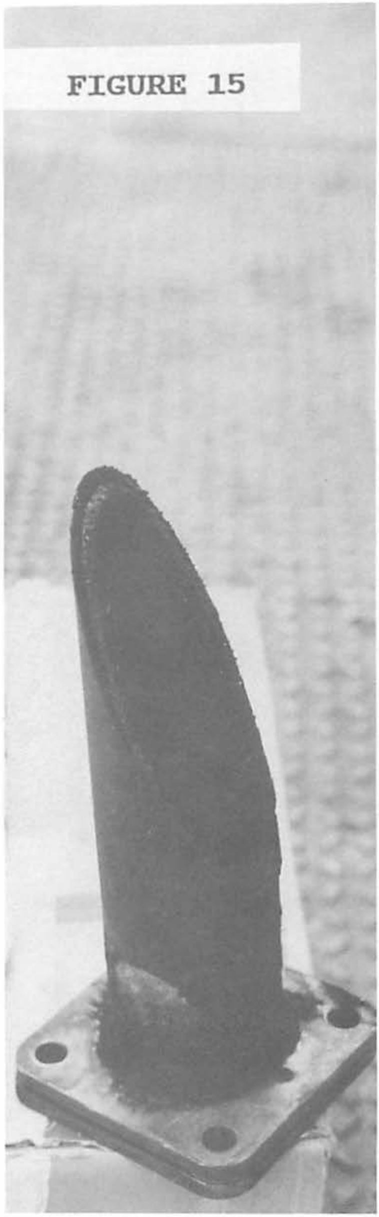


FIGURE 15

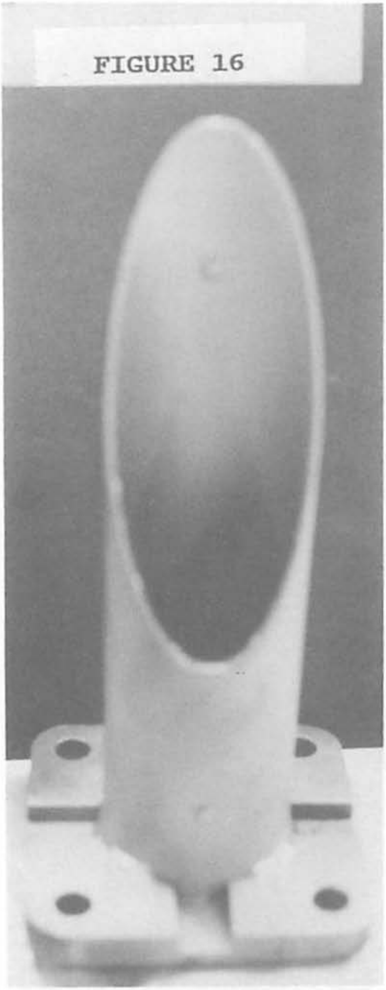


FIGURE 16

FIGURE 17

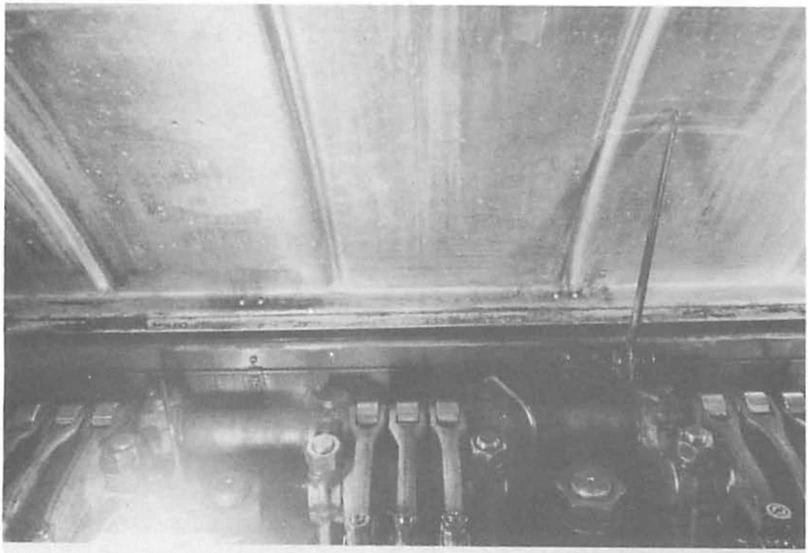


FIGURE 18

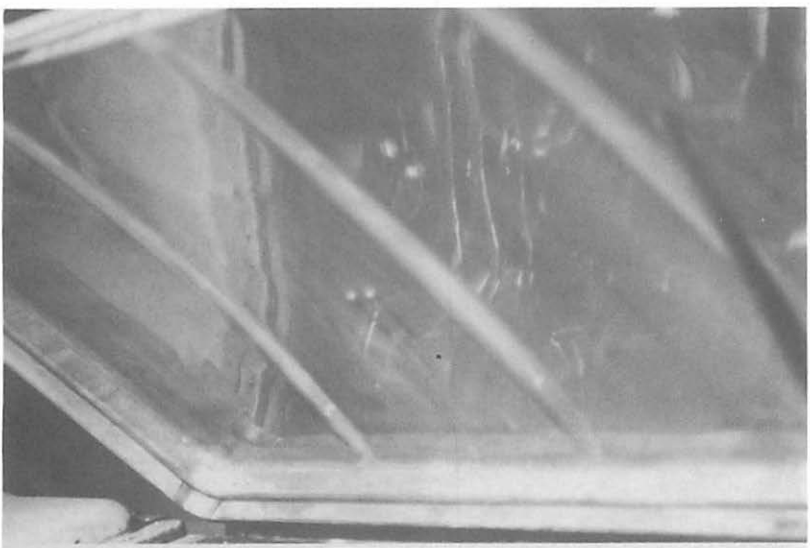


FIGURE 19

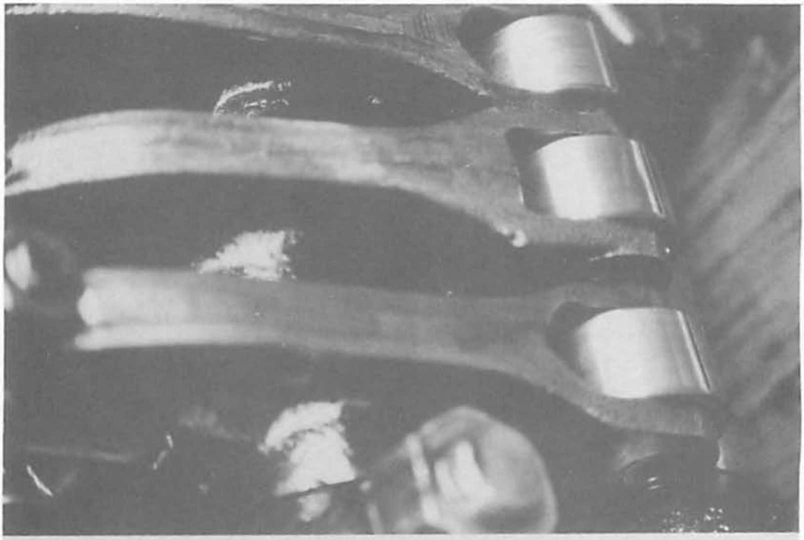


FIGURE 20

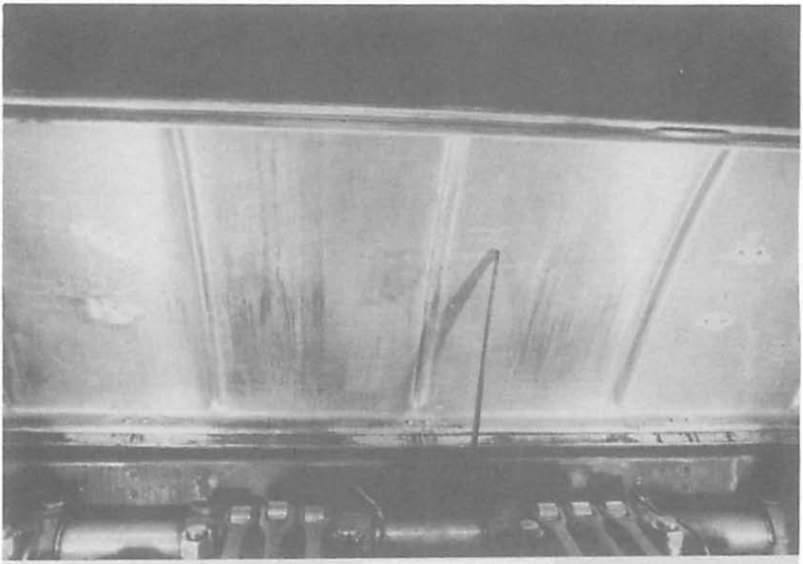


FIGURE 21

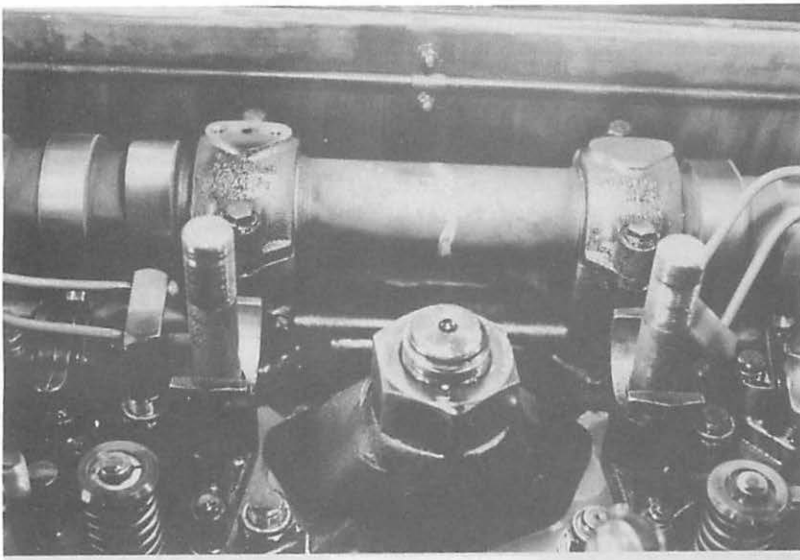


FIGURE 22

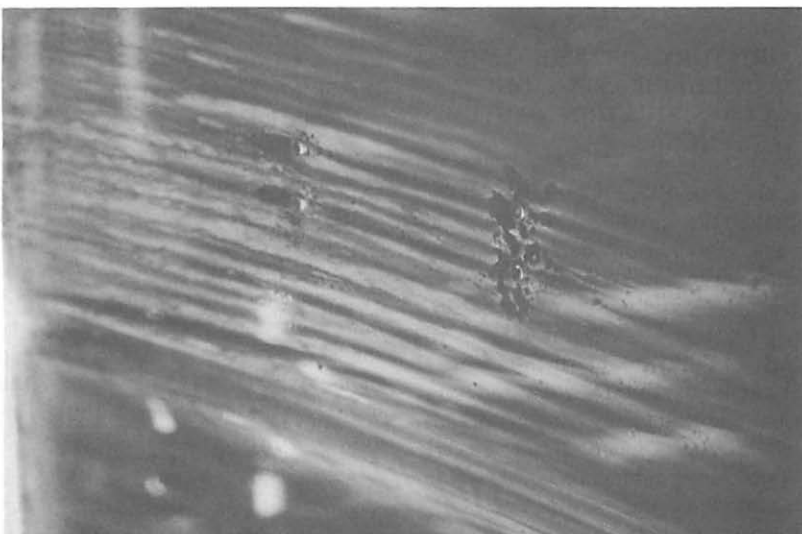


FIGURE 23

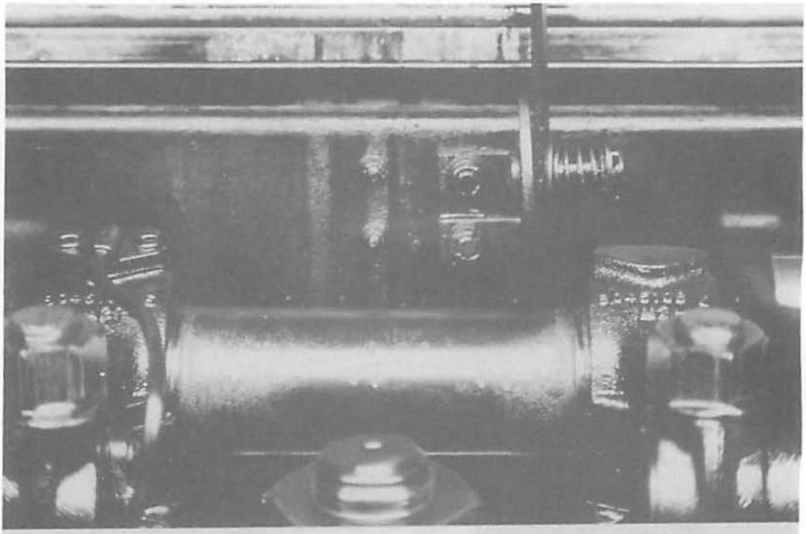


FIGURE 24

II.

HISTORY OF THE LMOA LUBRICATING OIL CLASSIFICATION SYSTEM

Changes in the Railroad Industry

On June 17, 1933 when Ralph Budd, the president of the Chicago, Burlington & Quincy Railroad, ordered the first diesel electric locomotive for over-the-road use he started a revolution. A revolution that would bring radical changes to the railroad industry. Changes which, by the year 1961, would see 28,500 diesel electric locomotives replacing 50,000 steam locomotives and hauling twice the tonnage at half the cost. Cost reductions in fuel, maintenance, and lost revenue gave a distinct advantage to diesel electric locomotives.

Diesel Electric Locomotives

Diesel locomotives were pulling heavier and heavier loads longer and longer distances. More and more power had to be pulled out of the diesel engine (see Figs. 25 & 26). Fuel consumption had to be reduced. Maintenance intervals had to be lengthened. Such were the needs of the changing railroad industry then; and such are the needs of the changing railroad industry now.

As the age of the diesel electric locomotive was ushered in, it became apparent that such diesel engines required advanced lubrication, using advanced lubricants de-

signed not only to lubricate but to keep the interior of the engine clean, to keep the compression rings from sticking, and to neutralize the acids formed as products of combustion. Lubricants had to be able to withstand both heat and pressure without oxidizing or otherwise breaking down.

LMOA Involvement

In developing more powerful diesel engines the manufacturers worked with the oil companies and the railroads. One group which was instrumental in this collaboration was the Locomotive Maintenance Officers Association. Through its Fuels and Lubricants Committee LMOA provided a forum for the manufacturers, oil companies and railroads to work together to solve mutual technical problems, thereby advancing technology and the railroad industry.

What were/are the requirements of modern diesel engines?

The railroad diesel, including 2 and 4 stroke models required the following characteristics.

- Control of deposits at high temperatures
  - Hard carbon
  - Piston ring sticking
  - Piston undercrown deposits
- Adequate lubricity
- Corrosion protection
- Resistance to scuffing
- Frictional properties to avoid turbo clutch slippage
- High dispersancy
- Tolerance to water leaks
- Optimum valve train lubrication
- Protection for silver bearings
- Performance
  - Viscosity control
  - Thermal stability
  - Alkalinity retention

These were and still are the major requirements of railroad diesel engines. In the formulation of railroad diesel engine lubricating oils there is a need for balancing the lubricant to meet all of these needs.

Performance Distinctions

As technical problems involving engine design and lubrication were solved and as advances in technology were made, there developed different classes of lubricating oil. Eventually these different classes of lubricating oil were given such names as:

Superior Class I

Superior Class II

Superior Class II High Alkalinity

Extra Performance.

Although these names identified classes of lubricating oils the differences between the classes were unclear. During the early 1970's an effort was made to start a classification system for railroad lubricating oils based on demonstrated performance. The end result of this effort was the development of the Generation nomenclature currently used by the LMOA

and the railroad industry (Figure 27).

The Generation nomenclature was adopted because it embodies in its name that a significant advance in technology has taken place. Major changes in the performance level of a railroad lubricating oil have not taken place frequently. Since 1940 only four generations of lubricating oil have been defined.

What are those four generations and how are they different?

Generation 1 (Introduced 1940) TBN < 7

Generation 1 oils included straight mineral oil as well as some oils which were lightly compounded with detergents and antioxidants. Dispersants were not yet developed and the quality of lubricants varied widely. Subsequently their use in rapidly evolving diesel locomotives resulted in a quick loss of alkalinity, lead corrosion and bearing failures.

Generation 2 (Introduced 1964) TBN $= 7$

Generation 2 oil introduced ashless dispersants which allowed greater insoluble concentrations in the oil. It also had moderate levels of calcium based detergents which improved alkalinity. Generation 2 oils came about due to a need for reduced sludge and better oil filteration.

Generation 3 (Introduced 1968) TBN $= 10$

Generation 3 demonstrated improved alkalinity retention as well as higher dispersant levels and calcium detergent. Generation 3 oils came about in response to a need for reduced piston ring wear.

Generation 4 (Introduced 1976) TBN $= 13$

Generation 4 oils demonstrated another improvement in alkalinity retention along with further improvements in detergency and dispersancy. Proof of these improvements was documented during the development of the LMOA (see LMOA paper for Fuels & Lubes Committee 1976) field test procedure.

It should be noted that for convenience each generation is grouped by alkalinity as measured by ASTM D-2896. Even though the oils are grouped by alkalinity the improved performance parameters are not limited to alkalinity.

Requirements of new or uprated engine designs may to a certain extent drive the development of new performance generations. Important also is the fact that perceived field performance limitations of commercial products can also require the development of a new lubricating oil performance category. This simply says that most major oil developments have come about as a result of a demonstrated field need.

However this was not true for Generation 4, which is the current standard for railroad lubricating oils. The fact is that Generation 4 oil was made available to the rail-

road industry somewhat in advance of the broad need for its performance level. Increased performance was developed in advance of the requirement for it.

What changes in engine design have occurred?

Some of the design changes which have taken place over the years are listed below:

Increased power levels

Increased full load speeds

Lower idle speeds

Higher compression ratios

Increased piston displacement

Greater fuel injection rates

Improved fuel injection quality

Higher lube oil operating temperatures

Higher peak firing pressures

More exposure to oxidation catalysts

Lower lube oil consumption.

Many of these changes have taken place more than once. Each of these changes puts some additional stress on the lube oil.

What changes in operation and maintenance have taken place?

Operational and maintenance changes have occurred which affect lube oil performance. A list of some of these changes is given below:

Increased shutdown of engines

Interchange of locomotives between railroads

Use of lower grade fuels

Deferred engine maintenance

Desire for longer lube oil drain intervals

Desire for longer lube oil filter life

Increased duty cycles.

While some of these changes will minimally affect the lube oil performance, others will definitely reduce it due to added stress. Customer desires further change the definitions used to judge what is acceptable lube oil performance.

What are the trends in engine design?

In the past few years there has been a demand for improved engine performance in the following areas:

Improved fuel efficiency

Higher horsepower

Broadened fuel specifications

Reduced maintenance

These trends are not likely to change in the future. As the manufacturers try to utilize all available means to improve these performance parameters the lubricating oil will most likely be subjected to more stress.

Are there Generation 5 oils?

Whether it is required now or not, it is inevitable that sooner or later a new generation performance level will be necessary. Already there is interest in Generation 4 lubricant with longer life. Several companies have in the past few years developed or are currently testing new oil additives. Improvements in performance can be demonstrated.

Figures 28 and 29 illustrate improved alkalinity retention in bench engine tests (D17 and D7). This improvement is evident in spite of the fact that the test conditions for these tests have increased in severity. The increased severity has prevented any obvious improvement in viscosity control (Figure 30). However, that the viscosity control has not become worse demonstrates that there is indeed an improvement in oil thickening control. Figure 31 also demonstates improvements in ring groove deposit control.

A perspective on the needs of the railroad industry is given in the next section.

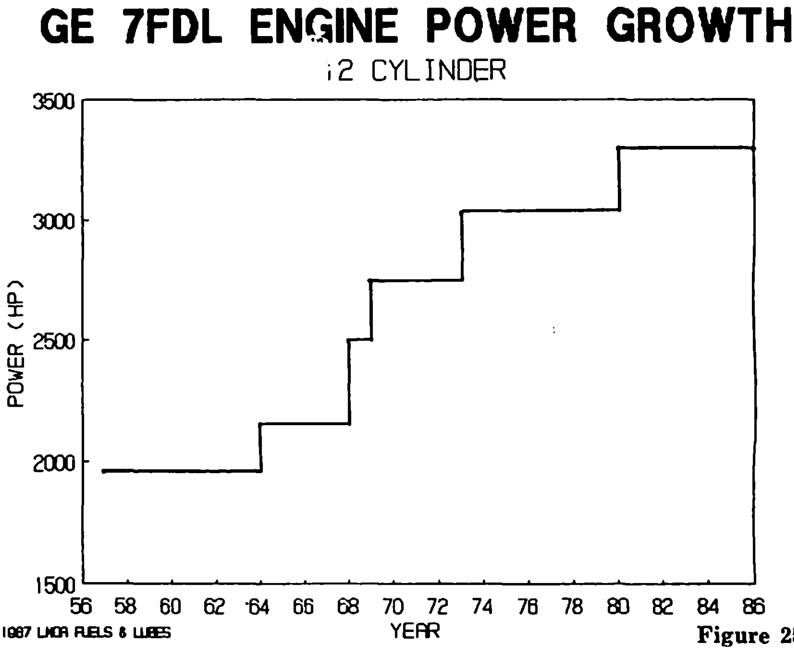


Figure 25

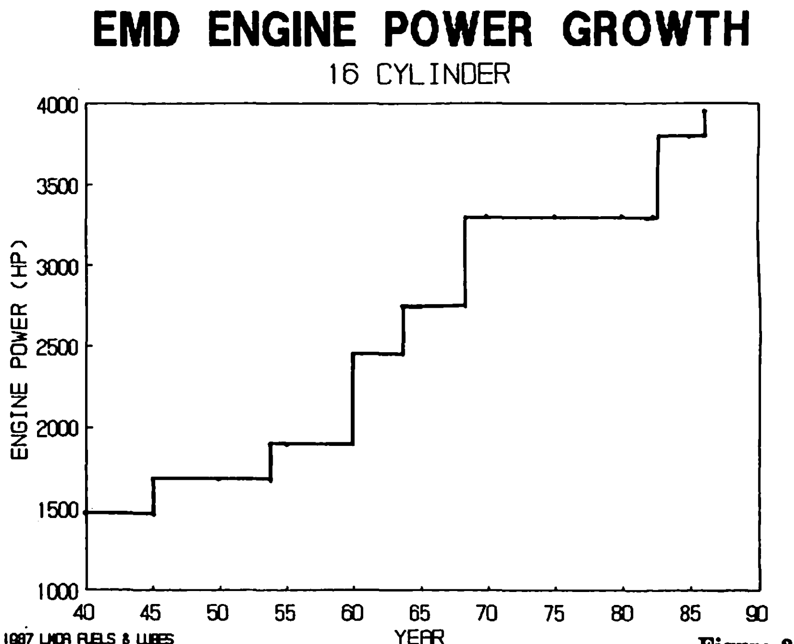


Figure 26

RAILROAD OIL CLASSIFICATION

LMOA DESIGNATION	PERFORMANCE PARAMETER	FORMULATION CHARACTERISTIC	INTRODUCED
GENERATION 1	FIRST RR LUBE OIL	STRAIGHT OIL MIN. ADDITIVES	AROUND 1940
GENERATION 2	EXTENDED OIL & FILTER LIFE	DISPERSANCY FIRST ADDED	1964
GENERATION 2	REDUCED STUCK RINGS IN FOUR CYCLE ENGINES	IMPROVED RING BELT DEPOSIT CONTROL WITH NEW DETERGENT	1968
GENERATION 3	IMPROVED BASE RESERVE FOR 2 CYCLE ENGINES	INCREASES IN ALKALINITY AND DETERGENCY	1968
GENERATION 3	IMPROVEMENTS IN ALKALINITY AND CONTROL OF INSOLUABLES	HIGHER LEVELS OF ALKALINITY AND DISPERSANT	1975
GENERATION 4	INCREASED PROTECTION FOR ADVERSE ENGINE OPERATING CONDITIONS	MUCH HIGHER ALKALINITY AND IMPROVED DISPECSANCY & DETERGENCY	1976

Figure 27

ALKALINITY DELPETION IN LAB ENGINE TESTS

4 CYCLE D-17 TEST

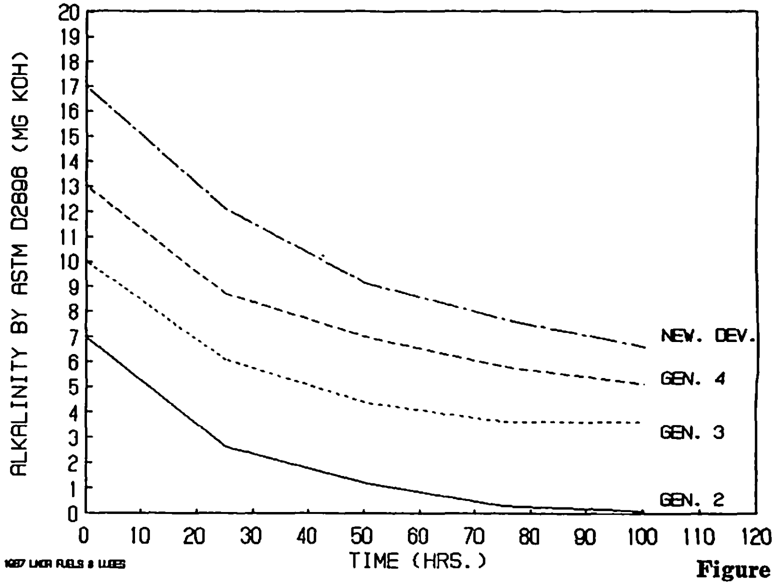


Figure 28

ALKALINITY DELPETION IN LAB ENGINE TESTS

2 CYCLE D-7 TEST

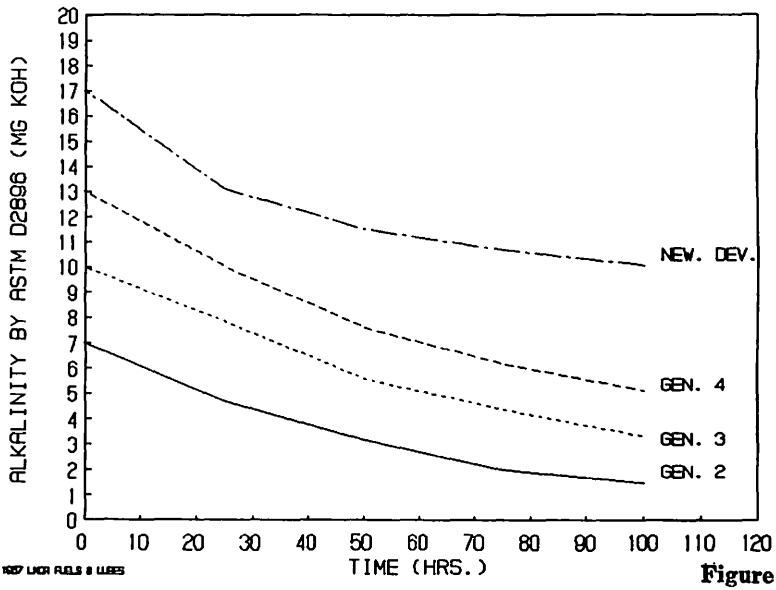


Figure 29

VISCOSITY INCREASES IN LAB ENGINE TESTS

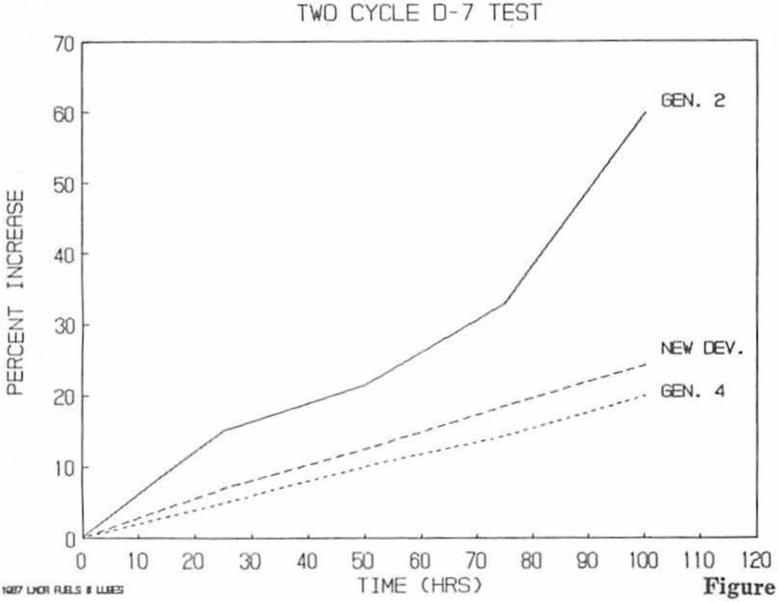


Figure 30

PERCENT TOP GROOVE FILL

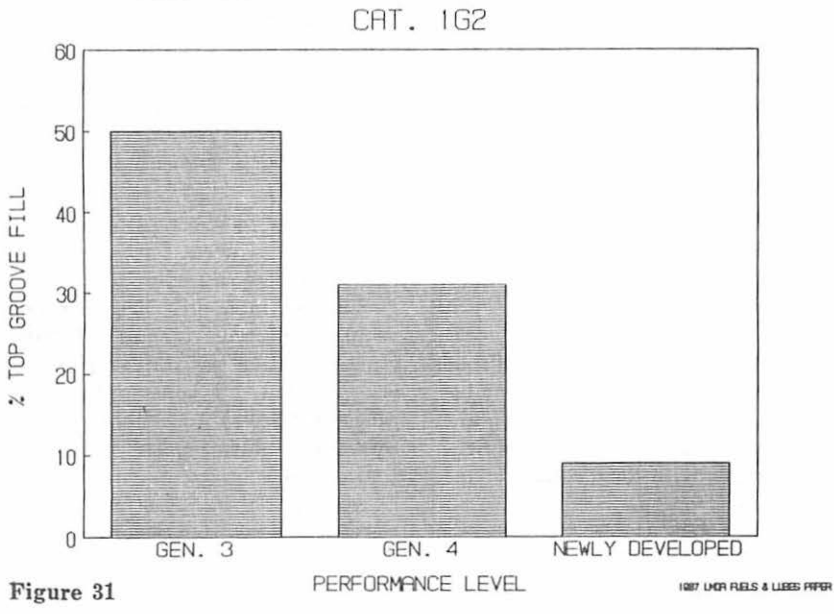


Figure 31

III.

PERFORMANCE REQUIREMENTS NEEDED BY THE RAILROADS FOR A NEW GENERATION LUBE OIL

The greatest impact on engine oil performance today is from higher operating temperatures and lower operating oil consumptions which lead to shorter oil life.

Both General Electric and Electro-Motive have realized savings from these changes, but further improvements may be limited by the capabilities of current Generation 4 lubricants. Present Generation 4 lubricants normally satisfy the OEM lubricant requirements, but may not fully meet the railroad operational requirements.

New Generation additive packages developed to meet the challenge of the late eighties and beyond must extend oil drain intervals and enable higher temperature operation in newer locomotives.

As mentioned in the previous section, present railroad operating practices have changed and contributed to the shortened Generation 4 oil life. This subject was also addressed in depth by a paper in the 1986 LMOA book titled "Importance of Maintenance and Operating Practices," Pages 109 to 112.

The bottom line for railroads today is to improve profitability. This has involved mergers, higher locomotive utilization, longer, heavier trains, with longer maintenance intervals.

The newer locomotives are part of this improved profitability picture, with reduced fuel consumption, higher operating temperatures and lower oil consumption. All of the design and operational changes above place tougher demands on the engine lube oil (Table 4).

Lubricating oils to satisfy today's locomotives must provide:

1) An oil film which is non-corrosive and provides satisfactory lubrication to engine bearing materials including silver, copper and lead;
2) Adequate film strength to satisfactorily lubricate all moving parts;
3) Ability to neutralize acids of combustion;
4) Sufficient dispersancy to provide satisfactory oil filter life, control oil cooler deposits, and maintain open oil passages;
5) Control of deposits in critical areas which can cause ash, carbon and sludge to a degree sufficient to interfere with the performance of the engine.

A survey was conducted to determine the needs and requirements of the railroads for a new generation lube oil. The primary requirement was for an oil with good oxidation resistance, particularly in low oil consumption engines, sufficient to extend operations 180 days under moderate service, without excessive viscosity increases.

The next requirement was to have good dispersancy - detergency to prevent sludging in extended service, reduce filter loading and maximize filter life.

The new oil should also have sufficient reserve alkalinity to meet any anticipated lower fuel quality and maintain a high equilibrium TBN to provide maximum wear protestion.

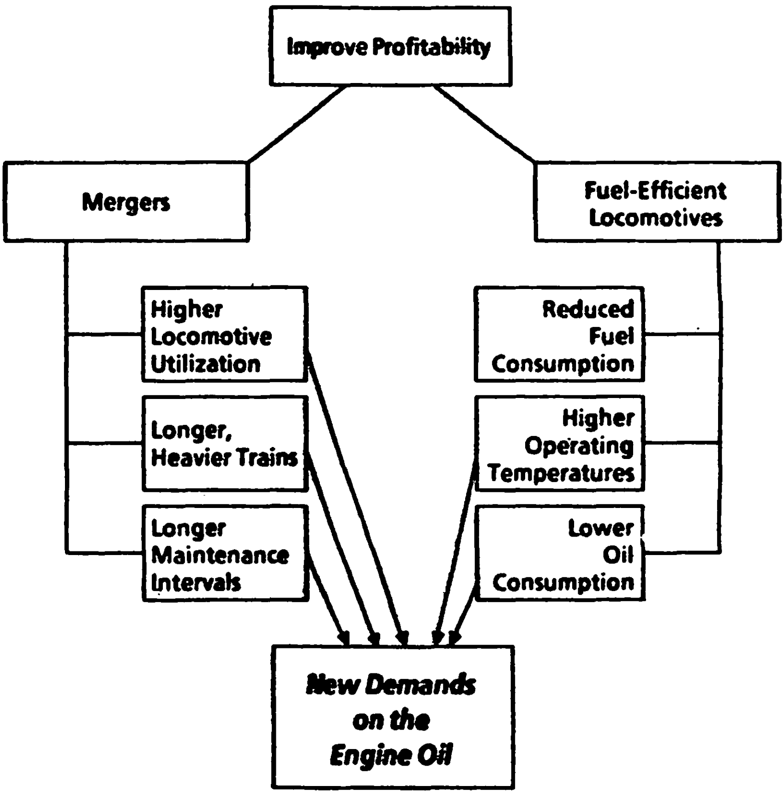
The current generation lube oil does not satisfy all requirements of the new locomotives and operating conditions.

This committee has the tools to undertake an evaluation of proposed new generation lube oils. It may, in cooperation with the manufacturers, review compartive laboratory test data, including engine bench tests. It also has the results from full scale field tests, all of which follow LMOA guideline, which can be reviewed to ascertain if a significant advance in railroad lubricant technology has taken place. Results from these tests can form the basis for defining the new generation performance level and a definition based on improvement in performance.

The suppliers have the capability and can meet the needs of today's railroads.

Table 4

Changes in the Railroad Industry Demand Improved Lubricant Technology



IV.

HOW DO WE PROVIDE THE PERFORMANCE NEEDED FOR A NEW GENERATION OIL?

Lubricant Performance Properties

Today's demanding engine and service environment requires more from the crankcase lubricant than ever before. The blend of base oils and additives used in formulating these products must be carefully balanced to provide satisfactory performance, since overemphasis or neglect in any one area may degrade performance in another. Table 5 lists the major variables and performance properties which need to be considered when formulating a railroad lubricant.

VISCOSITY is important since locomotive engines are designed for a specific viscosity range. An excessively high viscosity can increase fluid friction and fuel consumption, while reducing oil flow. An excessively low viscosity can reduce the oil film thickness and accelerate wear.

OXIDATION INHIBITORS extend oil life by controlling viscosity increase and minimizing the production of acids.

ALKALINE ADDITIVES neutralize corrosive acids as well as help control oxidation and deposits. They are the major source of base, i.e. TBN (Total Base Number) in railroad formulations. Insufficient alkalinity contributes to more rapid ring and liner wear, increased oil oxidation and increased deposits.

DISPERSANTS suspend oil insolubles, minimize low temperature sludge and varnish deposits, and reduce filter plugging. They can improve viscosity control by keeping fuel soot particles from agglomerating.

DETERGENTS are essential to minimize high temperature deposits which can cause piston ring sticking, bore polishing and reduced heat transfer.

Laboratory Bench Tests

The lubricating oil must perform satisfactorily under all operating conditions. While the condition and performance of the engine in actual service provide the ultimate criteria in reaching a final judgment on oil suitability, there are several laboratory tests which are useful in making preliminary product evaluations. Table 6 correlates some of the available locomotive lubricant bench tests with the oil performance properties.

Current laboratory testing emphasis is on oxidation bench tests since viscosity increase due to oxidation is one of the limiting properties of today's Generation 4 lubricants. The oxidation tests currently used by major U.S. Railroads and Original Equipment Manufacturers (OEM's) are listed in Table 7.

All of the tests are run at elevated temperatures (285°F to 350°F) using oxygen and catalytic metals to accelerate the oxidation reaction. The oxygen, as air or elemental oxygen, is introduced into the oil via two different methods, bubbling or stirring. The catalyst metals are usually copper and iron, and are introduced to the oil as either solid coupons (metal strips) or as soluble organo-metallic compounds. At the end of the test, the oil viscosity and other parameters are measured. These data are analyzed to determine the oil performance.

OEM Evaluation Procedure

The OEM's require a series of bench, engine, and field tests before approval is granted for general use. This procedure is outlined in Table 8.

After the lubricant has successfully completed the field test and the OEM's have reviewed the data, it is approved as "satisfactory for general use." The OEM's may require additional field testing for significant base stock changes. Products which have been approved by the OEM's in this manner are designated using LMOA nomenclature.

Laboratory Performance of Newly Developed Lubricants

The performance of newly developed lubricants was evaluated in multiple bench and laboratory engine tests. The products tested were: a 13 TBN MVI oil, a 17 TBN MVI oil and a 13 TBN HVI oil.

Figures 32 & 33 show the results from two stirring oxidation tests which were run comparing the new, 17 TBN MVI product (Oil D) with three 13 TBN MVI Generation 4 products. The results show that the new 17 TBN product outperforms the three Generation 4 lubricants in both of the bench oxidation tests.

Table 9 shows results from a dynamic oxygen absorption test similar to the modified more severe Sinclair oxidation test shown in Figure 33. The criteria for measuring oxidation stability in this test are: the induction time, in minutes, for the oxygen absorption rate to begin increasing rapidly; and the time, in minutes, for 2 liters of oxygen to be absorbed by the sample. Significant improvement in oxidation control was obtained for the new product, a 13 TBN MVI oil (C), when compared with two commercial Generation 4 oils (A and B).

Table 10 compares the oxidation performance of nine oils in a series of laboratory oxidation tests. Blends 1-8 used different HVI base oil blends plus the same 13 TBN additive system while blend 9 is a commercial 13 TBN, Generation 4 reference oil using MVI base oils. The data show a broad range of performance for the HVI products depending on the base oil characteristics (e.g. crude source, processing, etc.). Blends 2, 5, 7 and 8 give superior oxidation performance when compared to the reference oil while the other HVI products, using base oils from different sources, give bench test oxidation performance comparable to the MVI reference oil. Therefore, VI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alone is not a measure of oxidation stability, nor necessarily do all HVI oils outperform all MVI oils in these tests.

Figures 34 through 39 document the performance of the MVI products in three laboratory engine tests. All of the Generation 4 reference oils which were tested are commercial products. To minimize the effects of engine variability on the test results, all of the products were run in the same engine stand, during the same time period. Oxidation performance, base reserve and diesel piston deposit control were evaluated. As Figures 34 and 35 show, the new 17 TBN product (Oil D) shows superior oxidation performance when compared to the 13 TBN Generation 4 products. This will benefit the railroad by minimizing the engine oil viscosity increase and allowing longer oil drain intervals in those units sensitive to oil thickening.

The base reserve (TBN) of the oil at the end of these same engine tests was also measured. As Figures 36 and 37 show, the new 17 TBN product contains substantially more base at the end of the test than the 13 TBN, Generation 4 oils. This reserve will be available to neutralize acids from combustion and will act to minimize corrosive wear as oil drain periods are extended using products with improved oxidation performance.

Finally, the diesel piston deposit performance of the MVI products was tested in the Caterpillar 1G-2 engine test. This single cylinder piston deposit test is required by GE for product approval. The results show that the new 17 TBN product (Oil D) gives good top groove and total piston deposit control performance. These results are shown in Figures 38 and 39.

Field Performance of Newly Developed Lubricants

Field testing provides the final determination of how a product will perform in service. After completion of satisfactory bench and engine test programs two improved lubricants, one 13 TBN HVI product (Blend 2, Table 10) and the 17 TBN MVI product (Lubricant D), were field tested. In each case, a 13 TBN MVI commercially available Generation 4 reference oil was included for comparison. While not all of the testing is complete, the used oil analyses which are currently available show that both of the newly improved products control oil viscosity increase substantially better than the Generation 4 reference oils. In addition, the 17 TBN MVI product shows improved base retention when compared to the 13 TBN reference oil.

The newly developed HVI product has completed testing in four GE C39-8 locomotives in coal service. Preliminary oil analyses show that the newly developed HVI product is controlling oil viscosity increase significantly better than the reference oil. Using the typical railroad condemning limit of 30% viscosity increase, the locomotive

drain interval could be extended 45%, from approximately 115 days to approximately 165 days in this service (Figure 40). The pH depletion for the HVI product is comparable to the reference oil. An interim inspection of the test units showed good deposit control in the rocker cover and rocker box areas.

The field tests on the new 17 TBN MVI product in both GE B36-7 and EMD SD-50 locomotives have been completed and preliminary used oil and engine inspection data are available. The viscosity increase control and base retention of the new product is significantly better than the 13 TBN MVI Generation 4 reference oil in both locomotive types. Because of the improved viscosity increase control, the oil drain period in the GE test engines has been lengthened 45%, from 100 days to 145 days (Figure 41). The base depletion (D-664 TBN) for these test units also shows improved performance for Oil D compared to the 13 TBN reference oil and allows the oil drain to be lengthened to 150 days before reaching the GE condemning limit (Figure 42). In the EMD units, the 17 TBN product did not require oil change due to high viscosity for the duration of the test. The viscosity increase reached an equilibrium level of 10% to 15% while the D-664 TBN stabilized at 6 TBN to 8 TBN.

Used oil insolubles and wear metals confirm that the product is giving good performance. Engine inspections have indicated good wear and deposit performance from this new product and confirm the findings of the extensive laboratory bench and engine test screening programs.

The laboratory test results predicted that the newly developed products would offer improved oil performance. The field test results are confirming this prediction. Both the 13 TBN MVI product and the 17 TBN MVI product show approximately 45% improvement in viscosity increase control compared to the Generation 4 reference oils. In addition the 17 TBN lubricant also shows improved TBN retention which, combined with improved oxidation control, will permit railroads to safely extend their oil drains. These improved products will become important to the railroads as they maximize the productivity of their new locomotives and consider extending maintenance intervals in order to reduce operating costs. Additional tests with various base stocks and additive packages are in progress. This committee will report the results at a later date.

Formulating Variables Affect Lubricating Oil Properties

Variable	*Property*
Viscosity	Oil Film Thickness
Oxidation Inhibition	Viscosity Increase Control
Alkalinity (TBN)	Corrosive Wear Protection
Dispersancy, Detergency	Insoluble Suspension, Deposit Control

Table 5

Table 6
Locomotive Lubricant Bench Tests

Test	**Parameter Evaluated**
Oxidation	
— EMD	Viscosity increase Silver corrosion
— GE	Viscosity increase
— Railroad (e.g., BN, UP...)	Viscosity increase
— Oil and Additive company	Viscosity increase
GE bronze fricton	Bronze friction and wear

Oxidation Tests Used By Major U.S. Railroads and OEMs

	CATALYST	
OXYGEN Source	*Solid*	*Soluble*
Bubbling	Union Pacific Norfolk Southern	Conrail
Stirring	EMD GE	Burlington Northern

Table 7

Table 8
O.E.M. Evaluation Procedure

	EMD	GE
BENCH TESTS	Silver Corrosion and Oxidation Test	Oxidation Test Bronze Friction Test
ENGINE TEST	25 Hr. EMD 2-567	480 Hr. Caterpillar IG-2 750 Hr. GE 7FD
	APPROVED FOR FIELD TEST*	
FIELD TEST	3-10 Late Model Locomotives One Year and 100,000 Miles	

* Approval for field testing is granted by the OEM after the candidate oil has satisfactorily completed the bench and engine tests.

Table 9

Oil Oxidation Control

DYNAMIC OXYGEN ABSORPTION TEST

(360°F, 5 O_2/hr. with Copper and Iron Catalysts)

Oil	Oil Type	Induction Time (Minutes)	T2000* (Minutes)
A	Commercial GEN. IV, MVI	40	146
B	Commercial GEN. IV, MVI	61	139
C	New Product 13 TBN, MVI	214	266

* Time to absorb 2 liters of O_2

Bench Test Oil Thickening Results

Percent Viscosity Increase at 37.78°C (100°F)

*Blend No.**	*VI*	*EMD 72 hrs. at 141°C*	*EMD 72 hrs. at 163°C*	*Sinclair 144 hrs.*	*G.E. 48 hrs.*
1	102	2	26	41	0
2	108	0	16	23	1
3	89	10	38	37	1
4	105	5	20	55	0
5	110	0	7	0	0
6	103	0	19	51	0
7	108	0	11	6	0
8	107	0	0	0	0
9	76	8	26	33	8
Limits For Pass		15 max	-	-	10 max

** Blends 1-8 use a common, 13 TBN additive system*
Blend 9 is a commercial 13 TBN Generation 4 product

Table 10

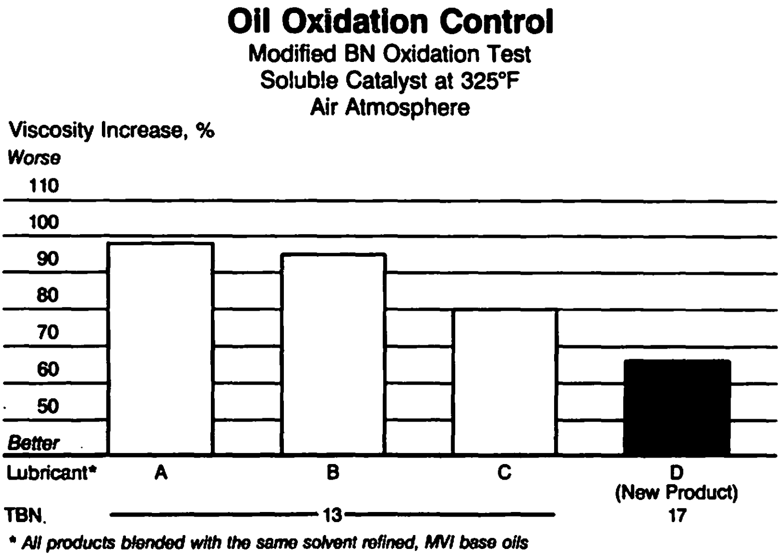

Figure 32

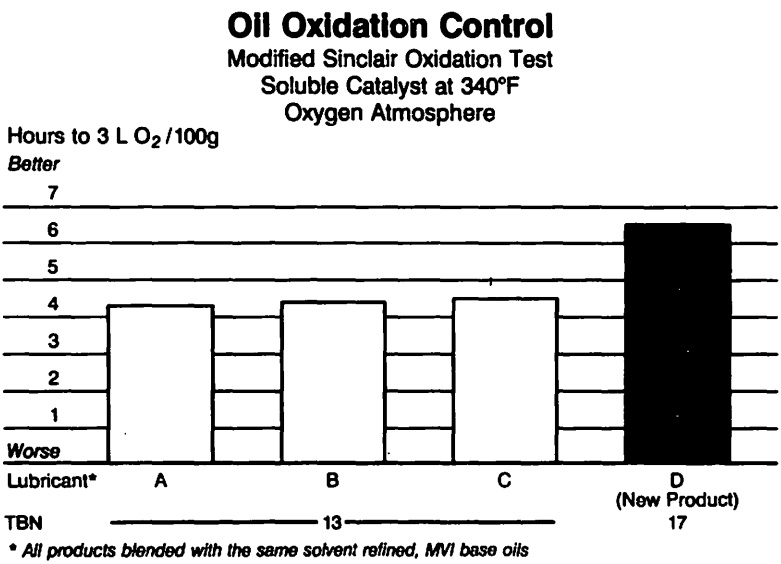

Figure 33

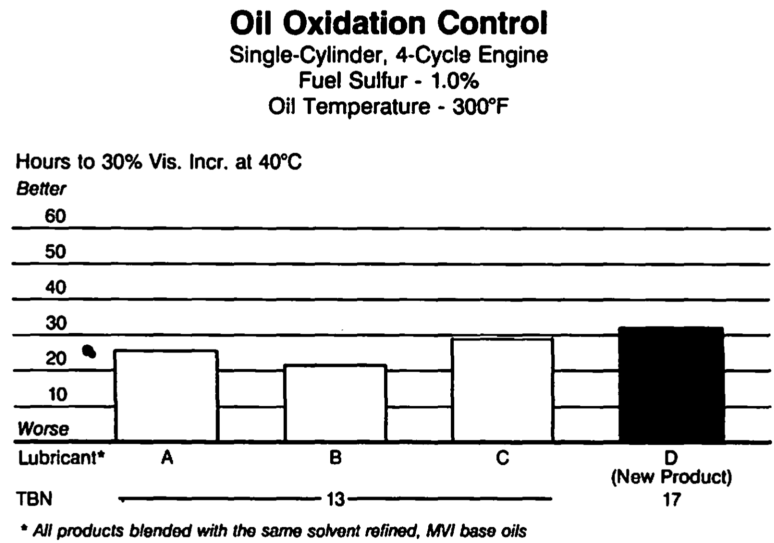

Figure 34

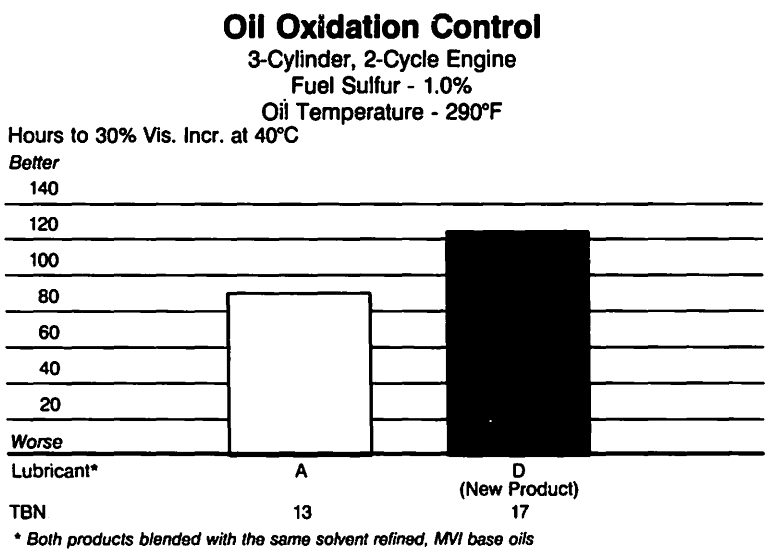

Figure 35

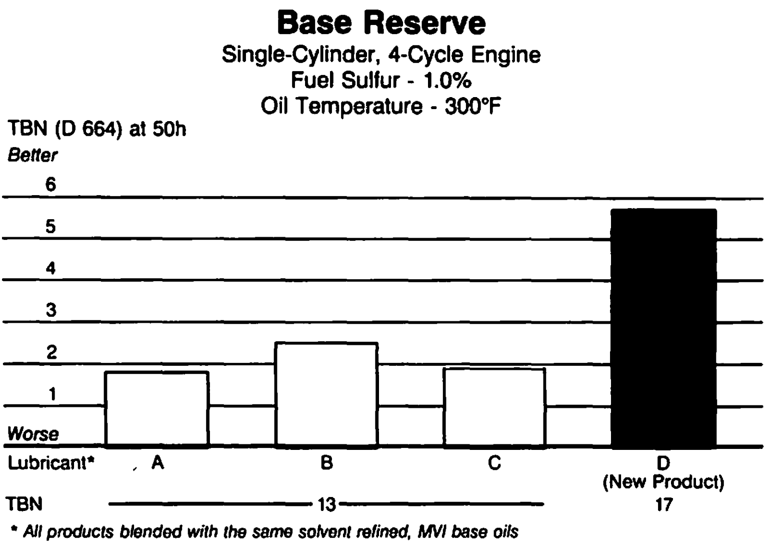

Figure 36

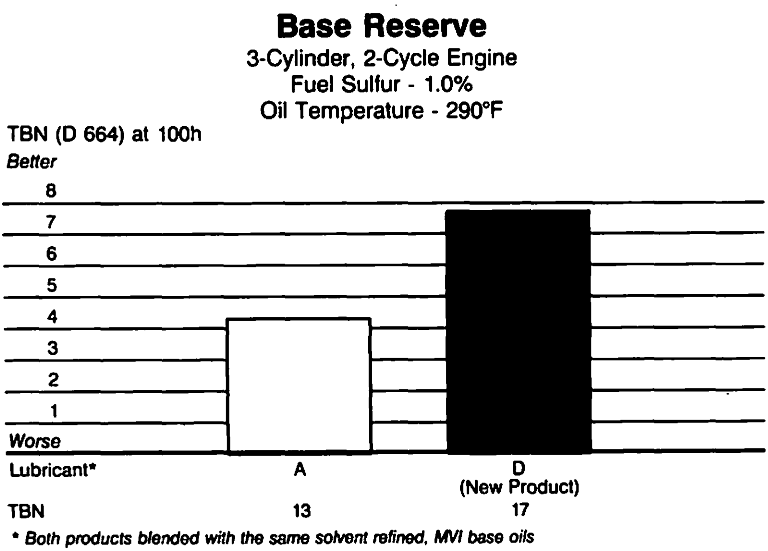

Figure 37

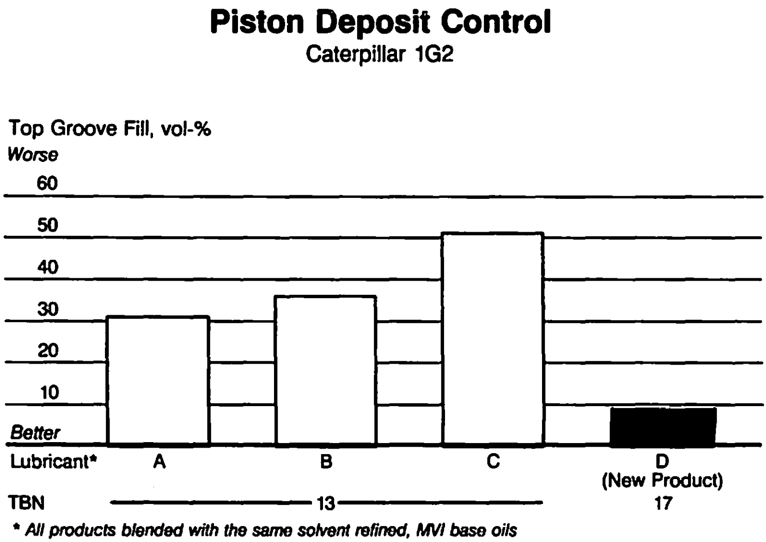

Figure 38

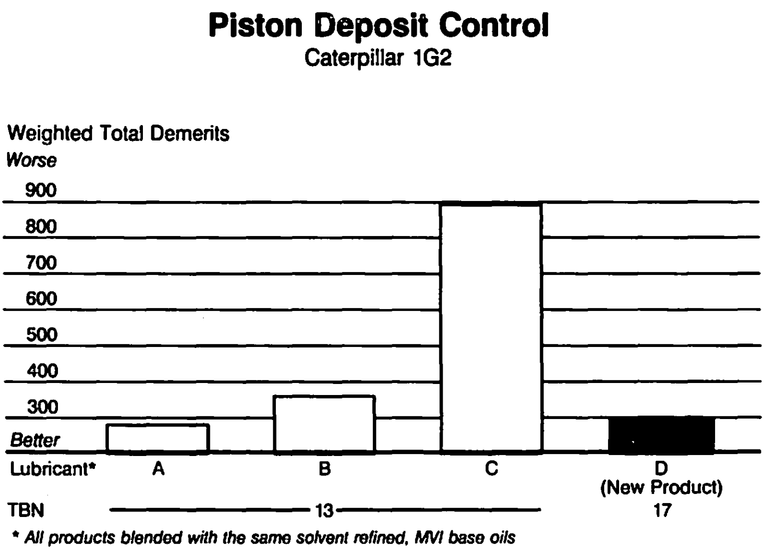

Figure 39

Oil Oxidation Control

GE C39-8 Field Test

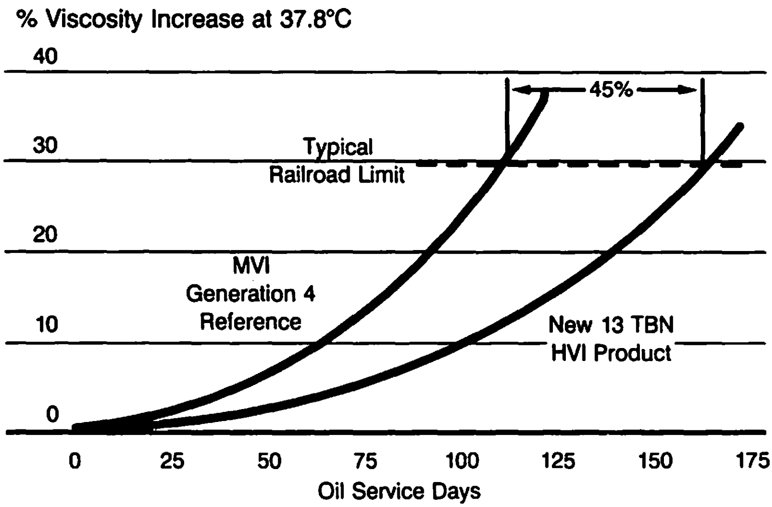

Figure 40

Oil Oxidation Control

GE B36-7 Field Test

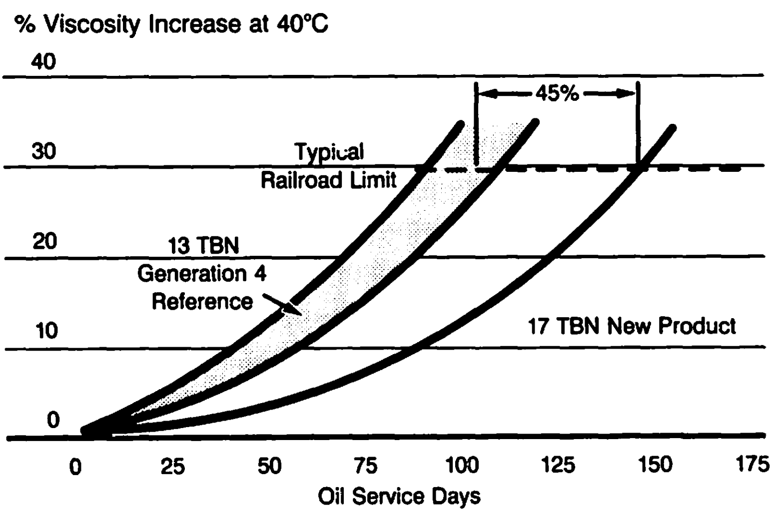

Figure 41

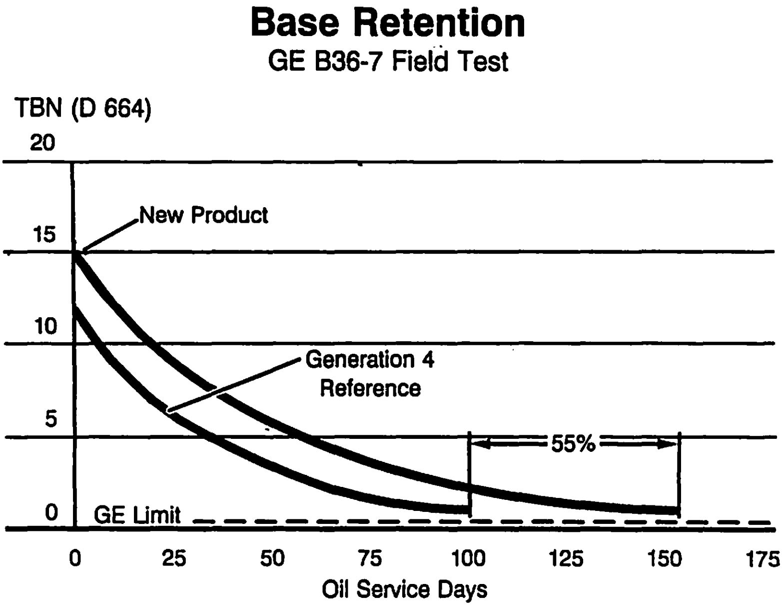

Figure 42

FUEL AND LUBRICANTS COMMITTEE

Six-Year Index

1986

Fuel and Lubricants — Effect on the Bottom Line

1. Extended Performance Lubricants Through Better Chemistry
2. Fuels and Lubricants Handling Hygiene
3. Fuels Availability and Price Outlook
4. Selection of Lubricants for Wheel Flange and Rail Lubricators

1985

Managing Maintenance For Quality Performance

1. Disposal of Lube Oil Drainings
2. Non-ASTM No. 2-D Fuel
3. Oxidation Analysis
4. Wheel Flange and Rail Lubrication

1984

Improving The Bottom Line: With Technology

1. Locomotive Filters

2. Traction Motor Gear Lube Field Test

1983

Changes in Fuels and Lubricants

1. Field Test Update of Multigrade Oils
2. Update of Alternate Fuel Testing
3. A Review of Locomotive Fuels

1982

Quality Maintenance Thru Fuel and Lubricants

1. Energy Conserving Lube Oils
2. Alternative Fuels Update
3. Availability of Medium and High Viscosity Index Railroad Oils
4. Journal Box Oil and Aniline Point
5. Traction Motor Gear Lubricant Update
6. Traction Motor Gear Case Seals

1981

Problems, Solutions and New Techniques In Fuel and Lubrication

1. Effects of Using Alternate Fuels on Existing Diesel Engines
2. Update on Cold Weather Procedures for Fuels
3. New Techniques in Lube Oil Analyses
4. Traction Motor Gear Lubrication
5. Multi-Viscosity Oils as an Energy Conservation Technique

V. H. MIZRAHI
Chief of M. P. & C. E.
CN RAIL
Montreal, Quebec

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 Material Control Committee in Montreal on April 21, 1987.

The attendance and interest exhibited was most gratifying.

Tuesday, September 15, 1987

10:30 A.M.

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

Pre-Convention Presentation: Montreal, Quebec

April 21, 1987 Hilton Bonneventure Hotel Montreal, Quebec

L. G. SALTS, Chairman
Engineering Assistant
Atchison, Topeka & Santa Fe Railway
Topeka, KS

VICE CHAIRMAN

C. A. Miller, Manager Production Control, Union Pacific Railroad, Omaha, NE

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D. G. Schonauer	Parts Materials Manager	EMD	Hodgkins, IL

1987 TOPIC:

MATERIALS — THE LINK BETWEEN PRODUCTIVITY AND QUALITY

PERSONAL HISTORY

LELAND G. SALTS

Mr. Salts was born near Mayetta, Kansas on July 22, 1933. He attended public schools in the Mayetta community and graduated from high school in 1951. He attended Washburn University at Topeka.

He worked for Pittsburgh Plate Glass Company for approximately eight years and started with the Santa Fe Railroad in February 1960 as a Machinist Apprentice. After his apprenticeship he worked in the Shop Extension Department for five years doing Mechanical Drafting and shop layout.

In October 1969, he was transferred to Kansas City where he worked as Safety Supervisor for seven years. He was then transferred back to Topeka where he worked as a foreman in the shop for about two years. In May of 1978, he was assigned to the Mechanical Engineers Office where he is presently working as an Engineering Assistant.

Leland and his wife Martha reside on a small acreage east of Topeka. They have three adult children, one boy and two girls.

INTRODUCTION

The Diesel Material Control Committee has in past presentations attempted to keep abreast of the latest and most effective methods presently in use to effectively process and handle material.

Last year our presentation revolved around electronic requisitions and electronic data interchange including electronic purchasing.

This year's presentation is structured to help you determine how to arrive at the proper material item to purchase at the best long term cost and how to evaluate shippers.

There are certain keys to quality vendor selection. The first is product quality — maximizing product quality at lowest life cycle costs.

Second is service level — maximizing service level by improving vendor shipping performance.

These two items combine for maximizing productivity through automated data collection to identify the top performing vendors.

One of the major tools in data collection is bar coding which is covered in detail in another portion of the paper to let you know how this important tool is used in our industry as well as others.

Airlines have some unique methods to help them have available very expensive material at a minimum cost to the user. Perhaps we should look at some of the things they are doing to help reduce costs for our railroad operation. A portion of our paper deals with this item.

Hopefully, each of you will find something in our paper which you may use to improve your operation.

1987 THEME
PRODUCTIVITY AND QUALITY — LMOA'S ULTIMATE GOAL

I.
SUPPLIER SELECTION FROM COMPONENT FAILURE ANALYSIS

Traditionally, price is the main criterion for component purchase, but is price the only key?

We all buy or repair power assemblies, traction motors, etc., and in the past most of us, due to the lack of reliable data, had no means of evaluating a product other than price.

Of course, there are a few exceptions. We all have had major problems appear when we analyzed specific products. But this took a lot of time and manpower and after the study was completed and the problem resolved, these studies usually were discontinued.

Several years ago, a question was raised regarding the cost to chrome plate cylinder liners. The answer was apparently simple — call Purchasing and get the price — but it was not that easy.

It turned out the price was not fixed; we paid one base price to chrome the bore and an additional price for each additional repair that was needed. For example, repair O.D. one amount, repair I.D. another amount, repair I.D. and O.D. still another amount and so forth.

Which vendor had the best price? To find that answer all the invoices had to be pulled and the price of each liner recorded and processed to achieve an average price per liner. It turned out that the price paid was a lot higher than suspected. In addition to the price, whose product was the most durable? That question is the basis of the following study.

We will look at one specific item — engine cylinder liners. We will look at studies that are being done on two railroads to determine the quality and longevity of this product, studies that give this product a quality rating.

The first need was to determine what information was available. Every cylinder liner has an OEM serial number and if it was previously chrome plated it will have a vendor serial number. This serial number identifies the company and the year in which the work was performed.

How do we gather this information? Since all power assemblies in this case are stripped and repaired at one location, the first step was to design a form to be completed by a designated person at the power assembly stripping area.

This form requires specific information, such as, the OEM serial number, chrome plater's serial number, if any, type of liner, repair that the liner needed and date the liner was removed from service.

While the information needed was being gathered, a computer program was written to sort the

data. This computer program allowed us to determine the life of each liner from repair to repair by the vendor. Over a two-year period this gave us a continuing average life per liner for each vendor.

What additional information did we now desire? Two items were foremost — vendor cost and the number of liners being scrapped. To gain this information, all vendors performing this type of work were contacted. They were asked to submit copies of their invoices and the serial numbers of any liners that they scrapped to a Mechanical Department designee on a continuing basis.

We now have three pieces of information at our disposal: the cost to repair the liners by vendor, the average liner life per liner by vendor and the number of liners scrapped by vendor.

Following is an analysis of this information:

Refer first to Figure 1. In 1984 the price per liner was not at a fixed rate. Each repair performed to a liner had an additional cost added to the base cost to replate. 1984 reflects the average cost per liner in that year. In an attempt to gain better control of costs, each vendor was asked to submit bids for a fixed cost per liner repair, which is reflected in 1985. As you can see, in most cases, the unit cost was reduced from the previous year. 1986 shows the fixed price per liner repair in that year. Note the continuing reduction in cost. It would seem that substantial cost savings are being achieved.

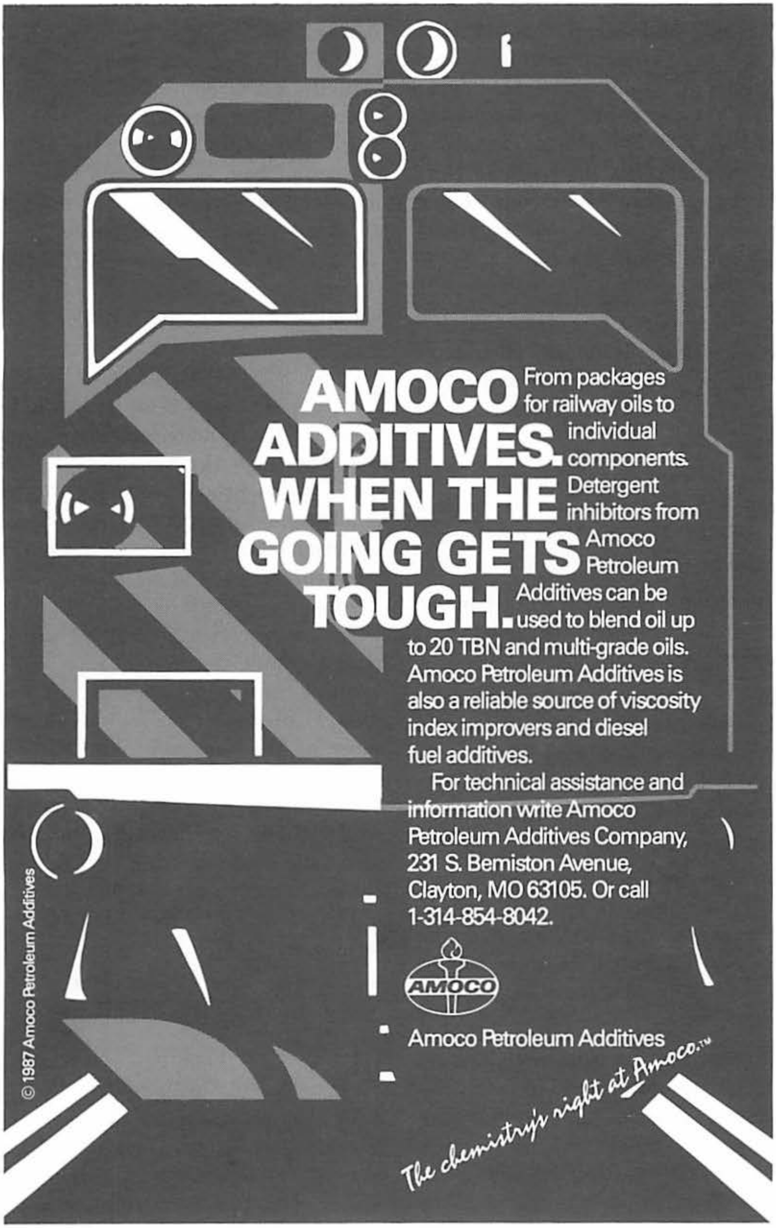
Figure 2 is a comparison of average life per liner conducted by two railroads working independently over a 2½-year period using the same procedures. The results of this survey indicated that the average life for each vendor is closely comparable, and that in both studies, Vendor D had the longest liner life.

Railroad X's study is based on over 3,500 liners.

Railroad Y's study is based on over 4,500 liners.

What does the average liner life mean in economic terms? If one supplier's liners have to be replated twice to equal the liner's life of another vendor, the cost effect is double to the railroad if he uses the first vendor.

A three-year comparison by vendors of liners scrapped (Figure 3) shows Vendor D with the lowest scrap rate. Vendor B's scrap rate is moderate but increasing yearly. Vendor C shows consistence in comparing 1984 and 1985 with a drop in 1986 scrap rate. Vendor A's scrap rate is the highest, twice as high as the other vendors, in each year. The significance of scrapping a liner is that it must be replaced to replenish the pool. This replacement cost, which is usually the cost of a new liner, will impact the overall cost by increasing the average unit cost of the supplier to the railroad.


AMOCO ADDITIVES. WHEN THE GOING GETS TOUGH.
From packages for railway oils to individual components. Detergent inhibitors from Amoco Petroleum Additives can be used to blend oil up to 20 TBN and multi-grade oils. Amoco Petroleum Additives is also a reliable source of viscosity index improvers and diesel fuel additives.
For technical assistance and information write Amoco Petroleum Additives Company, 231 S. Bemiston Avenue, Clayton, MO 63105. Or call 1-314-854-8042.
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When we compare each vendor's liner life and scrap rate (Figure 4), we see Vendor D with the longest liner life and a moderate scrap rate. Vendor C has the next longest liner life and a moderate scrap rate. Vendor B's liner life is third and the scrap rate is moderate, but increasing. Vendor A has the lowest liner life and the highest scrap rate.

Let's now put our data together to see what decisions should be made, in order to determine our most cost effective supplier.

The first comparison (Figure 5) shows us that based on price alone Vendor A would be the one picked to receive the largest portion of the liner contract.

When we add the life factor, Vendor D becomes the most cost effective supplier.

When we add the scrap rate, Vendor D continues to be the most cost effective, and also widens the margin between himself and Vendors A and B.

Before this study was made, it appeared that a large cost saving could be achieved by awarding a contract to the vendor with the lowest price; but in fact, the lowest price actually cost more in the long run.

Studies of this type with the resources we now have at our disposal are becoming an everyday reality. We must continue to look for ways to improve the reliability of our fleet, if we are going to be competitive in an ever-changing market place.

The data for this study, as presented, were compiled manually; the computer was then used to sort the data. An alternative method of bar coding could be used, and that subject will be covered in a later section of this paper.

II.

VENDOR PERFORMANCE OR SERVICE LEVEL

In the previous section, we have proposed a vendor selection process based on the vendor's product quality and product life cycle cost. Another major factor in vendor selection has to be the shipping performance, the service level, that a vendor gives his customers.

Let us review the key elements which comprise service level, and identify some of the underlying causes of low service level. If some of the causes of low service level can be identified and evaluated, we can formulate some rules which could enhance shipping performance while keeping costs under control.

The four elements of service level are:

1. The correct material
2. In the correct quantity
3. At the correct location
4. At the right time.

The requirement to ship correct material is obvious. This is a shared responsibility between buyer and seller. The buyer must have com-

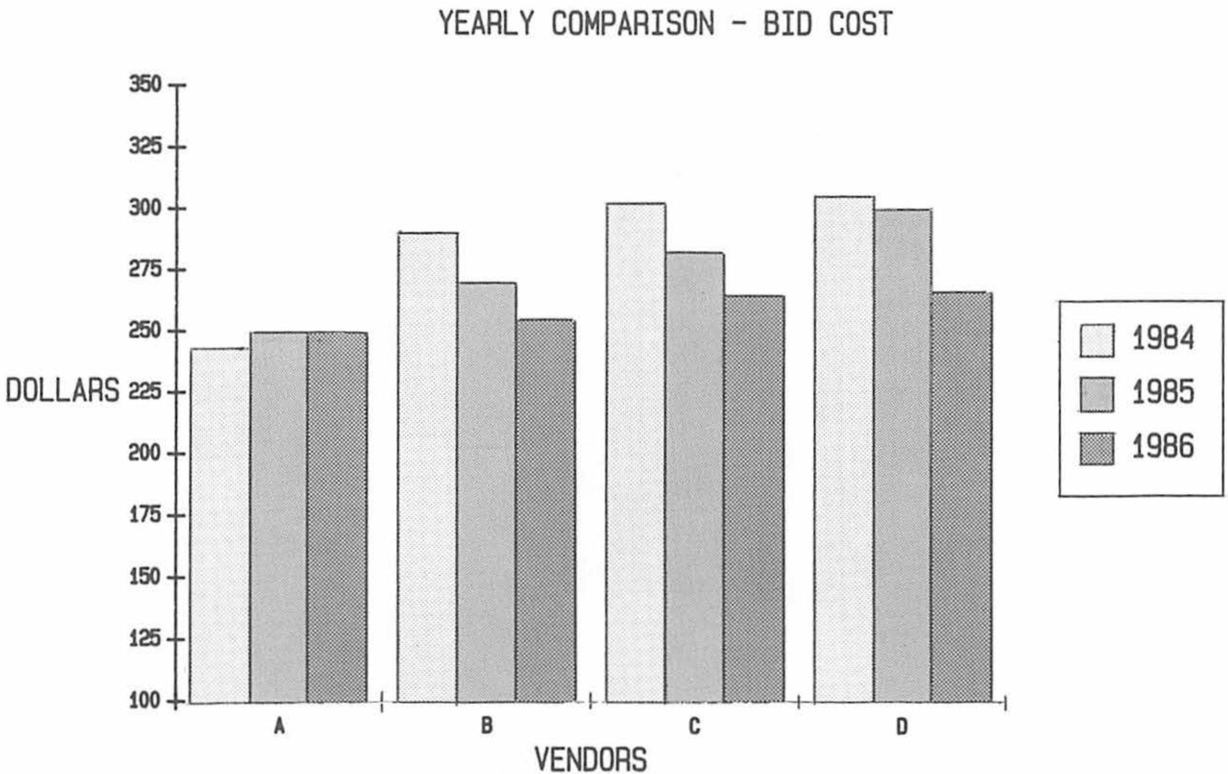

YEARLY COMPARISON - BID COST
DOLLARS
350
325
300
275
250
225
200
175
150
125
100
A
B
C
D
VENDORS
1984
1985
1986

Figure 1

Figure 2

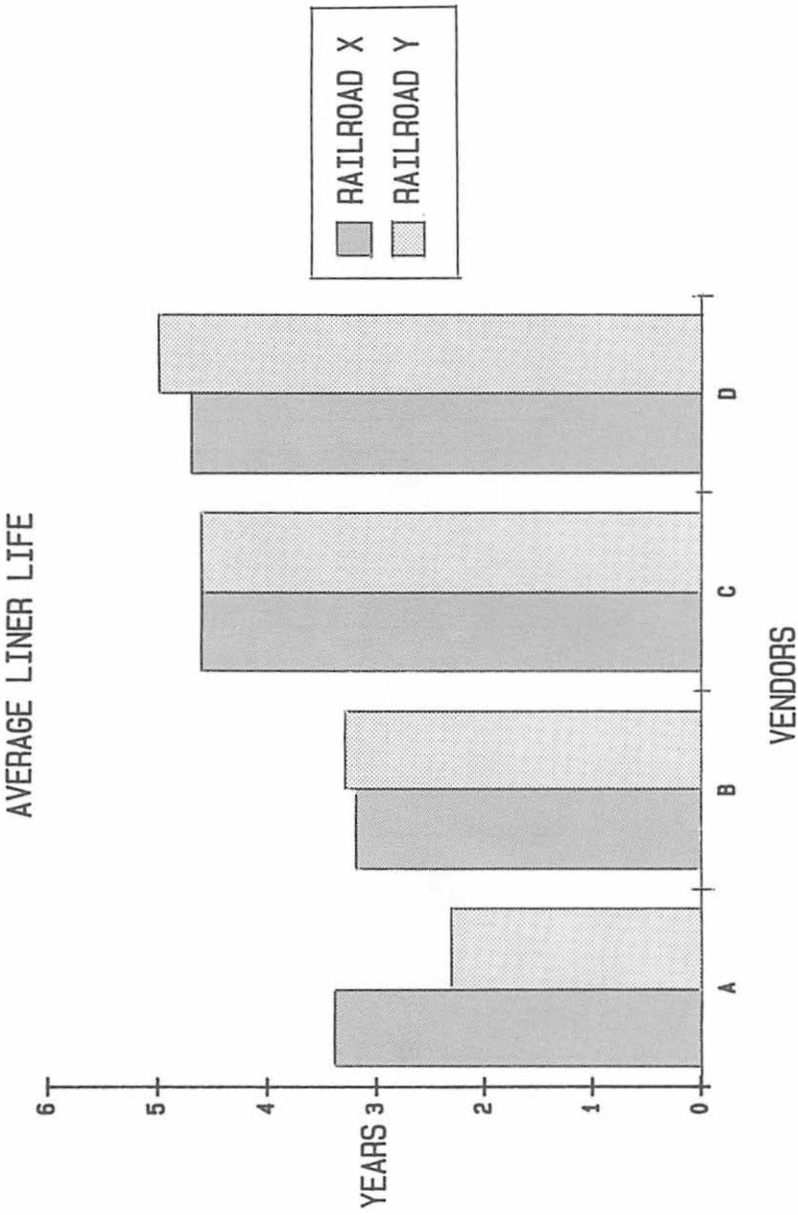
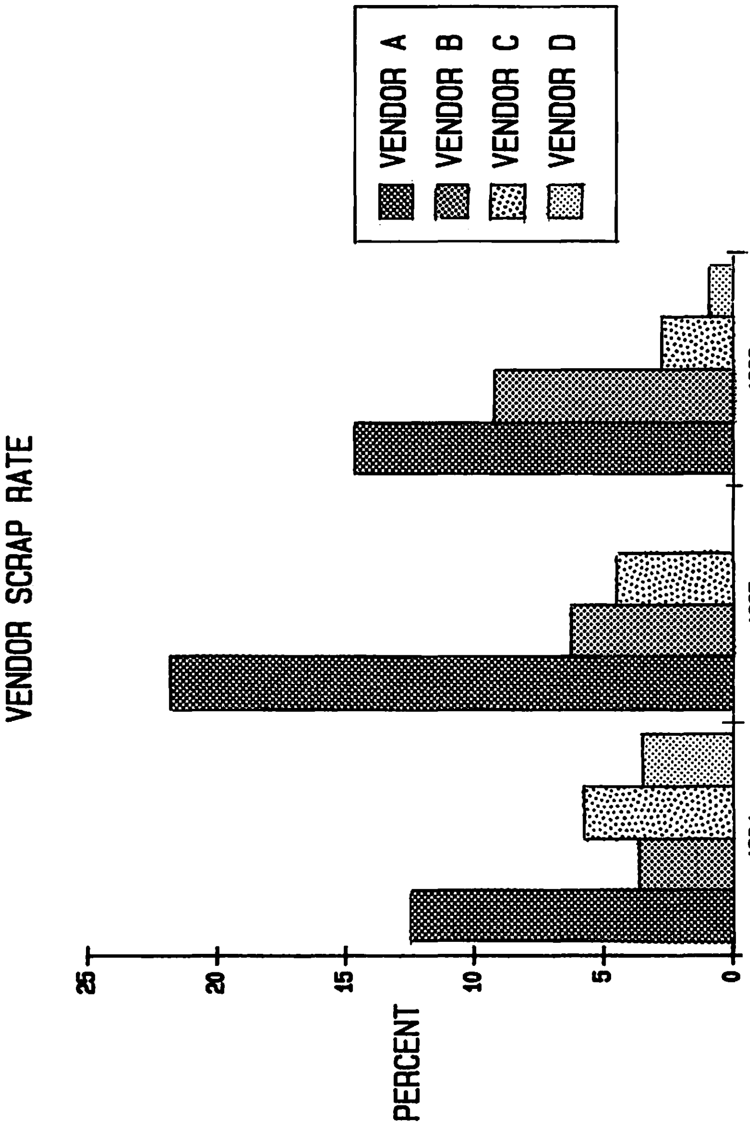

AVERAGE LINER LIFE
RAILROAD X
RAILROAD Y
YEARS
0
1
2
3
4
5
6
A
B
C
D
VENDORS

Figure 3


VENDOR SCRAP RATE
VENDOR A
VENDOR B
VENDOR C
VENDOR D
PERCENT
0
5
10
15
20
25
1984
1985
1986

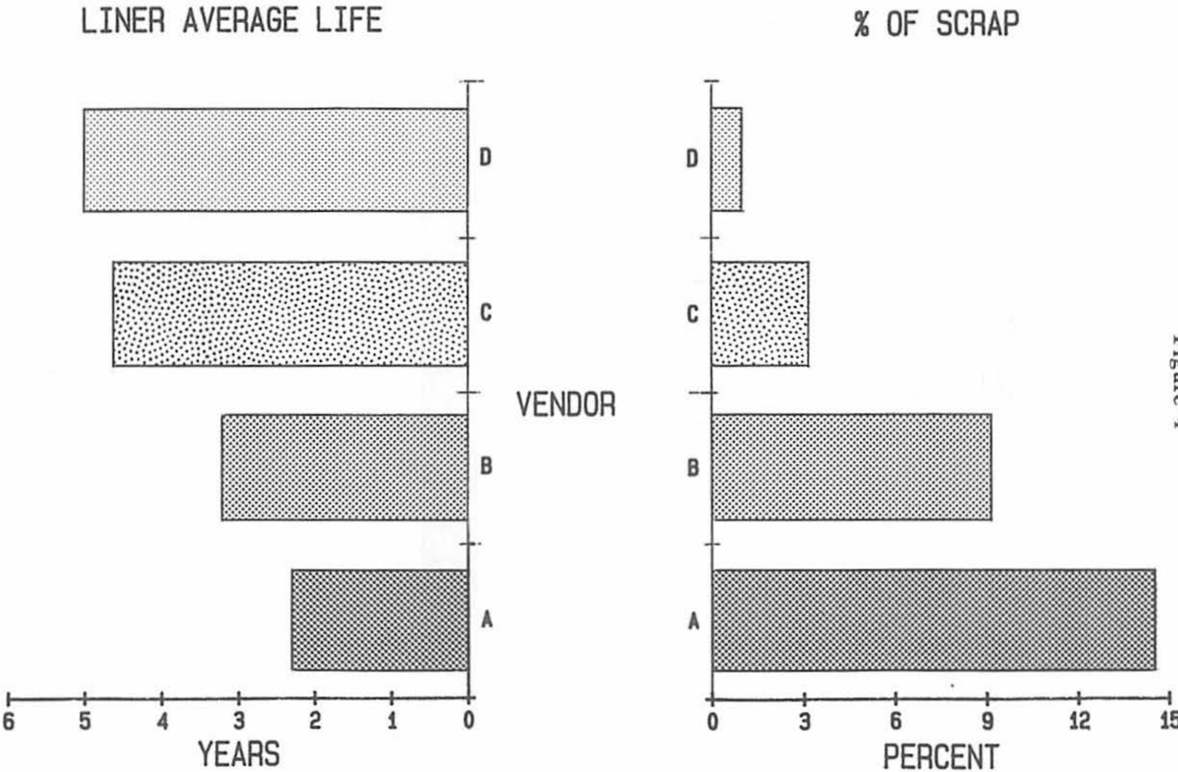

LINER AVERAGE LIFE
% OF SCRAP
D
C
B
A
VENDOR
6 5 4 3 2 1 0
YEARS
0 3 6 9 12 15
PERCENT

Figure 4

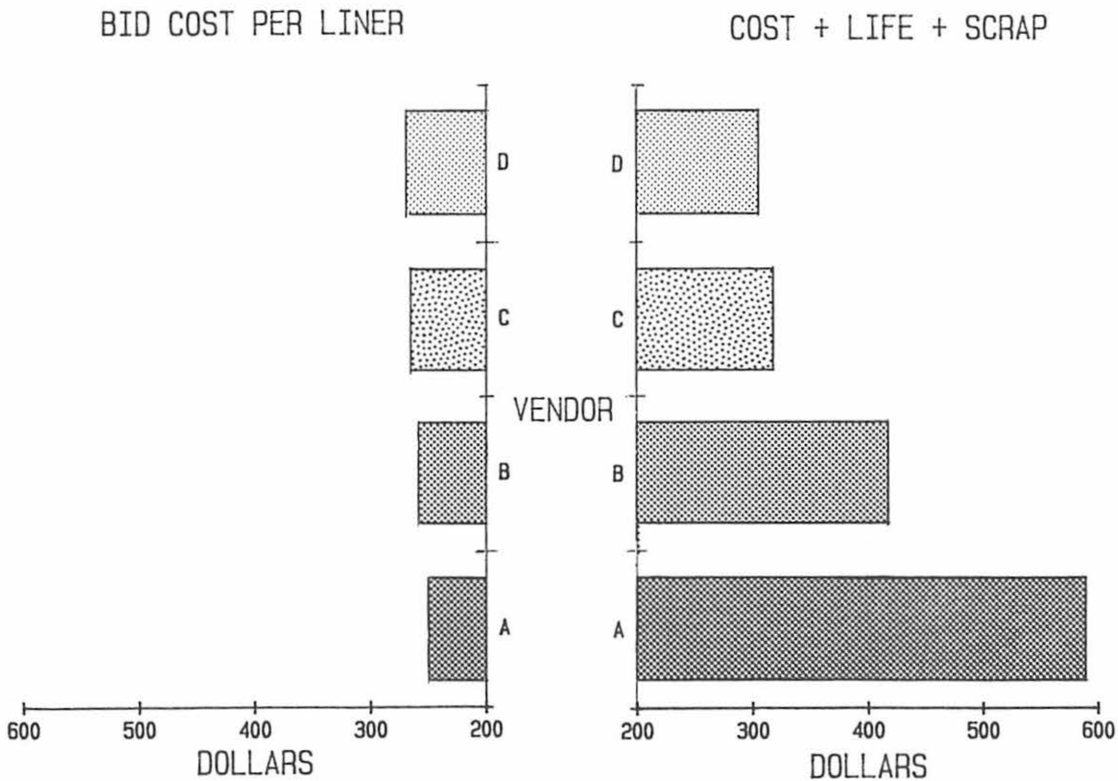

BID COST PER LINER
COST + LIFE + SCRAP
VENDOR
D
C
B
A
600
500
400
300
200
DOLLARS

Figure 5

plete and correct ordering information for the product. The buyer has the responsibility to identify the material by its catalog number. If the part ordered has been replaced by a more up-to-date part or the part has been reidentified, it becomes the seller's responsibility to assure that a correct and interchangeable replacement is shipped. The company that provided the original apparatus is in the best position to ship correct material since it controls the fit and function of the material in the apparatus and it knows all of the quality requirements. Unless the correct material is ordered, the remaining service elements of correct quantity, location, and time are meaningless.

These remaining elements of service level — quantity, location, and timing — are the basis for all material requirements planning systems and the cornerstone of shipping performance (Figure 6).

The ideal shipping performance of 100% implies that the entire quantity ordered for a specific location to a specific date has been shipped. If this shipping performance occurred routinely, there would be no need for finished goods inventory, since all material would be used as it became available. In this respect, every dollar of finished goods inventory represents a failure or breakdown of the forecast process.

There are at least three ways that service level can be degraded. The examples in Figure 7 are designed to show the three ways in which service level can be affected.

Example 1 compares two railroads with different degrees of forecasting accuracy. In Example 1, both Railroad A and Railroad B know the quantity of an item they both use, but the planning of Railroad A allows the material at the correct location, and in the correct quantity, a slightly greater percentage of the time. The resultant service level advantage of Railroad A over Railroad B is significant.

Example 2 contains a theoretical comparison of two different types of suppliers. The original manufacturer can make a better estimate of quantity and timing, due to his greater knowledge of failure rates and part life and his broad sales base. He is therefore inherently able to provide a higher service level.

Example 3 shows a service level comparison which might exist between a direct sales system and sales using distributors. Since there is no organization between a sup ulier and a railroad in a direct sales situation, requirements are not subject to adjustment or interpretation. A distributor wins points for having some percentage of items at point of use a greater percentage of the time, but many distributors rely on expediting to fill orders for high cost items which they may not be willing to stock.

Figure 8 shows the potential erosion in service level percentage which can occur using a distribu-

tor network. The forecast accuracy at every interface is at least 90% in every case, yet there is a 13 point difference in availability of material at site. If you have ever asked your organization why material is available only 80% of the time while your forecast accuracy is 90 to 95% (and you have "X" million dollars of excess inventory), this could be one of the reasons.

We can conclude from these examples that, although forecasting accuracy is a major determinant of service level, the nature of the supplier himself and the type of distribution system he uses are significant factors affecting service level the railroad receives.

There is at least one additional cause of service level deterioration which is inherent in the material forecasting system itself.

> Every time you split your business for a given part, both suppliers second guess your present needs and also the share of business you may or may not give them in the future. Both suppliers will necessarily forecast lower base quantities and will have a tendency to gravitate to a lower readiness to serve. If they don't count on you, you can't count on them . . .

Suppliers recognize that excellence in both product quality and service level are key to long term market share, and are therefore committed to continued improvement and accurate measurement of quality and service level.

Figure 9 shows a hypothetical memo of shipment for two intrinsically different items having different quantities, lead times, and prices. An equitable way to evaluate the supplier's shipping performance for this transaction is to evaluate each item separately against the supplier's lead time. The lead time evaluation should determine, first, which qualified supplier has the shortest lead time and, second, whether the supplier is performing to his lead times. A meaningful service level rating could be developed for each supplier over a range of transactions, and this rating could be used to identify outstanlding suppliers.

As a result of this analysis, we have some recommendations which can be implemented immediately for improved performance:

- —Don't split business by part number.
- —Don't use a distribution system with a lot of interfaces.
- —Do try to use vertically integrated suppliers.
- —Do select suppliers with quality and service level goals and the programs to support them.
- —Do select suppliers who have a track record of demonstrated success.
- —Do measure your suppliers fairly.
- —Do work with your preferred suppliers to improve forecast accuracy.

The results from this pattern of activity will be significant to your overall business results:

— You will have fewer, higher quality suppliers.

— Product performance will improve.

— There will be fewer program reschedules.

— You will have significantly less inventory.

— You will have fewer expedites.

— Infrastructure costs will be reduced.

— Your service level from your suppliers will improve.

To summarize, the selection of quality vendors who have high service levels will provide that competitive edge you require to be successful.

SERVICE LEVEL

SERVICE LEVEL RESULTS FROM THE FORECAST OF FOUR VARIABLES....

CORRECT PART	&	QUANTITY	&	LOCATION	&	TIME	=	SERVICE LEVEL
100%		100%		100%		100%		100%
ALMOST NEVER A PROBLEM		MODELED USING HISTORY AND MATHEMATICAL METHODS		GENERALLY NOT A PROBLEM		USED WITH QUANTITY TO DEFINE "RATE" OF USE		

EASIEST TO FORECAST WITH GOOD ACCURACY - QUANTITY
MOST DIFFICULT TO FORECAST - TIME

Figure 6

SERVICE LEVEL

A SLIGHT ERROR IN FORECASTING CAN HAVE A SIGNIFICANT EFFECT ON SERVICE LEVEL....

<u>EXAMPLE 1</u> - RAILROADS WITH DIFFERENT FORECASTING ACCURACY COMPARED

	QUANTITY	LOCATION	TIME	SERVICE LEVEL %
RAILROAD "A"	100	90	95	85.5
RAILROAD "B"	100	85	90	76.5

<u>EXAMPLE 2</u> - TYPES OF SUPPLIER COMPARED

	QUANTITY	LOCATION	TIME	SERVICE LEVEL %
ORIGINAL MANUFACTURER	100	100	90	90.0
AFTERMARKET SUPPLIER	90	100	85	76.5

<u>EXAMPLE 3</u> - DISTRIBUTION SYSTEMS COMPARED

	QUANTITY	LOCATION	TIME	SERVICE LEVEL %
DIRECT SALES	100	100	90	90.0
SALES VIA DISTRIBUTION	85	100	95	80.8

MINIMUM SERVICE LEVEL SHOULD BE AT LEAST 90%....

Figure 7

SERVICE LEVEL

FEWER PROCUREMENT INTERFACES RESULT IN FEWER "SECOND GUESSES"....

	PERCENT FORECAST ACCURACY	
	MANUFACTURER WHO SELLS DIRECT	SUPPLIER VIA DISTRIBUTION
RAW MATERIAL PROCUREMENT	99	99
MANUFACTURING CYCLE & QUANTITY	99	90
SERVICE LEVEL TO DISTRIBUTOR	--	95
DISTRIBUTOR ALLOCATION OF AVAILABLE	--	95
SERVICE LEVEL TO USER	95	--
% OF TIME CORRECT MATERIAL AND QUANTITY IS AT POINT OF USE	93.1 PASS	80.4 FAIL

RESULT: FEWER EXPEDITES AND LESS PROTECTIVE INVENTORY

Figure 8

Figure 9

SERVICE LEVEL

MEMO OF SHIPMENT

CUSTOMER: XYZ

ORDER DATE 1/1/87
SHIP DATE 1/6/87
WANT DATE 2/15/87

ORD. QTY.	SHIP QTY.	PART NO.	DESCRIPTION	NLT DAYS	UNIT PRICE	EXTENDED PRICE
10	7	123	FILTER	10	10.00	70.00
20	10	ABC	CYLS	60	2000.00	20,000.00

III.

BAR CODES

Without fanfare, bar codes have become an important part of our lives. They have crept into businesses as diverse as automobile factories and corner grocery stores. Bar codes and automatic identification systems are the most cost effective management tools of the 1980's. They have gone far beyond their original intent of controlling inventories, indeed their use is quickly rewarded by improved asset management and resource allocation. Bar code based management systems have been successful in combating the negative trending of productivity.

A bar code is a self-contained message with information encoded in the widths of bars and spaces in a printed pattern. Because of their interface with a computer, bar codes are binary; they are based on a system of numerical notation to base 2. The code essentially switches a circuit on or off, indicating one or zero to the computer.

Bar codes are read by sweeping a small spot of light across the printed bar code symbol. The sweep starts at the white space which follows the last bar. Because a bar code cannot be read if the sweep wanders outside the symbol area, bar heights are chosen to make it easy to keep the sweep within the bar code area. The longer the information to be coded, the longer the bar code. As the length increases, the height of the bars must be increased to allow more wandering during reading.

It is not the intent of the paper to explore the technical aspects of bar coding; that is an entirely separate subject. This paper will concentrate on various applications of bar coding and future potential advantages the railroad industry may wish to consider.

The most commonly recognized code is the Universal Product Code (UPC) which is used on approximately 90% of all grocery items. More than 5,000 grocery stores are equipped with scanner checkouts to facilitate customer movement, inventory disbursal and replenishment, and limitation of clerical intervention and chance of error.

Other major applications of bar code systems include:

A. Automotive industry — Chevrolet Motor Division, in Buffalo, New York, has used bar code labels on assembled automotive axles for conveyor coding since 1975. The scanner sorts 21 styles of axles and routes them correctly, replacing a manual operator.

Pontiac's home plant in Pontiac, Michigan, uses bar code labels on engine blocks to identify the 33 possible combinations of carburetors, distributors, and exhaust gas recirculation valves specific combinations are necessary to meet EPA emission requirements). An inspector with a light pen reads the codes on

the components, and any mismatch is instantly identified.

Pontiac car bodies from Fisher Body Division also bear bar code labels read by laser scanners to identify equipment options.

Buick uses two laser scanners as data collection devices in an integrated scheduling and production control system in Flint, Michigan. Bar code labels identify and count over 4,000 automatic transmissions per day with their accuracy approaching 100 percent.

The Automotive Industry Action Group (AIAG) has developed some interesting and effective uses for bar codes.

1. **Manufacturing process monitoring** — A part moves down an assembly line; as it reaches a machine, a scanner can read the bar code on the part, relay this information to a microprocessor that triggers instructions to the machine. Actual work performed by the machine and the quality of this work for each particular part can be also monitored.
2. **Broadcast component requirements** — A scanner can read a part's bar coded label to identify what part is next in line to be assembled. This information can be used to trigger an electronic terminal that displays assembly instructions to the workers.
3. **Assembly verification** — As a quality check, components can be scanned after the fact to verify that the right parts are assembled on the right assembly.
4. **Production status reporting** — As parts move through the in-process and out of their final operations, they can be monitored at strategic points (by scanning bar code labels) to capture with precision where the parts are; that is, the locations, the stages of production, and the quantities.
5. **Shipper generation** — As material is loaded for shipping, checkers typically read labels and manually keep track of what is being loaded. Scan bar coded labels can replace this practice by feeding this information into a system that prints shippers, updates inventory and shipping records for Material Conrol and Accounting and forwards in-transit information to the receiver.
6. **Receiving verification** — Bar coded tags or labels can be scanned at receiving to establish proof of delivery. This information can then be mechanically sorted, summarized and matched either to a packing slip, to forwarding information provided by the supplier, or to an invoice.
7. **Warehousing - random storage** — Recording transactions for putting material into or taking material out of a warehouse can be aided by bar coding.

Container or part labels can be scanned for identification and quantity. Bar coded bins or aisle designations can be scanned to capture precise storage locations.

8. **Automatic sortation and routing** — Laser scanners that monitor material moving down an assembly line or conveyor system can sort and route material to the desired locations.
9. **Cycle checking** — When cycle checking parts, bar coded part numbers, quantities, and locations can be scanned and then mechanically sorted and summarized. Scanning of item serial numbers or tag numbers can improve the accuracy of cycle checks by eliminating duplications and by aiding in recheck comparisons.
10. **History file development** — By scanning bar coded sequences on serial numbers, a file can be established, reworked, rebuilt, etc., and on what day, shift, hour, etc.

B. **Blood banking** — Bar code labels on blood bags identify blood type, as well as the source and donor of the blood. This system which uses the codabar code, is being implemented nationally to expedite the accurate and rapid processing of blood and blood products on an interstate basis.

C. **Libraries** — Fast checkout of library books, with unparalled accuracy in recording both the book and the borrower, is possible by using library cards with a bar code and bar code labels on books. As used at Hartford Community College in Bel Air, Maryland, the system even flashes a warning to the librarian if the borrower has overdue books of if the library card is invalid.

D. **Medical histories** — Adding bar codes to patient records helps accurate control and avoids mixing records of patients with similar names. Bar code labels can also be used for efficient, positive identification of patient specimens for laboratory tests. Drug labels controlled by bar codes aid in their safe administration.

E. **Military** — The Department of Defense has now completed a test of bar codes called LOGMARS (Logistics Applications of Automated Marking and Reading Symbols). Its purpose is to establish a system of bar codes for the management of U. S. weapons and material on a world wide basis.

F. **Package routing** — Federal Express Corporation is using Codabar bar codes on its airbills to route air express packages at the rate of 70,000 packages per day. It is planned that each package carrier will have a portable scanner, permitting automatic data entry when the packages are picked up from the shipper.

G. **Photo finishing** — Photo finishing plants use bar codes on cus-

tomer order envelopes for both sorting and pricing. Automatic conveyor sorters can sort envelopes into hundreds of separate bins, each for a different dealer.

H. **Stock room control** — Research Center employees of Xerox Corporation in Webster, New York, have identification cards with bar codes. The stock room attendant scans the bar codes on the supplies and on the employee ID card with a light pen. Data are fed directly to a computer for fast and accurate departmental billing.

I. **Warehousing** — This is one of the most useful applications of bar codes. Bel Knap, Inc., a leading warehouse distributor of hardware, modernized its nine floor warehouse with a system of powered conveyors, moving beam scanners, and tilt-tray sorters. This system now handles about 4,000 inventory items.

Colgate-Palmolive Company achieves a sorting reliability of over 99 percent with bar codes preprinted on shipping cases read by laser scanners. Cases intermixed from several production lines move to the warehouse over a single conveyor. The scanner identifies each product, determines if the case is upside-down, and maintains running counts of each product and total cases.

From these examples one can see that applications of bar codes and automated identification systems are nearly limitless. New uses in new environments are being discovered almost daily. This is a key especially relevant to the railroad industry; the continuing pressure to reduce cost finds scarcer human resources. Bar coding is a systems alternative to numerous manual endeavors.

The utilization of bar coding in the back shop environment has caused some concern. The bar code label is not adequate to withstand an oily, dusty shop environment for prolonged periods. Options to cover the shop environmental elements include laminated tags and/or permanent codes etched into the part during or after manufacture. The metal surface would first receive a coat of white paint, then bars would be etched automatically. If the desire to utilize bar coding is strong enough the methods are available.

Bar codes increase productivity in three basic and relatively simple ways:

1. **Speed** — Data are entered into the computer with an automated identification system more rapidly than with any other method.
2. **Accuracy** — Bar code systems provide for almost totally accurate data entry because they do not rely on the human element, and the underlying technology is quite simple.
3. **Reliability** — With automatic check digits coupled with simple, reliable technology,

the resulting system is consistent and dependable.

Automated identification systems have a greater positive impact on productivity than perhaps any other single tool or concept. Bar codes will continue to play a key role in a variety of applications and environments for many years to come.

IV.

BAR CODING — RAILROADS

As noted in the previous papers, most analysis that is done to determine product quality and vendor service performance is predicated on the review of mounds of data captured by shop floor forces and fed into computers. At present, railroad managers rely on volumes of computer printouts to assist them in their decision-making process. This decision-making process is in jeopardy, however, because of the low confidence level in the data base itself.

Perhaps the major hindrance to this data integrity is the trend in the railroad industry to eliminate many clerical and mechanical forces. These are the same people we count on to capture and enter the data.

It is naive to think that this trend will change, or that management will want fewer reports and analyses performed. Therefore, the urgent problem is the need for improvement in the reliability of data being captured.

Across the country, data are being captured by the mechanics in the form of turnover books, work order forms, tags attached to components, shopping lists and little black books kept in someone's back pocket. The list is as long as the imagination can stretch. There is no uniformity in how the data are captured, and how they are entered into the computers. In almost all cases, a mechanic must take the time to write the data down to pass on to someone else for later data entry. Some circumstances that affect correct data collection and entry include number transposition, changing forces due to "bump-and-roll" practices, computer down or in-use, and pressure to "fix locomotives" in a hurry.

We all know that our first objective in the Mechanical department is to repair locomotives in a safe, efficient manner with quality work in the quickest time frame. The second objective, if there is time, is to capture the data required for reports for our mechanical managers.

One of our objectives for assisting the mechanics to "fix locomotives" and still furnish the data our management requires, is to make the data collection easier, more accurate and faster.

Bar coding can help the railroad industry!

The Materials departments on some railroads have taken their lead from the automotive and grocery industries and also from the

Government by establishing a bar code standard. Recently, the National Association of Purchasing Agents drafted standards that included label sizes, specifications for print density, spacing, and most importantly, they have settled on the 3 of 9 code as a standard. In most cases the first, and possibly only, use for bar coding in the railroad industry today is in materials control. One major midwestern railroad has successfully applied bar code technology to its receiving, storage, retrieving and inventory adjustment operations. This same railroad has approached suppliers to use bar codes for their shipping and billing transactions, in addition to package marking. Understandably, most suppliers want to sit back and wait for an industry standard.

Now it is time for bar coding to go beyond inventory control. Bar coding is nothing more than a communications process, and we in the Mechanical departments need to improve communications with our shops locomotive repair personnel. We now communicate with our mechanics by capturing the locomotive failure records, component change-outs and locomotive servicing data.

Bar coding is one way we can improve communications and increase productivity through quality data collection and entry.

Use of bar coding can ease the load on our mechanics, while expanding the data accumulation to new areas like

1) Labor data collection, bar coding time cards and job descriptions
2) Federal inspection records
3) AAR billing, coded for use with a coded matrix
4) Warranty monitoring the bar coded serial numbers
5) Locomotive fueling records
6) Locomotive and car marking for train consisting
7) Floor controls in repair shops

No doubt there will be those operating officers who fought the computer, but now use many computer reports to assist them in their work, who will also say, "Bar coding is okay for inventory control, but not for the 'working railroad.' "

Some railroad officers will remember the ill-fated car identification program using a bar code type label instituted by the AAR in the late '60s. The early labels and scanners were not adequate and required much maintenance. This problem, coupled with the difficulty of trying to label more than two million cars, and the complexities of attempting to operate joint interchange points, led to the early abandonment of this system.

But the recent advances made in bar code technology rival the advances made in the space programs.

New label materials that withstand high heat and chemical washes, and special infrared ink that can be read through dirt and grease, are now available.

Scanners and code readers, stationary, moving and hand held, can be purchased.

We have a choice between hand held readers that record the scanned data for later downloading into the computer, and also hand held units that transmit the scanned data via radio frequency directly to a receiver tied to a P.C.; results, no waiting or no downloading. A variety of printers with various speed and print types is also available. And now, bar code laser etching that will permanently mark a code on your component is available.

How will bar codes help me run my shop, my department? What benefits will I see?

By bar coding serial numbers, inspection sheets, order catalogs, fueling stations, time cards, and anything else that we collect data on, we can:

1) Input information directly from a work site, eliminating a recording step;
2) Minimize errors caused by manually keying in data;
3) Eliminate time lost going to and waiting in line for CRT terminals;
4) Eliminate time lost while computers are down;
5) Improve data input by making it convenient and simple to use the bar code equipment;
6) Eliminate paper.

To summarize:

A) The mechanic, repairing our equipment, is the key to data collection.
B) The need for data will increase, while the force level will decrease.
C) The suppliers are ready to implement bar coding into their operations.
D) Bar code technology can offer speed, accuracy and reliability in data accumulation.

What do we do now?

The railroad industry must establish workable, mutually agreed upon standards, such as:

1) Which code to use as a standard.
2) Which components are to be bar coded.
3) What type of marking:
   a) Labels
   b) Etching
   c) Tags
4) Where to apply the label or marking for ease of reading, while not affecting the use of the component.
5) What data should be coded:
   a) Serial number
   b) Vendor name part number
   c) Date of manufacture
   d) Other.
6) Whether marking should be man readable also.
7) Technical marking data, like density, spacing, dimensions, etc.

It is imperative that a committee of the LMOA or AAR pick up the

challenge of industry standardization and begin!!

When an agreement is reached, suppliers can begin to mark the components we are buying, and the unified process will be under way. Who will begin?

V.

MATERIAL HANDLING INNOVATIONS BY THE AIRLINE INDUSTRY

The airline industry has a number of differences in the way it handles material when compared to railroads, but a unique and cost effective one involves what is call ed the International Airlines Technical Pool (IATP).

In December of 1978, an article in **Airline Executive** magazine titled "Technical Pool Saves World Airlines 150 Million." In today's terms this savings could easily equate to more than twice that amount. This saving does not include benefits from the shared use of airport ground handling equipment or maintenance equipment. Equipment sharing in these two areas is estimated to save at least as much as the spare parts figure, possibly more.

IATP was formed by an agreement among 78 scheduled airlines to share spare parts and equipment at 250 locations around the world. No fewer than 4,000 different items are involved. The spirit of cooperation and the equitable financial basis by which IATP is operated surely makes it one of the outstanding examples of international business organization.

What IATP means in an oversimplified version is this: Instead of each airline having one of every high-value spare part at every major station it serves, a situation it could never afford in the first place, each pool member achieves this same result at only a fraction of the cost.

It works like this. Each pool member (there are 85 today) pays a one-time fee of $10,000 to join. to qualify, one must be capable of being a provider of one or more pooled parts at one of the 250 stations.

Each season (The April-October and November-March timetable periods), an airline pays an availability charge for each item it shares at each station. Say the availability charge is $1,000 and four airlines are participating in the pool.

The providing airline absorbs 25% of the cost ($250.00) but receives 75% from the other three members for a net difference at that station of $500.00. At another station, this provider airline may be strictly a user.

An example might be a battery for an airplane. The participating airlines will pay a small pro-rated monthly fee which is also based on usage of the battery. If the battery is drawn from the pool and used, it may then be pulled at a convenient maintenance shop and replaced with one of the airline's batteries. The pool battery is then returned to the airline's home base, documented hours of use are recorded and serviceability of the battery. It is then put back in the pool at the point or station that needs it most.

The pool concerns itstlf with parts ranging from as low as $100 to as high as $100,000 or more. The seasonal availability charge is based upon 20% to 25% of the cost of the part per year, thus a providing airline could recover its entire investment in a spare part in five years from other pool members and have "free" use of it for the remaining lifetime of the part.

Whenever an airline makes any modification to any part involved with pooling, it must immediately advise all other partners of the change and of any effect it will have upon the pool.

Aircraft recovery kits are also pooled between several carriers. These are kits which include items to recover a plane from the water or some other unscheduled place. The kits may cost $50,000. A member who uses it will replace missing items and pay freight to ship the kit back to where it is most needed in the pool.

All of the charges and all of the share calculations are administered for IATP by Continental Graphics, Inc. of Culver City, California and the financial settlement between carriers is processed via the International Air Transport Association (IATA) Clearing House. An airline does not have to be a member of IATA to join in the pooling agreement, but it does have to meet certain stringent tests before it is accepted for membership. IATA is somewat similar to the railroads' AAR.

The International Airlines Technical Pool is run by a seven member management committee elected by the membership every two years. A slate of candidates is nominated from which the top ten vote getters are named to the committee. The top seven serve on the committee and the remaining three are standby members to serve in the absence of one of the seven during the two year term.

One airline executive stated that even though the airlines are in stiff competition with one another, the parts pool works for the mutual benefit of all members for savings of many millions of dollars annually.

Airlines also are highly computerized on all major replacement items used on the planes. They will monitor the life of components and knowing their life cycle, they will stock spares and replace accordingly.

The tracking of all line replacement units (LRU's) is not only used for replacement on a scheduled time cycle, but also to keep track of warranties on the various parts.

The railroads do follow many parts on their locomotives by computer, but we are not generally having the part changed by a computer generated flag.

It may be that we could learn from our counterparts in the airline industry, and possibly save ourselves considerable money by adopting some of its procedures. Maybe someday there will be a National Railroad Technical Pool (NRTP). Think about it.

DIESEL MATERIAL CONTROL COMMITTEE

Six-Year Index

1982

Maintaining Product Quality Through Improved Material Handling

1. Use of kits in locomotive maintenance
2. Cost effective methods of shipping material from vendors
3. Union Pacific's Component Inventory Maintenance System (CIMS)
4. Advantages of using shipping containers

1981

Diesel Material Control: Innovations In Material Handling and Control

1. Disposal of Unserviceable Component Parts: What is the Most Profitable Method?
2. Innovations in Stores Material Handling, Via Computer Technology
3. Locomotives Held for Material: An Update for the 80's
4. The Best Approach to Procuring Material; New, UTEX, Repair and Return or Shop Repair

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"Why not write our Secretary today and request a membership application?"

D. P. MILLER
PRESIDENT
Asst. Vice President Purchasing
and Material Management
CSX Transportation
Baltimore, MD 21201

J. S. MASTRANGELO
SECRETARY
717 Pinecliffe Drive
Chesapeake, VA 23320

Tuesday, September 15, 1987

9:00 A.M.

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

Pre-Convention Presentation: Southern and Southwestern Railway Association

April 23, 1987
Holiday Inn (Gateway)
Huntington, WV

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General Locomotive Foreman
CSX Transportation
Grafton, WV

VICE CHAIRMAN
R. E. Nieto, Supervisor Locomotive Equipment, Union Pacific Railroad, Omaha, NE

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1987 TOPIC:

MAXIMIZING FUEL EFFICIENCY THROUGH QUALITY ELECTRICAL MAINTENANCE PROGRAMS

PERSONAL HISTORY

A. E. (GENE) BRIDGES, JR.

Gene was born in Cumberland, Maryland on December 30, 1949. He graduated from Bishop Walsh High School in 1967 and attended Allegany Community College in the Cumberland area. In March, 1968, he began his railroad career at Martinsburg, West Virginia as a Trackman with the Baltimore and Ohio Railroad.

In August of 1968 Mr. Bridges began serving an Electrician Apprenticeship at the Cumberland Locomotive Shop. Upon completion of apprenticeship worked there on various electrical positions and at Bolt & Forge Reclaimation Plant as a Maintenance Electrician. In 1977 he acquired 2nd Class Radiotelephone License with ship radar endorsement and moved to the communication department as an Electronic Maintainer at the system microwave center in Willard, Ohio. From there he was transferred to Cumberland, Maryland as Electronic Maintainer assigned to radio repair. In March of 1979 was promoted to Project Engineer in the mechanical department and relocated to Huntington, West Virginia. While there was promoted to Locomotive Maintenance Supervisor in 1981 and General Locomotive Maintenance Supervisor in 1982.

In October, 1983, relocated to Grafton, West Virginia, where he is presently employed as General Locomotive Foreman. He and his wife, Marita, have one daughter, Tracy, who is a full time student on scholarship at the University of Maryland.

MAXIMIZING FUEL EFFICIENCY THROUGH QUALITY ELECTRICAL MAINTENANCE PROGRAMS

Our 1987 Diesel Electrical Maintenace Committee theme "Maximizing Fuel Efficiency Through Quality Electrical Maintenance Programs", has resulted in development of two written texts and the loan of a video tape which illustrates the remanufacture of a traction motor armature.

The first technical paper examines maintenance requirements, programs and performance of existing locomotive fuel saving options. In the other text we look at the traction motor testing program being conducted by the AAR at the Transportation Test Center in Pueblo, Colorado. This testing program is directed toward providing a reliable data base to measure energy efficiency and quality of remanufactured traction motors. Also, a video tape developed by a supporting railroad as a training tool and made available on loan to the association, illustrates GM (EMD) traction motor armature rewinding techniques. This video provides an example of one railroad that is directing effort towards training its employees in the skill of armature rewinding with the intent of performing this remanufacturing activity in-house. Viewing of the tape will be part of our annual technical presentation.

I. PROPER MAINTENANCE OF ELECTRICAL FUEL SAVING OPTIONS

Introduction

This year the Diesel Electrical Maintenance Committee presentation will focus on the requirements necessary to maximize fuel efficiency thru quality electrical maintenance programs. In order to achieve this we, as representatives of Mechanical departments, must ask ourselves three basic questions:

1) What fuel savings options exist?
2) How much maintenance is required to gain projected fuel savings?
3) Is there a need for scheduled maintenance activity to confirm that fuel saving options are functional?

Fuel efficiency was not a primary consideration in the development of first and second generation locomotives. The locomotives of the third generation type have now been introduced and are extensively in use. These relatively new locomotives have been designed taking into account a very important factor: high energy costs.

The energy crisis of the seventies and the subsequent skyrocketing fuel prices have generated an increased consciousness of the need for better fuel economy designs applied to railroad equipment.

Mechanical and electrical improvements and the application of the most recent technological developments, like the microprocessor on fourth generation locomotives, have helped produce fuel economies of as much as 20% (J. A. Stoddart, Railroad Energy Technology Conference, May 20, 1986).

Many of the fuel saving devices, which are standard equipment on later model locomotives, can also be retrofitted on older types with a resulting reduction in fuel consumption.

The LMOA Electrical committee has examined some of the most widely used fuel saving options and devices, their worthiness and their maintenance requirements.

To help the committee in this task, a survey was conducted throughout the industry on the use of the different types of devices, to acquire "feedback" from the users themselves, and better evaluate their acceptance and use. This survey was accomplished through a questionnaire that was mailed to upper level management of all major railroads along with a cover letter outlining our committee intent.

For each surveyed option, A) through J), the following questions were asked:

1 - Total number of locomotives equipped
2 - Percentage of active fleet equipped
3 - Manufacturer
4 - Amount of fuel saving achieved or anticipated
5 - Your opinion of the value of fuel saving option.

A) Low Idle

The low idle feature consists of the reduction of engine idling speed to about 50% of its normal idling rpm in some applications. This is achieved by energizing particular solenoids of the engine governor. However, the engine speed is returned to the normal idling mode whenever conditions like high oil temperature, low main reservoir pressure, low ambient temperature and low water temperature are experienced.

The average fuel saving obtained on locomotives equipped with low idle and having normal utilization is evaluated at slightly less than 1%. Larger savings will be obtained for low duty cycle locomotives.

The locomotive manufacturer suggests annual verification of the operation of the low idle system controls; i.e.:

— verification of the low idle speed with a tachometer
— verification of engine speed change (low to normal) by simulation of the nullifying conditions.

The low idle feature has not met with unanimity among the railroads. Many have given it a good rating while others have found that

it was better to completely disable it because of consequential problems, like overloading of the auxiliary generator (retrofitted locomotives) or · high levels of engine souping. Eight of nine railroads responding to our survey are equipped with this fuel saving option to some extent.

B) Two Speed Dynamic Braking

The two speed dynamic braking feature saves fuel by lowering the engine speed during dynamic braking, to a level at idle or number two (2) throttle position. Engine speed is increased whenever the level of dynamic braking current is such that additional cooling of traction motors is needed.

The two speed dynamic braking option is considered capable of achieving fuel savings ranging from 1.1% to 1.5% depending on the type of locomotive.

The recommended system verification consists of an annual check of the engine speed change following the specified conditions, while performing the dynamic brake test.

Almost all the surveyed railroads use this option on many of their locomotives and their evaluation on the savings achieved ranges from "minor" to "substantial"; no negative comments were expressed on the feature itself

C) Two (2) Speed Radiator Fan—EMD

The two speed radiator fans system saves energy by reducing the cooling fans speed when the engine coolant temperatures are below a certain level. The radiator fans speed will increase to high speed whenever cooling is insufficient. The speed ratio between high and low speed is about 2 to 1.

The locomotive manufacturer does not specify the expected amount of energy savings achieved by this feature, but some consider that a 2% fuel saving is a realistic figure. The amount of fuel saving as seen by the railroads ranges from "minor" to "appreciable".

The system maintenance requirements are limited to an annual verification of the temperature switch operation and the verification of the speed change sequence.

Five of the nine surveyed railroads have locomotives equipped with such devices and their evaluation is generally positive. There are no reports of any particular problem.

D) Eddy Current Clutch — GE

The eddy current clutch is used to drive the engine radiator fan at two different speeds and allow for less energy consumption when a lower fan speed is sufficient to adequately cool the engine; it also completely decouples the fan when no radiator cooling is necessary.

The expected fuel economy can range between 2% and 2.5% compared to a continuously driven radiator fan.

Annual verification of the clutch operation, brush holder, brushes and temperature switches are the

manufacturer's recommended maintenance requirements.

One railroad which has long time experience with this type of system prefers a semi-annual inspection and cleaning interval. Some railroads have experienced early problems with the brush holders; the manufacturer has since improved the design with good success.

Most of the railroads have not been using this device long enough to evaluate the fuel savings achieved. Many are concerned about its reliability. Five of nine railroads responding to our survey are equipped with this fuel saving option to some extent. One railroad has locomotives equipped with this type of fan drive and is satisfied with the fuel savings, although the specific amount is very difficult to evaluate.

It is generally believed that once the reliability of the system is improved this option will be very economical.

E) Air Compressor Clutch — EMD

This device is used to engage or disengage the air compressor from the engine drive following the air requirement of the locomotive compressed air system. The air compressor clutch is a mechanical device which is operated by the compressed air of the system.

Direct fuel economy improvement is evaluated at about 0.5% for a medium duty cycle. The fuel saving will increase with lighter compressor duty cycles. Maintenance savings are also obtained with the reduction of air compressor wear.

The manufacturer-recommended maintenance is limited to periodic inspections and functional tests. Disassembly and replacement of major components are only required at major overhaul.

Few railroads have locomotives equipped with this device and in many cases only on a test basis.

Major problems have been reported affecting the reliability of the system. The locomotive manufacturer is revising the clutch design to improve its performance.

The reliability problem has completely overshadowed any positive energy savings given by this system.

F) Trainlined Fuel Saving Systems

These fuel saving devices are normally offered as options or add-on equipment and are not offered by the locomotive manufacturers.

They work on the principle that most of the time some of the locomotives in a consist can be throttled down while leaving the others at higher and more efficient notch levels. Some devices would completely shut down the unnecessary locomotives and restart them only when their pulling power is required.

Claimed direct fuel savings range from 5% to as much as 10% when all locomotives are equipped with such devices. Users' evaluation is not as optimistic, but nonetheless positive.

The few railroads which are using these devices have been positive in their remarks. They consider this option efficient and well accepted by the crews although there have been some reports of vandalism.

The only expressed concern is related to the problem of the uneven fuel consumption between locomotives, which may lead to modifying logistics for refueling.

G) Flange Lubricator

The on-board wheel flange lubrication systems improve fuel efficiency by reducing the fricton existing between the rail and the wheel flange. Wheel flange lubricators apply a thin film of lubricant directly on the wheel flange which results in less fuel consumption and reduced rail and wheel wear.

The direct percentage of fuel savings attained by the use of these devices is difficult to evaluate. Tests carried out on combined on-board and trackside lubricators have shown significant fuel economy. Savings may be even greater when considering the increased rail and wheel life.

From a locomotive maintenance department viewpoint, the on-board grease reservoir will require periodic recharging and the alignment and condition of the delivery device, such as spray tips, will be critical. A simple function (self) test to confirm total system integrity is essential.

Only one railroad has on-board lubricators on a fleet of appreciable size. Its experience is very positive but initial reliability problems had to be overcome. Other railroads have plans to test such systems in the near future.

H) Traction Motor Blower Inlet Guide Vane

The system is composed of a radial vane which controls the air flow through the traction motor blower in accordance with the cooling requirements of the traction motors. The automatic vane is electronically controlled and mechanically operated. Parameters such as traction motor current and temperature are continuously monitored to control cooling air.

The manufacturer expected fuel saving is in the order of 2%.

The manufacturer maintenance requirements consist of the periodic system verification and adjustment of the inlet vane operating mechanism.

The system has been found to be unreliable and it has been generally disabled by the railroads on the advice of the locomotive manufacturer. Recently, a modification package has been provided by the manufacturer to correct initial design deficiencies. This modification seems to have dramatically improved the reliability of the inlet guide vane.

I) Electronic Refueling Systems

Several manufacturers offer different types of automatic refueling

systems, the most common being those which avoid fuel spillage. They use electronic means to sense that the required fuel tank level is reached and automatically shut off the fuel delivery.

Direct fuel savings are obtained by the elimination of spillages, while indirect energy savings can be attributed to reduced cleaning and maintenance requirements.

Only one of the respondent railroads uses an electronic refueling system, citing fuel spillage and environment protection as the main reason for its application.

J) Layover Protection Systems

The layover protection systems are used to protect the locomotive systems during low temperature extended shutdowns. The system consists mainly of an engine coolant heater, battery charging system, cab heater, battery heater and pumps to circulate the engine coolant and lubricating oil. The supply to the system is from a 480 volt, 3 phase, wayside power source.

Direct fuel savings are proportional to the layover time of the locomotives involved and other savings are obtained indirectly by less equipment wear.

Only one of nine railroads responding has locomotives equipped with these systems and has expressed satisfaction with its application.

Conclusion

In today's cost-conscious railroad environment every fuel dollar spent must result in the maximum tonnage moved the longest possible distance.

All the different fuel saving devices and options appear to provide some economic benefit. Some offer considerable fuel saving potential but there remain technological gaps to be filled. Fuel savings may be offset by high maintenance cost and result in counterproductive decisions.

Each user railroad must choose the systems to be applied to its locomotive fleet by taking into account their cost saving effectiveness and their maintenance requirements. Reliability remains one of the most important factors by which these systems will be evaluated, even before their energy saving characteristics are completely established. In short, the utmost reliability is essential for the product to gain acceptance and it can only be achieved through improvements in equipment design or adherence to sound maintenance practices where they are needed.

II.
PRELIMINARY REPORT ON AAR TRACTION MOTOR STUDY

Introduction

The Locomotive Component Efficiency Study was established by the Association of American Railroads (AAR) Research and Test Department to help railroads evaluate the feasibility of improving or

restoring the efficiency of the existing diesel-locomotive fleet. For each component of the locomotive that consumes energy, an evaluation procedure will be developed. Data from component testing will be used to develop component efficiency numbers (CEN's) which can then be used to track the change in efficiency of the component over its service life. Accumulated CEN data will provide the means for evaluating rebuilding procedures and maintenance practices, as well as providing input required for economic analysis.

Evaluation procedures have been developed for traction motors, air compressors, and turbochargers. Currently under development are procedures for evaluating gears, gearcases (steel vs. fiberglass), and gear lubricants (grease vs. oil). Although the procedures are generally applicable for all series of components, they were developed specifically for the components used in locomotives of the GP/SD40-2 series manufactured by the ElectroMotive Division (EMD) of General Motors and the B/C30-7 series manufactured by the General Electric Company (GE). Some changes in the evaluation procedures are used to evaluate components from other locomotive series.

Traction motors were selected by the Locomotive Component Efficiency Steering Committee as one of the first major components to be evaluated. In developing the traction motor evaluation program some of the principal questions identified for this study were as follows:

> Do the energy losses, hence the efficiency, of a traction motor change with age or miles of service?
>
> Do subsequent motor rewinds restore initial efficiency to "as manufactured" levels?
>
> Do all rewind kits produce the same level of losses?
>
> Do all motor rewind shops produce rebuilt motors with comparable losses?

This paper will address some of the preliminary findings resulting from the testing of fifty traction motors.

Procedures

Available literature indicated that the most practicable and reliable method for determining traction motor efficiency is by determining the individual losses of the motor at rated conditions. The individual losses can then be subtracted from the rated power input to the motor and the efficiency calculated from:

$$\text{Efficiency} = (KW_{input} - KW_{loss})/KW_{input}$$

This method follows procedures recommended by the Institute of Electrical and Electronic Engineers (IEEE).

The efficiency of a standard direct current traction motor will be reduced because of both mechanical

and electrical losses. These losses can be grouped into six separate loss categories as follows:

Total rotational loss
Mechanical loss
Armature core loss
Series field loss
Armature circuit loss
Self-powered loss

The basic approach developed to determine these losses was to rotate the motor under test by connecting it to and powering it through the use of a "calibrated standard traction motor." Measuring the electric power input to the "calibrated" standard motor and subtracting the losses associated with that motor results in the power into the test motor. Thus, by knowing the power required to drive the motor under test and by using the test procedures developed for this program, the test motor losses can be determined. As the Locomotive Component Efficiency Steering Committee had directed that EMD D-77 and GE 752E8 series traction motors would be studied, both a new EMD and a new GE traction motor were calibrated for use in the test program.

Personnel at the AAR Transportation Test Center (TTC) in Pueblo, Colorado, designed and fabricated the traction motor test stand. They also assembled the power supply system and instrumentation necessary to operate the test stand. The stand accommodates either EMD or GE traction motors in an armature shaft-to-armature shaft configuration. Power supply and electrical circuitry were designed to allow the test stand operator to designate either motor as the drive motor and the other as the generator. Provisions were made for warming up the test stand motors and for performing a total loss determination by connecting the motors in a classical KAPP test configuration.

For the KAPP test procedure, one motor is designated as the "motor" while the other is designated as the "generator". With the armature shafts of the two motors mechanically coupled together, electric power is applied to the "motor". The armature of the "generator" is then rotated mechanically within its frame. The series field coils of the "generator" are excited by a separate external power supply and the output voltage of the "generator" is observed. When this generated voltage matches the value and polarity of the direct current voltage supplied to the "motor", a paralleling switch is closed, connecting the output of the "generator" to the input of the "motor." The power output of the "generator" can then be increased and the "motor" in turn will draw on this power to match the imposed load. Because the generated power in this electrical and mechanical configuration, will always be less than the power required to operate the "motor", the power deficiency must be made up from the external main power supply. The

measure of this "make-up" power is exactly equal to the sum of the total losses of the two motors under test. This procedure is used to warm-up motors, after which the individual loss tests are made. These tests are conducted at four specific rotational speeds: 500, 1000, 1500, and 2100 RPM, which respectively correspond to approximately 14, 21, 42, and 59 MPH. The lowest speed is in the region of minimum continuous speed for a locomotive and the top speed is in the region of maximum locomotive speed. Armature current is near a maximum at the lowest speed, thereby influencing copper circuit losses most heavily. Motor voltage is near a maximum at the top speed, thereby significantly influencing core losses.

Total rotational loss:

For this test, the armatures of both motors are mechanically coupled together. The series field of the "generator" (the motor undergoing testing), is excited with the full load current necessary to produce test speed. The armature circuit is left open. Voltage is applied to the armature circuit and to the series field of the driving motor so as to rotate the coupled armatures at the established test speed. The voltage and current applied to the driving motor armature are measured and recorded. The power in kilowatts required to rotate the "generator" under these conditions is a measure of the total rotational loss of the motor. It includes the power necessary to overcome the rotating friction in the armature bearings, the friction attributable to the commutator brushes, the windage friction of the armature rotating in the cooling air, and the electrical drag (commonly called core losses) caused by the eddy currents in the motor armature laminations and hysteresis in the magnetic material of the pole faces.

Mechanical loss:

With the armatures mechanically connected, the excitation is removed from the field circuit of the "generator." The voltage and armature current required by the driving motor to rotate the two coupled shafts at test speed are multiplied to give the total kilowatt power input to the test setup. The power required by the driving motor alone is obtained from the motor loss calibration curves for the standard driving motor and this power is subtracted from the total input power to give the mechanical power loss of the "generator" which is the motor undergoing test.

Armature core loss:

At each of the preselected speeds, the difference between the total rotational loss and the mechanical loss of the "generator" is equal to the no-load core loss of the "generator."

Series field loss:

The resistance of the series field of the "generator" is calculated

from the current required at the test speed and the voltage necessary to produce that rated current flow. The loss is calculated from the product of the rated current squared, multiplied by the resistance.

Armature circuit loss:

The resistance of the armature circuit, at each preselected speed is determined by following Forgue's method. In this procedure, the armature of the "generator" is mechanically coupled to the armature shaft of the driving motor. The "generator" armature circuit is opened and excitation is removed from the field coil circuit. When the coupled armatures are rotated, the "generator" armature is subjected to a weak flux caused by the residual magnetic field of the "generator." A small current of reverse polarity is applied to the field circuit to cancel out the residual magnetic field. This condition is achieved when the "generator" armature circuit shows zero volts reading at the open circuit terminals. With no excitation applied to the series field circuit and no residual magnetism in the field poles, the armature circuit now exhibits pure resistance. Current of a preset level is now passed through the armature circuit and the voltage required to impress that current is recorded. This measurement is repeated at several different levels of current. The current and voltage relationships thus measured are plotted and the slope of the least squares fit line is the resistance of the armature circuit at that RPM. The armature circuit loss at that RPM is calculated from the corresponding full load current and the resistance obtained through Forgue's method.

Self-powered loss:

The armature shafts of the two motors are mechanically uncoupled. Voltage is applied to the armature circuit of the "generator" while its series field is excited by the rated full load current at the test speed. The applied voltage and resulting current are multiplied to give the self-powered loss of the "generator."

Component efficiency determination:

The total rotational loss, the series field loss, and the armature circuit loss are added for each measured RPM. The CEN at that RPM is calculated from the efficiency formula as previously given. By separating the total losses into their individual components it should be possible to determine the effect each element of the rebuild process will have on component efficiency (CEN). Analysis should reveal which elements of traction motor rebuilding contribute specifically to degrading component efficiency.

FINDINGS

Preliminary findings, based on a sample size of fifty EMD traction motors, indicate the EMD motors

exhibited wide variations in some components of energy loss and insignificant variation in others. The losses increase with motor speed for some categories and decrease with speed for others. For each of the six loss categories, the mean value for the RPM having the largest loss is given in Table 1.

As measured by the standard deviation of the sample of the fifty EMD traction motors tested to date, series field loss, self powered loss, and mechanical loss show small variation from motor to motor and armature circuit loss and armature core loss show relatively large variability from motor to motor.

In the case of core loss, the basic fault can generally be traced to a break-down of insulation between laminations of the armature core or possibly because of a poorer grade of steel used in the armature laminations. Replacement of laminations is a relatively rare procedure. Restacking of laminations is more prevalent and the possibility of damage to the insulating varnish which coats the individual laminations increases with successive rebuildings of armatures.

One area that must be examined very closely, if high core losses are encountered, is the procedure used in stripping the windings from a damaged armature. It is well recognized that the practice of burning out the insulation covering armature coils preparatory to rewinding the armature can deteriorate the insulating varnish between the plates of the laminations. This breakdown of the insulation will lead to higher eddy current losses and will be detected by the testing procedure now in place. There is also the possibility that the plates of the lamination can be damaged directly by excessive heat, thereby changing the metallurgical structure of the steel, again leading to higher core losses. In general, these higher core losses manifest themselves as "hot spots" in the armature, leading eventually to shorts, excessive heat, and ultimately decreasing armature windings life. Certain early failures of traction motors following an armature rewind may be traced to damage in the armature laminations, insulation, and windings, damage which took place during the motor rebuilding operation.

The data obtained from testing these EMD traction motors have been statistically analyzed to determine if these initial tests are sufficient to base conclusions about the relative merits of different rewind shops and rebuild kits. For the most part there are insufficient data available at this time to conclude with confidence that the differences can be attributed to shop methods or the kits. However, the large variations in average performance measured among the rewind shops and kits suggests that significance differences do exist and that additional tests will provide the data necessary for making definitive recommendations.

TABLE 1

MEAN TRACTION MOTOR LOSS BY CATEGORY

Loss Category	RPM at. Max. Loss	Mean Loss kw	Standard Deviation % of Mean
Total rotational loss	2100	25.04	6.8
Series field loss	500	9.58	7.1
Self powered loss	1500	10.19	9.2
Mechanical loss	2100	15.05	9.0
Armature core loss	2100	10.06	16.3
Armature circuit loss	500	31.16	14.3

CONCLUSIONS

The traction motor evaluation procedures and test stand are satisfactory for evaluating traction motor energy loss. Test results obtained from the evaluation of fifty EMD Traction Motors indicate that the purely mechanical losses are uniform and small. Based on these test results, the authors of this report conclude that the traction motors are being rebuilt with close adherence to factory specifications in all mechanical parts such as bearings, alignment, and ventilating air path.

Examination of the series field losses also lead to the conclusion that series field coils conform very closely to original factory specifications and that the coils are being installed correctly by rebuilders of traction motors. No examples have been encountered to suggest that there are any deficiencies with regard to this element of traction motor rebuilding.

The two remaining categories wherein significant losses have been measured are core loss and armature circuit loss. Core loss is most harmful at high voltage, which occurs at high speed, whereas armature circuit losses are predominant at high armature current which occurs at low speed. Additional tests of traction motors will be necessary in order to provide the larger sample size necessary to establish with confidence the difference that exists between rewind shops and armature kits, as well as the influence mileage and/or type of usage has on the degradation of motors.

Further studies to be carried out on the traction motor test stand are being designed to address questions which have arisen since these preliminary results have been reported to the railroads. For example, the effect of traction motor ventilating air flow on motor losses will be investigated. The influence of pole piece and series field alignment will be studied. The effect of brush box alignment on motor losses has also been questioned.

As the causes of significant motor losses are determined, it has been proposed that early warning of impending failure or development of excessive losses would be beneficial in reducing traction motor failures and maintenance costs. It is planned to investigate the feasibility of using various transducers to measure vibration, acoustic and emissions as generated by known good motors and to compare them with similar emissions from known defective or high loss motors. The difference between the "standard" and known "problem" emissions may be a characteristic signature which can be monitored with suitable on-board instrumentation.

DIESEL ELECTRICAL MAINTENANCE COMMITTEE

Six-Year Index

1983

New Solutions to Locomotive Electrical Problems

1. Ground Relay Trouble Shooting
2. Traction Motors
3. Locomotive Storage (Electrical)
4. Water Cooling and Refrigerating Methods for Locomotive Cab Application

1982

Quality Maintenance — Assuring Thorough Repairs

1. Tests on Traction Motors
2. Transition Trouble-Shooting
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1981

Innovation: Past and Present

Traction Motors
  Evaluation of Improved Test Methods
  Teflon Bands

New Generation Locomotives

Electrical Troubleshooting

Batteries and Charging Systems
  Troubleshooting EMD AC Auxiliary Generator System

Selection of Locomotives for Major Locomotive Overhauls

D. W. MAYBERRY
Assistant Vice President and
Chief Mechanical Officer-Locomotive
Norfolk Southern Corporation
Roanoke, VA

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

Our Diesel Mechanical Maintenance 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.

Tuesday, September 15, 1987

2:00 P.M.

REPORT OF THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

Pre-Convention Presentation: Roanoke, VA

April 22, 1987 Hotel Roanoke Roanoke, VA

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Resident Superintendent
Burlington Northern Railroad
Erie, PA

VICE CHAIRMAN

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1987 TOPIC:

MANAGING PRODUCTIVITY AND QUALITY FOR COST EFFICIENCY

PERSONAL HISTORY

MARVIN L. VARNS

Born in Missouri Valley, Iowa on June 4, 1934. Began Railroad career in 1952 serving S.M.W. pipefitter apprenticeship with the Union Pacific Railroad. After ten years with the Union Pacific Railroad, left the Railroad industry and returned in 1964 with the Chicago, Burlington and Quincy Railroad. In 1967 was promoted to Roundhouse Foreman. After the CB&Q Railroad became a part of the merged Burlington Northern Railroad in 1970, was appointed as Foreman at Dale Street Shops, September, 1974, Foreman of Locomotives, Superior, Wisconsin, May 1977, Assistant General Foreman, West Burlington Shops, May, 1978, Superintendent Shops at Hillyard Shops and January, 1982, Superintendent, Shops, Livingston, Montana. In 1986 was appointed Resident Superintendent at Erie, Pennsylvania.

Marvin is married to the former Phyllis Walkins of Modale, Iowa. They have four children and two grandchildren. Marvin's hobbies include walking, community service, gardening and when time permits, taking motorcycle trips.

I.

EMD WATER PUMP REBUILDING

Of all the engine components, the one that probably lends itself best to the reclamation process is the water pump. However, satisfactory performance and service life can only be expected if proper attention is paid to the requalification of used parts. A recent survey of one member road's rebuilding procedures determined that the use of unqualified used parts is the main reason for early failure.

The most common type of water pump failures noted during the investigation were those due to oil leaks at the "tell tale" hole. A smaller percentage of pumps failed due to water leaks at the tell tale hole. The water leak failures were seal related (excessive carbon seal wear). The oil leak failures all involved the bearings. There was a definite pattern of excessive bearing wear. Approximately 20 pumps were examined; 75% failed due to oil leaks (bearing related); 20% were water related failures. Two pumps examined experienced severe impeller-to-housing contact, one caused by a failed impeller retainer nut, the other by a failed front bearing.

Teardown inspections confirmed a high percentage of bearing-related failures. Commonly, the rear bearing began to wear excessively, causing the shaft to run out of parallel and eventually wearing the front bearing to a condition that caused the oil leak at the "tell tale" hole. In the worst case noted of this failure mode, both bearings had excessive wear, causing drive gear tooth wear and slight impellers-to-housing contact. Common to all pumps showing

bearing wear were signs of either excessive clearance between the pump shaft and the inside diameter of the respective bearing, or excessive clearance between the outside diameter of the bearing and the respective pump support bearing bores. In many cases, the rear bearing had "spun" within the support housing bore. It is very important to insure that support housing bearing bores be carefully measured and mated to the bearings they will receive, as these bearing bores may be slightly oversize and the bearing outer diameter slightly undersize. The limits governing the fit are: Interface fit .0001 in. maximum - to a clearance of .002 in. The committee recommends that new bearings always be used when reclaiming any water pump.

Based on some of these findings, EMD has recently expanded its specifications on clearance and dimensional limits for its water pump components. Please refer to Section 10 of the latest engine maintenance manual applicable to your equipment; the specs given herein are taken from the 645E3B manual but should be applicable to all 645 engines. Some examples of specification changes are: minimum interference fit for the pump shaft impeller mounting diameter to impeller bore has been reduced from .0005 in. to .0002 in. Also included now are specs for pump shaft bearing journal diameter, which is 1.5745 in. minimum. These specs should be helpful in disqualifying worn shafts, as well as reclaiming them by metal spraying, plating, etc. More emphasis is placed on stationary bushing seal seat squareness in relationship to the drive shaft. Of equal importance is checking for proper impeller balance. The EMD spec for pump impeller balance is 28 inch grams static. However, several member roads try to bring them to within 5 inch grams or better. Any pump impeller that has been in contact with its housing should be suspect. The committee recommends that impellers be properly checked and/or balanced to assure long bearing and seal life.

It should be noted that improving dimensional checks to qualify reusable parts might lead to a higher scrap rate on key components, in the long run it will assure quality performance and reduced down time. One other cause of premature seal failure is high levels of impurities in the cooling water itself, such as silica (sand), etc. Also, excessively high concentrations of cooling water treatment can be detrimental to pump seal life. Improper cooling water maintenance can severely affect the total cooling system as well as engine performance.

Finally, if an engine is having repeated pump failures at either location, there is cause to suspect excessive gear train wear or vibration. This failure mode is symptomatic of possible vibration damper failure. The specification for

Bob Erdmann

pump drive gear backlash at the tooth face is .0008 in. to .016 in. new, a maximum of .030 in. used.

The committee recommends that each railroad review its mean time between failures and the types of duty cycles its equipment is experiencing and determine its own schedule for water pump maintenance.

II.

ON BOARD FLANGE LUBRICATORS

The concept of on board or mobile flange lubricators has been known to the rail industry for many years, but there was little interest until escalating fuel cost in the seventies started the industry looking for ways to save fuel. In recent years member railroads have done considerable testing to determine which units are best suited for their operations and environments.

Today there are many types of mobile flange lubricators on the market, ranging from a simple block attached to the end of a rod to complex electronic systems. The primary purpose of the flange lubricator is to reduce fricton between rail and wheel flange with the end result being less wheel and rail wear and reduced fuel consumption. Savings that can be realized on fleets of locomotives equipped with flange lubricators may justify their application. The object is to find a functional and affordable applicator and a compatible lubricant. These are the main factors to be considered for efficient operation and keeping maintenance and overhaul to a minimum in the repair shops.

One member railroad began applying flange lubricating equipment to locomotives in March, 1985, following reports on tests conducted by its Technical Service department during 1984, which indicated fuel savings potential approaching 14% on specific routes. One hundred twenty locomotives, one year old or less, were designated for installation of Willi Vogel STG-3 Systems in the 1985 program. Twenty-nine were given priority for the first application to be made part of the test schedule for the summer of 1985. These tests indicated that, averaged over all of the system routes, a 7% fuel savings could be achieved by equipping the heavy haul road units with flange lubricating equipment. By the middle of 1987, this member railroad will have completed its flange lubricator program by equipping over 600 locomotives.

Functional applicators must meet the criteria of train operation over any terrain and in any environment. The applicator may dispense intermittently, i.e., curves, grades, and tangent tracks, or it may dispense continuously with cutout circuits during sanding, reverse operation, braking or wheel slip. Rates of application and dispensing methods will vary, based on the type of lubrication that is best

suited to each member's mode of operation. Reservoir size is a flexible component of any of the designs and can be customized for the duty and maintenance cycle of a particular railroad. Some of the problems that were resolved by maintenance forces on the first units applied by member railroads included reservoir and control apparatus location. During installation, thought should be given to serviceability and maintainability of the equipment.

All lubricators are capable of applying lubricant to the wheel flange, but the question is, are they all reliable? Reliability of the lubricator is the next most critical gauge of effectiveness. The lubricator may apply the lubricant, but will the application be consistent? Generally, the lubricator that is functional and has the least number of parts is considered to be the most reliable, and in reverse the more complex the system, the greater the potential for failures.

One lubricator manufacturer had problems with steel tubes breaking and fittings leaking. This was overcome by replacing the steel tubing with high pressure hydraulic hose and fittings. Another member railroad had problems with nozzle plugging/leaking at fittings and nozzle alignment, which were corrected with filter and fitting changes. The present maintenance practice is to inspect the operation of lubricators each time a locomotive is placed on the service track. Defects can be corrected and the unit checked for proper operation before dispatch.

Overhaul: Member railroads of this committee at the present time have not established an overhaul cycle for lubricators because most lubricators applied to their locomotives are still in an early life cycle. Vendors have been unable to provide overhaul data at this time.

Troubleshooting: Because of space and time limitations this committee cannot cover the trouble shooting of individual lubricator systems in use by the member railroads. Some items, however, should be routinely checked on all units:

1. Check lubricant level in reservoir.
2. Check air pressure on pressure type units.
3. Check power source to unit.
4. Inspect all switches and reset for correct positioning.
5. Inspect filters for blockage.
6. Inspect wheel flange for lubricant.
7. Inspect connections, hose and fittings for leaks.
8. Inspect unit for blown fuses.

Conclusion: The committee feels a test arrangement should be developed to allow one man to perform a periodic inspection on these systems. Additional service time will be required to determine the reliability and maintainability of the applicators. This topic will be continued on a future paper.

III.

GEAR CASE, BULL GEAR AND PINION GEAR LONGEVITY IN THE 80'S

GEAR CASES — CANADIAN NATIONAL EXPERIENCE

This topic concerns fiberglass gear cases and oil lubrication as used by Canadian National Rail.

The development of the fiberglass gear case for diesel locomotives owes its success to a combination of good and bad fortune.

On the positive side, a California resident had conceived the idea of a fiberglass case, drawing on his extensive experience in the aircraft industry. The fibreglass used in the gear case construction bears little similarity to that used in the construction of boat hulls and automobile bodies, but is rather a combination of fiberglass cloth woven to produce very high physical properties, and a resin system formulated to resist chemical and hydrocarbon attack. This thermosetting material provides the capabilities of mass producing a molded gear case with the virtues of steel, but without steel's inherent problems and disadvantages such as weight and difficulty of repair. To exemplify this, a GM type fiberglass gear case weighs 40 lbs. versus 150 lbs. for steel. A GE fiberglass gear case weighs 67 lbs. versus 300 lbs. for the steel. A steel gear case, when damaged, inherently distorts, whereas the resiliency in the fiberglass returns the case to its original configuration.

In the early 1970's, this product was offered to the railway industry.

Coinciding with the launching of this new product, the bad fortune previously mentioned manifested itself on the Canadian National Railway. In the short span of a couple of weeks, two Canadian National operated passenger trains suffered derailments due to dropped gear cases. The light fiberglass case presented an *exciting option*, and number of these cases were immediately purchased and installed for test purposes.

The concept showed considerable merit but the product, at this stage in its development, still had faults such as unsatisfactory dimensional tolerances causing excessive lubricant leakage, poor securement of the brackets and poor seals.

The original manufacturer ultimately gave up on the project, and at CN's request, a Canadian representative acquired the total enterprise.

The new manufacturer, working with Canadian National, spent the next few years modifying and improving the gear case until full satisfaction was achieved with this grease lubricated case. Only at this time did CN standardize on the fiberglass gear case. At the present time, all CN General Motors locomotives and Bombardier (ALCO) units are equipped with fiberglass gear cases.

CN's initial goal was to develop a gear case which would remain firmly attached and retain a light lubricant so that frequent additions would be eliminated. A tightly sealed case, therefore, was of utmost importance.

Early in this challenging project it became evident that felt seals at the pinion gear and wheel hub would not provide the longevity required. Many styles of plastic seals were tried before long-term sealing ability was achieved at these vital locations.

At CN we now have a lubricant-tight gear case, but we are still using lithium based grease, which has several disadvantages:

* It is not the ideal lubricant.
* The grease tends to channel in cold weather, providing dry starts.
* Grease, unlike an oil splash system, is a poor medium for the transfer of heat away from the gears.
* With grease lubrication, it is virtually impossible to determine the lubricant level; therefore, the only alternative is to add grease at frequent intervals. Ultimately this surplus lubricant purges itself through the overflow duct falling on the road bed. Not only is this costly, but on diesel shop trackage, it effectively plugs the ballast, providing unsafe and dirty conditions.

Oil which flows readily permits the gear case to be treated like an automobile differential, using plugs at the drain and fill/working level. This idea was incorporated into the gear case.

In early 1985, several light low horsepower locomotives in Eastern Canada were operated successfully with oil, providing the confidence level to extend testing. In June 1985, four heavy-haul SD40 units, assigned in Western Canada, were equipped with oil in the gear cases. On these locomotives the gear oil in the cases was sampled frequently to ensure that no oxidation of the lubricant occurred.

Several different oils, formulated by Esso, were tested. Included in this group was one light synthetic oil. This latter product was subsequently discarded because of excessive cost and premature gear wear. It is interesting, however, to note that even this very fluid oil was successfully retained.

The test work on SD40s was most satisfying, showing very little oil loss and no gear wear. It is now readily apparent that this component, when properly applied, can retain lubricant through the inspection interval without attention. CN's long range goal, of course, is to have a truck which will operate between 92-day inspection dates without lubrication. We believe that the oil case, coupled with traction motor roller bearing support assemblies, will satisfy this target. All new locomotive

specifications issued by Canadian National require this feature, as well as fiberglass gear cases. A few short years should see a substantial portion of our fleet equipped with these modernizations.

In the meantime, to take advantage of oil lubrication on other new power, all further purchases of gear cases, as well as those being repaired, are being equipped with the drain and fill plugs. It is interesting to note that the lithium based grease now used by CN with its greater slumpability relative to the heavier greases can also be checked for lubricant level by the use of the upper fill/check plug.

The use of oil is being accelerated on CN to:

* Take advantage of a superior lubricant, particularly in cold weather;
* Effect economies through a significant reduction in the annual cost of lubricant;
* Reduce incidence of dry and burned gears, where grease application has been overlooked or neglected;
* Allow easier clean-up of gear cases upon removal, and subsequent disposal of residual lubricant.

Briefly then, CN moved into fiberglass gear cases for the following reasons:

* To have a light container that could be made lubricant tight for extended periods and retain this capability throughout the life of the motor and gear case assembly;
* To have a container which would withstand the vibration and shock at this unsprung location without coming loose and/or falling beneath the locomotive in service;
* To eliminate cracking and breaking of the traction motor gear case support arm;
* To incorporate the above features in a component that could readily be repaired by railway forces.

The success of the fiberglass gear cases on GM locomotives (some 6500 in CN service) led to our requesting the manufacturer to design and produce a similar case for the GE 752-TM. This has resulted in CN's standardization of fiberglass gear cases on the 752 motors with 1500 in service. As a next step, we contemplate the use of oil in GE cases, and the continued testing of redesigned GM and GE cases to adapt to the roller bearing support fixtures. As mentioned previously, all future new locomotive purchases will be equipped with roller suspension bearings.

The incidence of broken GM traction motor support arms is illustrated in Figure 1. You can clearly see that from an average of approximately 80 incidents annually six years ago, the problem has been totally eliminated. When you consider that a broken support


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arm means tying up the locomotive for at least a shift, and in most cases requires the purchase of a new cap with the resulting line boring, etc., the saving can be readily appreciated.

The results of tests, requested and witnessed by the locomotive manufacturer, are included in Figures 2a, 2b and 2c. The General Motors people have, for some time, expressed concern with respect to the contained temperatures within the gear case. There is no question that fiberglass does not conduct heat away from the source as well as steel.

After several year's investigation, CN has concluded that the heat here is not of concern, relative to the lubricants in use.

The test gear cases (reference Figure 2a) were on an SD-50 locomotive in middle position of a three-unit consist. The train was westbound from Edmonton to Jasper, Alberta. Weight of train was 9800 tons; length was 6801 feet, and the average speed was 40 mph, although 50 mph speed was reached occasionally.

The gear cases (reference Figure 2b) were applied to No. 4 and No. 5 positions in trailing truck on Unit 5400. The No. 4 leading position was lubricated with Galena lithium base grease QS-3177-A. The No. 5 middle position in truck was lubricated with oil, Esso QS-8712-C. Thermocouples were applied to the sumps of the gear cases as well as to both No. 4 suspension roller bearings.

The actual test (reference Figure 2c) needs some explanation. Note the oil case which ran hotter was in the mid position on a three-axle truck, sheltered from the benefit of wind wipe. We have noted in all previous tests that the mid position case tended to run 20 to 30F hotter because of its position.

The observations and conclusions from this test are:

* The oil lubricated case, because of its location in the truck, ran 20 to 25F hotter than the grease case.
* The maximum temperature recorded at lubricant level in fiberglass cases was 188F at an ambient of 68F, well below the 250F design upper limit temperature of the lubricant.
* Pinion end outer race in No. 4 position reached 120F, and the inner race reached only 98F.
* The temperature variations within the gear case did not have any effect on the operating temperatures of the pinion end suspension bearings.

Illustrated in Figure 3 are the specifications of the mineral oil, Esso QS-8712C, that we have found to provide the most desirable characteristics for our purpose. Basically, this is Galena Tramo 3177 litium grease, without the addition of soap as a thickener. It is a heavy fluid, 2500 centistoke oil approximately twice the thickness of No. 90 gear oil.

The location and number of locomotives operating on Esso QS-8712C oil is tabulated in Figure 4.

The comparison on the usage of oil versus grease through a 14-month period on the four SD-40 locomotives in Western Canada is summarized in Figure 5. It should be noted that it is 60% less costly to use oil.

As can be seen by the amount of grease used annually (reference Figure 6), a potential yearly saving of $200,000 can be had by the use of oil.

GM Traction Motors
Gearcase Support Arm Failures

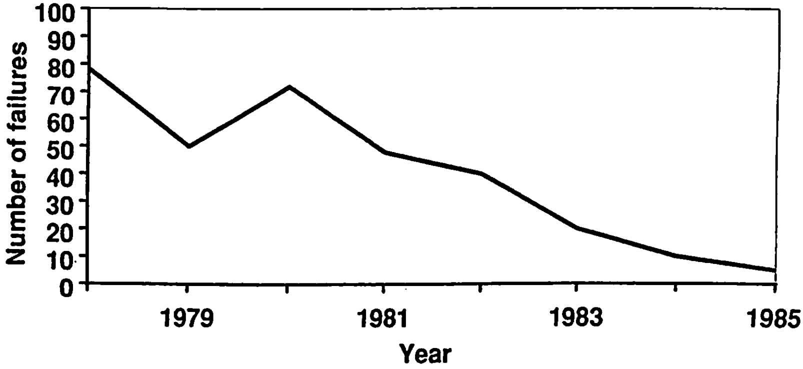


Figure 1

LOCO Consist

5355	5400	5023
(SD-40) Trailing	(SD-50) Middle	(SD-40) Leading

Test Location

Westbound from Edmonton to Jasper

Weight: 9800 tons	Length: 6801 feet
Avg. speed: 40 mph	Max. speed: 50 mph

Figure 2a

Test Detail

Middle Unit 5400:

Fibreglass Gearcases in no. 4 & 5 position (Trailing Truck)

No. 4 Leading Position:

Galena Lithium Base Grease QS-3117-A

No. 5 Middle Position:

Oil QA-8712-C

Both Test Gearcases:

Thermocouples in Sumps of Gearcases immersed in the lubricant

Thermocouples:

Applied no. 4 Pinion End Outer and Inner Races of the Hyatt Roller Suspension Bearings Fixture

Figure 2b

Actual Test

Time	Temp. F° Ambient	No. 4 (Grease)	No. 5 (Oil)	Speed
5.25	(Depart Edmonton)			
7.00	49	158	178	50
8.40	49	159	186	50
11.55 (Jasper)	68	165	188	40-50

Figure 2c

Specifications QS 8712-C Oil

Esso QS8712-C Mineral Oil

KV 40 °C CST	2480
100 °C	119
VI	129
4 Ball EP	
Weld point K.G.F.	250
Load wear index K.G.F.	53
4 Ball wear	
Scar diam. mm.	0.369
Brookfield	
Poise 93 °C	168
Poise 0 °C	516

Figure 3

Status to Date of Locomotives on Oil

Esso QS8712-C Mineral Oil

- 4	SD-40 at Prince George, B.C.	24
-10	SD-40 at Edmonton, Alta.	60
-51	GP-9 at Senneterre, Quebec	204
- 2	MF-636 at Moncton, New Brunswick	12
	Total	300

Figure 4

Comparison of Oil Usage vs. Grease (Cont'd)

CN maintenance practice is to add 3 lbs. or more of grease to each gearcase at every lube, intermediate and numbered inspection on a 23 day inspection cycle.

Therefore, the 24 gearcases would have had 18 inspections for a total cost of 18 x 24 =
432 x 3 lbs. = 1,296 lbs. x .98 a lb. = $1,270.

Difference in cost $1,270 - $500 = 770 or
60% less costly to use oil.

Figure 5

CN's Annual Tramo Usage

System	Tramo Used	No. of Powered Axles	Consumption Per Axle
1980	575232	9790	58.7
1981	575051	9806	58.6
1982	485904	10054	48.3
1983	437215	9926	44.0
1984	744327	9486	78.5
1985	489789	8758	55.9
1986	424099	8762	48.4

Figure 6

IV.

MAINTENANCE OF LOCOMOTIVE FUELING SYSTEMS FOR A SPILL FREE OPERATION

This portion of the paper will deal with the different fueling systems available to railroads today and the necessary maintenance required to reduce or eliminate fuel spillage at the service track or fueling facility.

First, we want to explain the terminology which will be used in the discussion.

Each fueling system is broken down into two main parts, those being the locomotive on-board equipment and stationary on-ground fuel equipment.

Most locomotive equipment is made up of the fuel tank, fuel fill neck, fuel fill adapter and a fuel level sensor.

Stationary equipment is made up of a fuel manifold, fueling hose, fuel nozzle and sometimes sensing lines running to a shutoff mechanism.

Three different shutoff principles are used in automatic fuel system control; they are:

1. Pneumatic
2. Electric
3. Hydraulic.

Pneumatic shutoff systems utilize a venting line attached from the locomotive fuel tank to the fuel fill adapter or fuel fill nozzle. When fuel level reaches and covers the vent, the adapter or nozzle senses this and automatically shuts off the fuel flow.

Electrical shutoff systems utilize a level switch in the fuel tank. When the fuel level reaches the switch, a float rises, opening or closing the switch, energizing or deenergizing a solenoid which shuts off the flow of fuel.

Hydraulic shutoff systems utilize a pilot valve in the fuel tank. When the fuel level raises the float on the pilot valve, the flow of fuel from the adapter or nozzle via a connecting hose to the pilot valve is interrupted; the flow of fuel into the tank is also interrupted.

A. Pneumatic Shutoff Systems

Pneumatic shutoff systems, as described earlier, are in wide use on both American and Canadian railroads. Buckeye and Snyder are two manufacturers of automatic refueling systems utilizing the pneumatic principle.

Buckeye:

The Buckeye 1600 series system is made up of a G1630 fuel nozzle and a G1620 external or internal sensing adapter.

The system works like this (Figure 7): When the nozzle lever is pulled, it opens the main valve (B) and fuel flows through the valve into the adapter, fill pipe and finally the locomotive tank. Fuel flows past hole (C) creating a suction which pulls the air out of the vacuum chamber (D). Air sucked into the tube end (E) travels

Here's how the Buckeye Automatic Refueling System works:

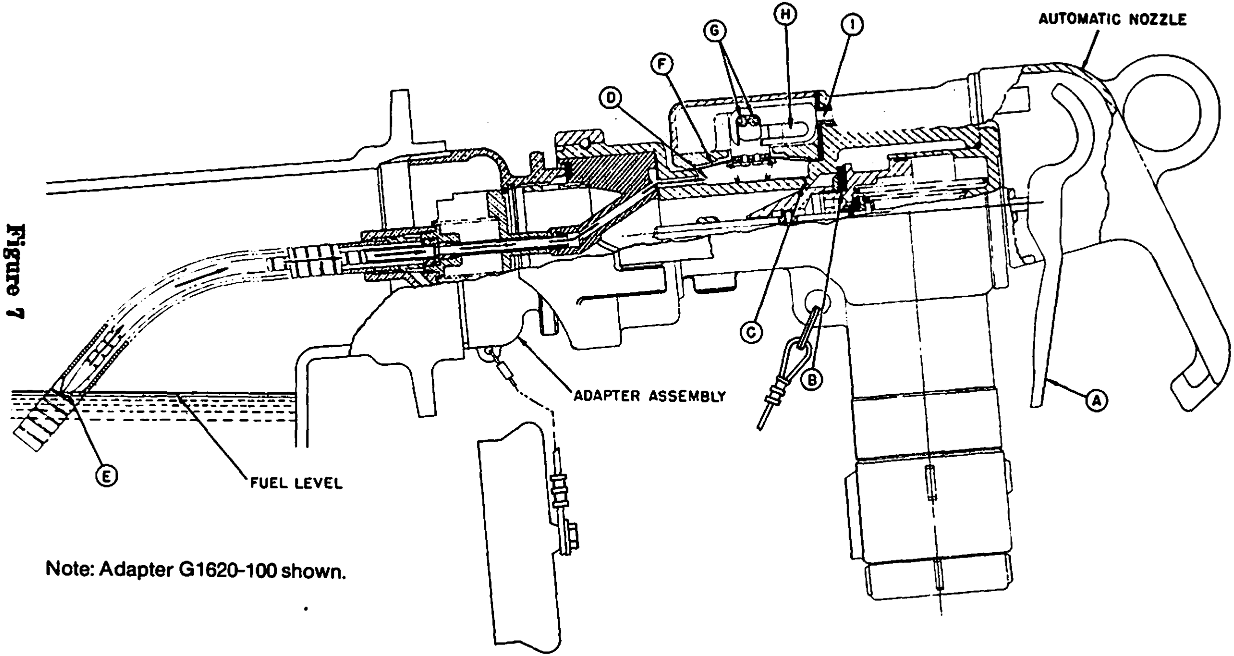


Figure 7

Note: Adapter G1620-100 shown.

through the shutoff tube, adapter, and nozzle to replace the air in the vacuum chamber and permit diaphragm (F) to remain stationary. When the fuel level reaches the end of the tube end (E), the air intake is stopped, a vacuum is created in the vacuum chamber (D) which sucks in the diaphragm (F) pulling the roller assembly (G) with it. As the rollers are pulled down, they slip into the elongated slot (H), releasing stem (I), which in turn releases the lever, closing main valve (B) and shutting off the flow of fuel.

The daily inspection of the G1630 nozzle for preventative maintenance will give trouble-free performance. Daily inspection of the nozzle consists of checking the O-ring on the nozzle stem because this is the main cause for the nozzle not to shut off automatically. Check the rubber seal or interface between the nozzle and adapter because this is the main cause for fuel leaks. Also check for loose screws and worn handle guards.

1. Check rubber end seal for wear. If worn, dripping will occur.
2. Check stainless steel insert in the nozzle for damage.
3. Check nozzle body for loose or missing screws and other damage caused from dropping.
4. Check lever to make sure it engages properly in hold open notch.
5. Check nozzle for leakage under full line pressure.
6. Observe fueling with nozzle attached to locomotive adapter for leakage and proper shutoff.

The G1620 adapter comes in various configurations to fit the style of tank on your locomotive. The automatic shutoff adapter which requires no modification to the fuel tank has internal sensing which is accomplished by using a sensing tube inside a quieting tube. The purpose of the quieting tube is to shield the sensing tube from fuel splashing in the tank while filling, which would cause premature shutoff. The quieting and sensing tubes come in varying lengths to meet the style of fuel tank on the locomotive.

External sensing is also available on the G1620 adapter. External sensing requires a threaded hole and threaded hose fitting in the slope sheet on EMD locomotives near the filler neck, 3 to 4 inches down from the top sheet of the tank. GE fuel tanks have a flat top, and use a threaded hole in the top of the tank with a threaded hose fitting specially equipped with a three to four inch extension down into the tank. In both applications, a rubber hose is connected from the hose fitting to the adapter providing venting between the tank and the adapter.

Regular maintenance at the fueling track or at periodic inspection

on the G1620 adapter requires checking:

1. The adapter shaft, for nicks or other damage. This could prevent the poppet from sliding and sealing when the fueling nozzle is removed. This could allow dirt to enter the fuel tank and possibly allow the fuel to spill out when tank is full and locomotive is moved or moving.
2. The adapter sealing face for damage, which could cause leakage while fueling the locomotive.
3. The snap ring, to ensure it is in place, so the poppet assembly is held securely and not allowed to fall out of the adapter.
4. That dust caps are applied to cover the adapter opening, so as not to allow dirt or other foreign material to enter the adapter.
5. The sensing hose and fittings. for damage or loose condition.

Missing, loose, or severed hoses allows the continued venting of the nozzle which permits fueling to continue after the fuel level rises above the sensing hole, causing overfilling with fuel spilling out the sensing hole and possibly spilling out the fuel tank vent. This is the primary cause for spilled fuel using this system.

Snyder:

Snyder also has an automatic fueling system available which employs the pneumatic principal for shutoff control. The Snyder II system is the latest fueling equipment from Snyder that incorporates some of the existing technology from the original Snyder system and some new enhancement that improves ease of use and reduced maintenance.

The Snyder II system is made up of fuel tank adapter and nozzle, fuel manifold and metering station. It works like this (Figure 8):

After the fuel nozzle is connected to the fuel tank fill adapter, the automatic fuel nozzle lever (A) is opened, diesel fuel flows through the nozzle and across an internal venturi (C) where a vacuum is created. Diesel fuel flowing into the fuel tank fill adapter (E) draws air from the locomotive fuel tank through the vent line (D) and into the tank adapter (E). Air is then circulated through the internal vacuum tube (F) of the nozzle spout reaching the venturi (C) to satisfy the vacuum, thereby keeping the nozzle open.

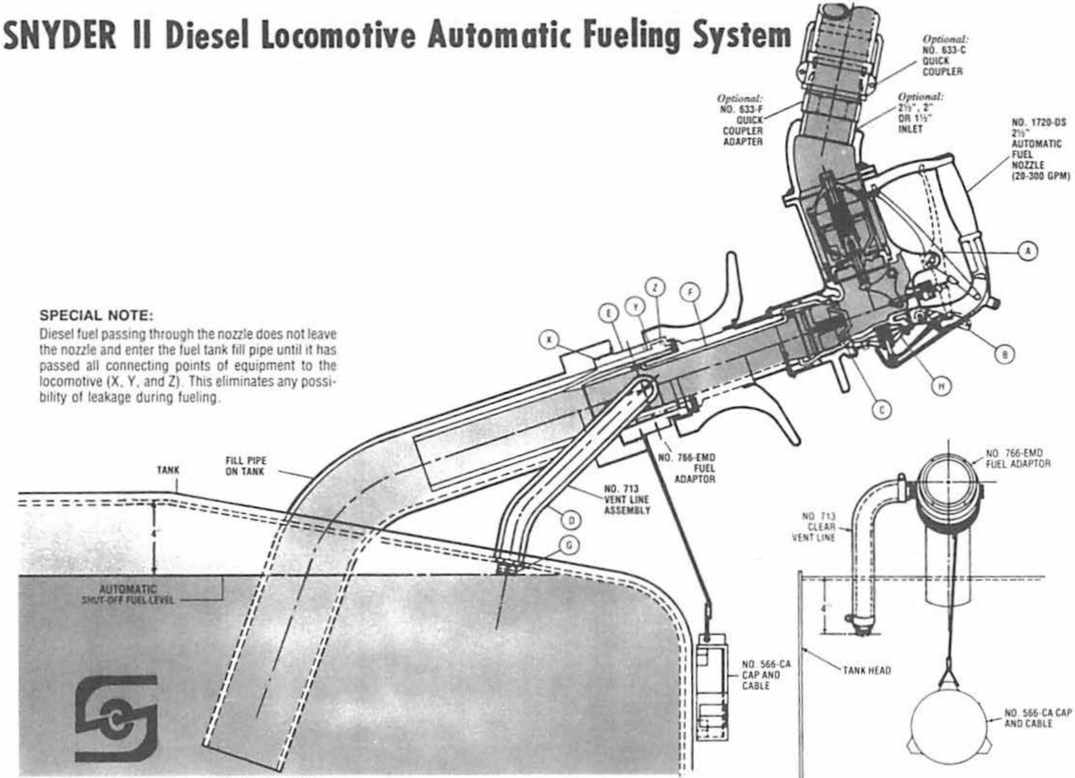
As the level of diesel fuel rises in the fuel tank, it will cover the tip (G) of the fuel tank vent line stopping the entry of air into the tank adapter (E). With the absence of air to satisfy the vacuum at the venturi (C), the vacuum activates the automatic shut-off mechanism (H) which releases the operating lever (A) and closes the nozzle.

The Snyder II nozzle, as mentioned earlier, is a durable piece of equipment which has evolved from

SNYDER II Diesel Locomotive Automatic Fueling System

SPECIAL NOTE:

Diesel fuel passing through the nozzle does not leave the nozzle and enter the fuel tank fill pipe until it has passed all connecting points of equipment to the locomotive (X, Y, and Z). This eliminates any possibility of leakage during fueling.



Snyder Engineered Equipment and Service Since 1939

Figure 8

the original Snyder nozzle design. The venting hose which is equipped on the original Snyder is removed and venting is now done internally in the Snyder II nozzle. This is viewed as a great improvement because it eliminates the hassle of the vent hose always being in the way and the maintenance involved with the hose.

Another feature of the Snyder II nozzle is the quarter turn quick coupling which, as the name implies, provides a quick and leak-free seal between the nozzle and the fuel tank adapter.

Regular maintenance of the Snyder nozzle involves the following items:

1. Check the nozzle ¼ turn coupling assembly. Remove any foreign objects that might prevent a proper seal between nozzle and adapter. Also inspect coupling gasket and remove and replace if found nicked or damaged.
2. Because of the high main fueling manifold fuel pressure, inspect main fuel hose for cracks, cuts or other damage that may cause it to burst when exposed to this high pressure. Also inspect pipe swivel fittings to ensure they don't leak.
3. Check the nozzle lever latch making sure it holds the nezzle lever in the open position. With the latch inoperative, fueling personnel often wedge tools, air hoses, or whatever they can find between the lever and the nozzle housing so they can do other work while fueling.
4. Check fuel leakage from the body of the nozzle and make all repairs that are possible. If repairs cannot be made at the fueling station, replace the nozzle and return the defective one to the repair shop or Snyder for repair and return.

The adapter on the Snyder II system is basically a point of attachment for the nozzle and transmits the venting air between the fuel tank and the nozzle to control shutoff when fuel level covers the vent opening.

Items to inspect daily on the Snyder II fuel tank adapter:

1. Before applying the nozzle to the adapter, check for and remove any dirt or other foreign material that might prevent sealing and cause leaks.
2. Inspect the adapter sealing edge to ensure a good tight sealing surface when mated to nozzle.
3. Inspect the fuel tank vent hose for cuts, cracks or holes, missing or loose hose clamps that would allow continuous venting of the nozzle, negating the automatic shutoff feature.

4. Make sure the dust cap is installed and the cap gasket is in place.

If repairs are required beyond those mentioned above, the nozzle or the adapter should be removed and returned to your repair shop or to Snyder for repair and return.

B. Electric Shutoff Systems

Electric shutoff systems, as described earlier, provide an electrical approach to fuel flow control. The Houston Company's H-3000 series refueling system is one such system.

With this system, fuel flow shutoff is controlled by a 2½ in. full orifice solenoid valve. This eliminates the hose and nozzle from ever being exposed to full fuel manifold pressure. This, Houston feels, greatly increases component life and eliminates much of the maintenance on refueling nozzles. Also, the H-3000 system cannot be overridden once desired fuel levels in the tank are reached.

In operation, the nozzle is attached to the locomotive coupler valve, then the nozzle control lever is pulled (Figure 9). A low voltage, (10vd.c.) 20 ma current is transmitted from the wired nozzle to the wired coupler valve via a center point-to-point contact. A sensing wire transmits this voltage to the level sensor in the fuel tank. If the level sensor is in the down position, the magnetically operated glass reed switch in the sensor is closed, completing the circuit to the solenoid valve on the fuel stanchion. The solenoid valve is energized and opens, allowing the fuel to flow into the fuel tank.

When the fuel level lifts the float on the level sensor, the magnet in the float breaks the contact of the glass reed switch, opening the circuit, causing the solenoid valve to close, stopping the flow of fuel. The fuel in the hose drains into the tank, the manual control handle can be returned to the closed position and the nozzle disconnected from the coupler.

Regular maintenance items to consider on the Houston H-3000 fuel fill system are:

Level Sensor:

If level sensor fails to operate or is broken, replace entire unit because the reed switch and lead wires are completely encapsulated and not individually replaceable.

Coupler Valve (Fuel Tank Adapter):

1. Replace the internal sleeve gasket if found damaged, if coupler valve leaks when coupled and fueling.
2. Replace check seal if fuel is leaking from coupler after filling when locomotive is moved or moving.
3. Replace probe if found damaged when locomotive fails to fill at one fueling location on the tank.

Nozzle:

1. Adjust poppet closure whenever fuel is seen leaking from

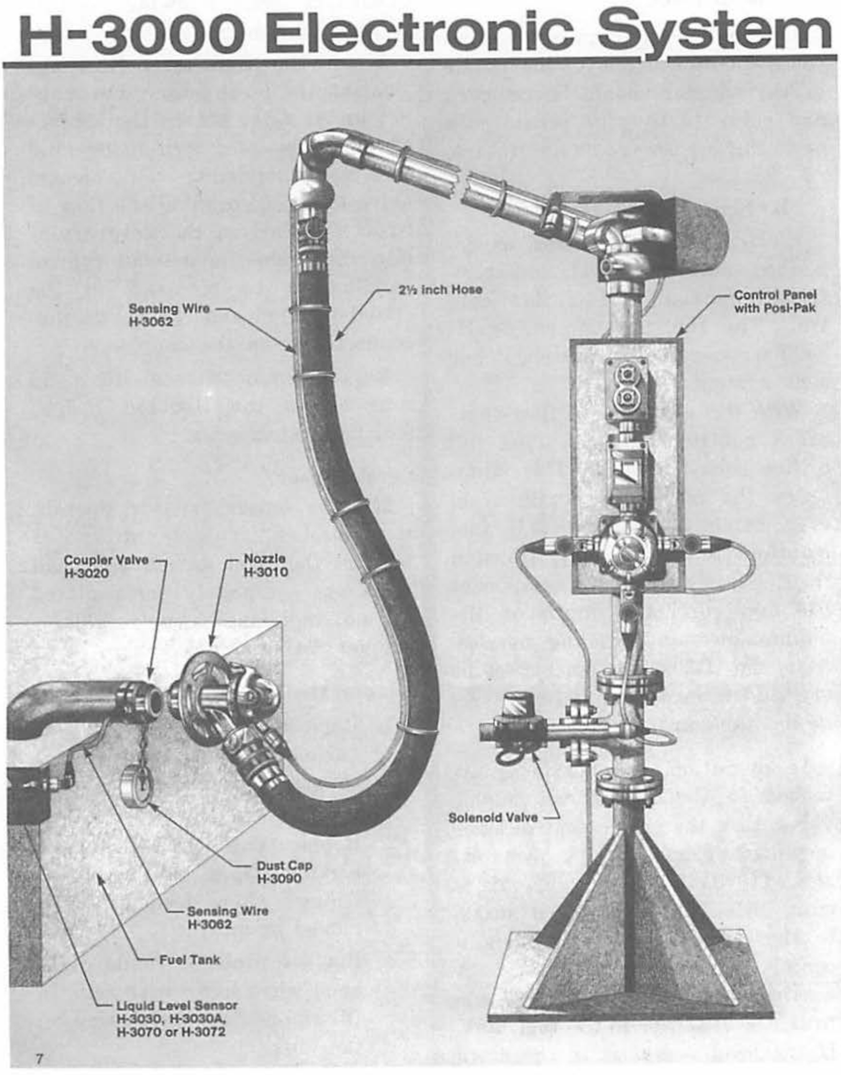

H-3000 Electronic System
2½ inch Hose
Sensing Wire
H-3062
Control Panel
with Posi-Pak
Coupler Valve
H-3020
Nozzle
H-3010
Solenoid Valve
Dust Cap
H-3090
Sensing Wire
H-3062
Fuel Tank
Liquid Level Sensor
H-3030, H-3030A,
H-3070 or H-3072
7

Figure 9

the nozzle when shut off and disconnected from coupler. This is done by removing the dome, loosening the cam set screw with a 5/32 in. Allen wrench, rotating the poppet on the front of the nozzle clockwise until a definite snap is felt when the control handle is in the full closed position. Tighten the set screw and replace the dome with sealant to make it water tight.

2. Replace the poppet gasket and stem O-ring if found damaged when fuel is seen leaking from the nozzle when removed from the coupler.

3. Replace the thrust gasket when a metal-to-metal sound is heard when attaching the nozzle to the coupler. This is a potential location for leaks while fueling the locomotive.

Any other repair to the level sensor, coupler or nozzle, not mentioned in the maintenance instructions above, is considered a major repair. The component should be removed from the locomotive, fuel hose or stanchion and returned to the shop or the Houston Company for repair.

C. Hydraulic Shutoff Systems

Hydraulic systems, as described earlier, provide a hydraulic approach to fuel flow control.

The Houston Company's H-1000 refueling system is one such system (Figure 10). With this system, the fueling nozzle is connected to the fuel tank coupler valve. The control handle is pulled, starting the flow of fuel to the fuel tank. When the fuel level rises, the fuel raises a float on the pilot valve shutting off the flow of fuel through the pilot valve. This causes an unbalanced hydraulic pressure in the nozzle diaphragm, causing the nozzle valve to close.

Regular maintenance on the Houston H-1000 refueling system is as follows:

Fuel Level Pilot Valves:

Check the pilot valve when the nozzle fails to shut off automatically. The only repair that can be made to this valve is replacing the float assembly.

While the pilot valve assembly is removed, check for freedom in the float action. If the action appears to bind, the arm may be distorted and repair is required. Also inspect the float bushings, pins and link for wear and replace them if necessary. Reassemble, making sure float hinges freely before re installing.

Whenever the pilot valve is removed, replace the expansion gasket between the pilot valve and the fuel tank.

Coupler Valve:

Inspect periodically the sleeve gasket, check seal and probe for wear or damage. Replace the sleeve

H-1000 Hydraulic System

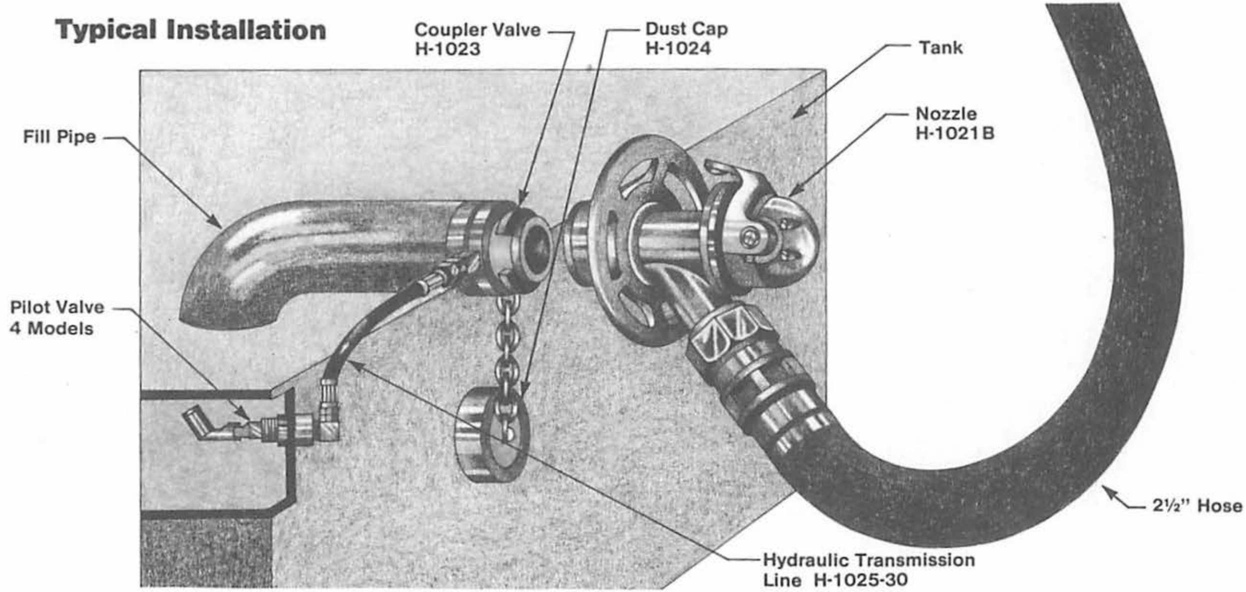


Figure 10

gasket if the coupler valve leaks when coupled and fueling. When replacing the gasket, make sure the gasket groove is clean and the gasket wiper is towards the locomotive.

Replace the check seal when fuel is seen spilling from the coupler. This condition allows dirt to enter the coupler and fuel tank. To remove the check seal, cut the rubber gasket material around the outside edge of the steel backing disc and pull out of the coupler. Push the new check seal into the coupler, making sure the side with the largest exposed rubber area is to the outside.

Replace the probe when the fuel nozzle fails to shut off automatically and external damage is seen. The probe is replaced when the check seal and spring are removed. A ½ in. deep well socket wrench is used to replace the probe. Use a sealant or Loc-Tite on the threads of the probe before installing.

Nozzle:

Ordinary maintenance on the nozzle can be performed without removal from the hose.

The poppet closure should be adjusted or poppet gasket replaced whenever fuel is seen leaking from the nozzle when shut off and disconnected from the coupler.

Adjust the poppet closure by removing the dome, loosening the cam set screw and turning the poppet until a definite snap is felt when the control handle is put in the closed position.

The poppet gasket is replaced by loosening the two set screws in the poppet guide and removing the poppet by turning it counter-clockwise. Lift the poppet guide and replace the gasket. Reassemble in reverse order.

The control valve O-ring should be replaced or inspected if the nozzle fails to shut off automatically and if fuel is seen through the control handle shaft when pressure is applied. The O-ring should be replaced if leakage is seen through the back of the nozzle poppet.

To replace the O-ring, disassemble as if replacing the poppet gasket. Pull the control valve out of the poppet, replace the O-ring and reassemble in reverse order. Replace the thrust gasket whenever metal-to-metal contact is heard when mating the nozzle to the coupler. To replace, simply remove the old gasket and insert the new one.

The diaphragm should be inspected or replaced when fuel is seen leaking at the control handle shaft hole when hand pressure is applied to the handle. To replace the diaphragm, remove the dome, loosen the cam set screw, turn the poppet counter-clockwise until the control handle assembly is released. Remove the upper housing and replace the failed diaphragm with a new one. Reassemble in reverse order, adjusting the poppet closure as per procedure mentioned above.

Any repair on the pilot valve, coupler and nozzle not mentioned above is considered a major repair and should be removed from the locomotive or hose and sent to the shop or returned to the Houston Company for repair.

All the fueling systems mentioned in this paper, whether designed by Buckeye, Snyder or Houston, are designed to provide a spill free, automatic shutoff fueling operation. Proper training of service track personnel is necessary and is provided by each of the fueling equipment manufacturers.

What can the locomotive maintenance officer do? Schedule and have performed regular inspections to ensure equipment is in working order. Through daily or scheduled maintenance of fueling equipment, both on board the locomotive and at the fueling track, you can be assured that the equipment you are using will be reliable and provide spill-free service.

DIESEL MECHANICAL MAINTENANCE COMMITTEE

Six-Year Index

1982

**Quality Maintenance —
The Key To Fuel Conservation**

1. Fuel Conservation — Effects on Maintenance
2. Fuel Conservation — What It Costs
3. Diesel Fuel Receipt and Disbursement
4. Turbochargers

1981

**Increased Service Life
Through Improved Technology**

1. Running Gear
2. Filtration
3. FRA Rules
4. Follow-up on Previous Topics

Chicago Railroad Diesel Club

We of the Chicago Railroad Diesel Club were again pleased to be hosts to the Locomotive Maintenance Officers Association for their 1987 Pre-Convention Presentation.

Meetings: We meet on the first Monday of each month except May (1st Friday), June, July, August and September.

Monthly Publication: Issued to all members.

Membership: We welcome all railroad and railroad supply per sonnel. For further details please contact our Secretary-Treasurer

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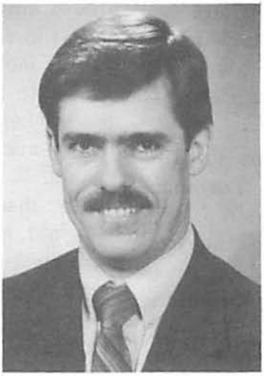
SECRETARY-TREASURER
Supervisor Bill. & Expend. Cont.
Illinois Central Gulf Railroad Co.
6037 Aspen Lane
Matteson, IL 60443

Wednesday, September 16, 1987

8:30 A.M.

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT

Pre-Convention Presentation: Chicago Railroad Diesel Club



April 6, 1987
Union League Club
Chicago, IL

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Union Pacific Railroad
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1987 TOPIC:

PRODUCTIVITY AND QUALITY IMPROVEMENT IN SHOP FACILITIES

PERSONAL HISTORY

WEYLIN R. DOYLE

Weylin was born in Cheboygan, Michigan. Following high school, he attended Lake Superior State College and then the University of Michigan in Ann Arbor where he earned a degree in Mechanical Engineering. He also did a year of graduate work in the field of Vibration Analysis.

He entered the Missouri Pacific Railroad Management Training Program in June of 1976. In January of 1977, he went to the Ft. Worth Diesel Shop as Locomotive Foreman and then to Marshall, Texas as Car Foreman. He was promoted to Diesel Supervisor in 1978 at Ft. Worth, then as General Foreman at the Kansas City Diesel Shop. In 1982, he served as Assistant Master Mechanic at Monroe, Louisiana, a year later returning to Kansas City as Master Mechanic. In 1985, Missouri Pacific promoted him to Assistant Mechanical Engineer in St. Louis until the merger with the Union Pacific Railroad, which brought him to his current position as Director of Advanced Equipment Engineering.

Weylin, his wife, Kathy, and three children now reside in Omaha, Nebraska.

PRODUCTIVITY AND QUALITY IMPROVEMENT IN SHOP FACILITIES

To adequately address the railroad's insatiable need for further improvements in productivity, management must use every available tool to make certain that its decisions are right the first time. A poor decision which must later be modified or scrapped can have as big an economic impact as the failure of an individual mechanic to meet the requirements of performing his job. The cost involved with having to re-do work can be enormous when all these nonconformances are totaled across your system.

Our discussion paper will we hope aid in your decisions by informing you of some of the new developments in GE tools as well as some up-to-date techniques in locomotive servicing facilites. We will be presenting you with one railroad's recent implementation of a formal quality process throughout its entire Mechanical department. Another railroad has just completed investing $3 million in a new traction motor shop which is producing long term gains through extended traction motor life while reducing man-hours. Finally, we will discuss all the recent changes in wheel truing machines to enable you to make the best decision as to which wheel truing technique is right for your railroad.

I.
MODERN SERVICING FACILITY FOR IMPROVED RELIABILITY AND AVAILABILITY

An efficient railroad is one that has a locomotive fleet that is both

reliable and available to the highest degree within the railroad's budgetary constraints. Most shippers seek a transportation mode which can consistently deliver their products within reasonable time without delays in transit. To have consistent service and meet published schedules, the railroad's Operating department must have readily available locomotives with a predictable level of reliability.

The most effective means of increasing locomotive availability is to reduce turn-around time in the terminals. The key element during the turn-around is the servicing and inspection process.

Some of the more progressive railroads have studied the servicing and inspection process and have found it to cause excessive out of service time for their locomotives. They have built facilities known as locomotive service tracks, or locomotive servicing facility which have reduced the time and effort to service and inspect locomotives. Since locomotive servicing and inspection is a daily procedure, the total impact of a locomotive servicing facility can be great if this time can be significantly reduced.

Prior to the installation of modern locomotive servicing facilities, locomotives were fueled at one location, washed at another, sanded at another and the inspection performed at another. Locomotive servicing and inspection time commonly took four hours or more when performed in this sequential manner.

With a modern locomotive servicing facility the locomotives are generally washed at one location and the balance of the servicing and inspection performed at one other location.

Locomotive reliability can be achieved by improving the turn-around servicing and inspection facility and by providing the necessary facilities to perform a high quality job. The quality of inspection is improved by prewashing the locomotives before they enter the locomotive servicing and inspection facility.

Updated locomotive servicing facilities are equipped to fuel, sand, add lubricating oil, add treated water. These services are usually manifolded and convenient dispensing stations are located so that service can be rendered wherever locomotives are placed in the facility.

Some facilities are built on a three-level design with an undertrack pit of sufficient depth to inspect the underneath features of the locomotives, replace brushes in motors and add journal bearing oil. The pit area usually contains piping with sufficient connections for lube oil draining, cooling water draining and air box drainage recovery. The second level permits inspection of locomotive appurtenances below running board level

and repairs such as brake shoes, brake adjustment, fueling, water, etc. Materials for repairs in the pit and this level; i.e. brushes, brakes shoes, covers are usually stored on the second level. Fuel meters are also installed in some facilities and a metered ticket is used for each locomotive to maintain a record of fuel usage for each locomotive. The third or upper level is usually a platform area from which inspection, service and maintenance work can be performed on the locomotives above running board level. This area is also used for storage of materials used in ordinary maintenance, i.e., fuel filters, lube oil filters, air filters, generator brushes, etc. Utility cabinets contain reels for dispensing air compressor oil, engine lube oil and engine cooling water. These reels are usually equipped with power rewind reels. The liquid dispensing units are located so that locomotives can be serviced wherever they are placed in the facility.

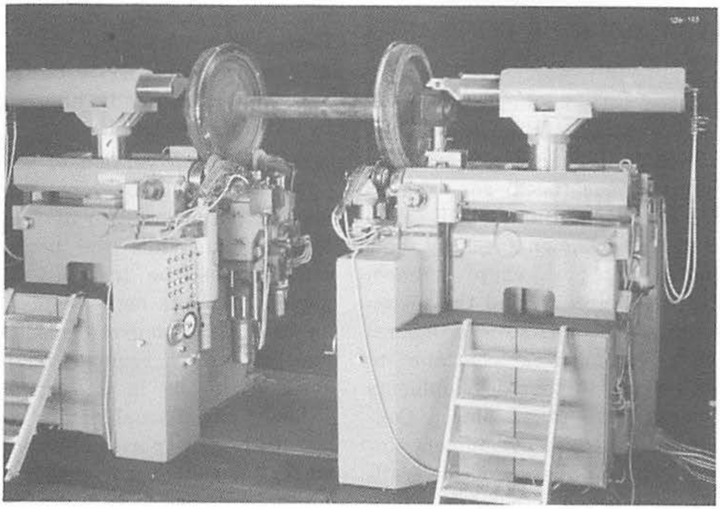
Some newer updated facilities now have bridge crane sanding systems. The crane also serves as a lifting device for changing cooling fans, power assemblies or other running maintenance work. Each locomotive can be sanded during the inspection, maintenance repair period.

Locomotive servicing facilities that are responsible for servicing and maintaining 100 or more locomotives have, or should have, a fully equipped lubricating oil laboratory. In addition to the normal lubrication oil tests for fuel dilution, viscosity and water, the laboratory should also have a spectrometer. This spectrometer is used to quickly analyze a lubricating oil sample to determine the amount of contaminants it contains. The accuracy of the spectrometer allows a locomotive to be diverted to the heavy repair shop for determination and correction of the problem.

The locomotive servicing facility must be designed to meet the specific requirements of the railroad it serves. The basic concepts that should be adhered to are:

1. Simultaneous inspection and servicing of the locomotive to reduce out-of-service time.
2. Enhancement of the inspection process so that more defects can be detected and corrected before the locomotive consist is released to the Operating department.
3. Completion of as many minor repairs as possible during the inspection/service procedure to keep the locomotive from going to a major repair facility.

In high volume terminals, low turn-around time for locomotives is essential. A locomotive servicing facility which keeps locomotive out-of-service time to a minimum is one of the key ways progressive railroads are meeting tight train schedules.



II.

NEW DEVELOPMENTS IN GE TOOLS

Since the introduction of General Electric's 7FDL diesel engine, locomotive maintenance officers have recognized the need for special tools when maintaining GE locomotives. Well known specialty tools included the "pork chop" wrench, fuel nozzle knocker, and the piston retainer "J" hook. As more General Electric locomotives continue to enter service, further developments in tooling have taken place. Contributors to tool development include tool suppliers, major railroads, and General Electric. This section surveys recent developments in GE hand tools.

From the beginning, lifting the GE power assembly has posed some special problems. The conventional lifting tool fastens to the cylinder jacket with two half-inch, high tensile strength bolts at the water outlet. Two lifting eyes position the power assembly in either the vertical position or at an angle of 22½ degrees.

Concern about the safety of lifting 1000-lb. power assemblies with two half-inch bolts, led one railroad shop to develop a slightly different lifter. This lifter fastens to the cylinder jacket with four bolts, two at the exhaust port and two at the water discharge port.

One recently introduced power assembly lifter attaches to the front of the cylinder jacket.[1] Four five-eights inch bolts thread into the holes for the air manifold. Better securement to the jacket and improved access to these bolts are the primary advantages cited by railroad mechanics.

An enhanced version of this GE power assembly lifter attempts to deal with the problem of two lifting points. While the power assembly must be installed or removed from the main frame at an angle of 22½ degrees, most shipping containers require the power assembly to be in a vertical position. Conventional lifters require laying the power assembly down to make this switch in rigging points. On this enhanced lifter, a hydraulic jack repositions an "A" frame to move the lifting point without setting the power assembly down.

Still another lifter, designed in a railroad shop, addresses this same problem. [2]This design uses a lead screw arrangement. When it is time to move the power assembly to the inclined position, an impact wrench drives the lifting eye forward to tilt the power assembly.

The familiar "iron hand", designed for EMD power assemblies has available an adapter for the GE power assembly.[3] This lifting

[1] available from Transporation Equipment Supply Co. (TESCO), Erie, Pa.

[2] developed at Norfolk Southern's Roanoke Shops, Roanoke, Va.

[3] available from Snyder Equipment Company, Baltimore, Md.

arrangement is novel because it attaches to the front and rear of a GE jacket.

Power assembly changeout has been addressed with other new tools in addition to lifters. [4]The master rod cap has always been difficult to handle inside the engine. A new tool for applying the master rod cap reduces the manual effort required for this job.

A similar lifting problem is encountered when removing and applying the main bearing caps on GE engines. A pneumatic main bearing cap lifter[5] uses two air bags to raise and lower the fifty pound main bearing caps inside the main frame. Benefits of this device are reduced physical exertion, increased productivity, and safer working conditions.

A new heavy duty rocker arm depressor aids power assembly changeout when the push rods are removed.[6] An additional 15 inches of handle at a 60 degree angle makes it easier to depress stiff valve springs.

Two tools have been introduced to aid in the replacement of camshafts and camshaft bearings. A fuel roller lifter[7] raises the fuel pump crosshead against the pressure of the injection pump spring. Once raised, the fuel roller is pinned in the up position for camshaft removal.

A camshaft bearing spanner tool[8] helps remove and install camshaft bearings in the tight fitting camshaft bore of the main frame. Two dowel pins fit into the locating holes of the cam bearing.

Dash Seven locomotives and later models use the New Torque air motor to turn the engine over. Applied to the governor drive unit, this tool is now available with remote control.[9] The remote control is convenient for making crankcase inspections and engine repairs.

Most running repair shops dealing with GE locomotives have the need to adjust the fuel racks and valve lash. Twenty and thirty thousandths of an inch feeler gauges for inlet and exhaust valves are conveniently located on another tool.[10] Shorter than many standard feeler gauges, these gauges are bent at 45 degrees to accommodate the design of the rocker arm area on GE power assemblies.

Prior to setting the fuel racks at individual injection pumps, the fuel rack jack must be used to raise the governor's power piston to the specified governor gap of 0.343 in. One of the hazards of this procedure is accidental start up of the engine in the full load

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[4] available from Transportation Equipment Supply Co. (TESCO), Erie, Pa.

[5] Ibid

[6] Ibid

[7] Ibid

[8] Ibid

[9] Ibid

[10] Ibid

position. This can quickly lead to an engine overspeed condition.

With this in mind, an alternative fuel rack jack is now available with an emergency lever.[11] Pulling the emergency lever releases the governor tailrod jacking screw immediately so the jack screw drops through the tool, returning the rack to idle.

Late model Dash Seven locomotives and the microprocessor based Dash Eight locomotives are equipped with a layshaft and different type of overspeed protection. These engines use a new fuel rack jack.[12] This device is attached to the governor gear box. Using the fuel rack jack, the layshaft is moved to the full load fuel position. Pulling the emergency lever release the layshaft moving the governor tailrod to the shutdown position.

After the governor tailrod is set to the full fuel position, a new universal rack gauge is available for setting the racks at the injection pumps.[13] With as many as thirty possible rack settings on GE locomotives, a variable rack setting gauge offers some advantages. Some shops will favor this tool while others prefer the standard rack setting tool.

Torque kits for the fuel system have long been available for GE engines. An alternative to welded tools, which have been known to fail, is the crowsfoot wrench.[14] These wrenches are used with standard torque wrenches.

Beginning in 1986, GE locomotives were equipped with 12-point hold down bolts on each fuel injection pump. Kits consisting of a 12-point socket, extension and a universal joint are required for changeout of these pumps.

More on the high tech side, advancements in borescopes and video equipment have improved visibility inside the GE power assembly.[15] This arrangement includes a scope made of flexible fiber optic cable. The scope is inserted in the fuel nozzle hole of a GE power assembly. A light source helps the viewer see inside the power assembly. Results can be viewed on a color monitor or recorded for playback and analysis.

In today's railroad environment, being aware of new developments in tooling can lead to increased productivity and reduced labor costs.

III.

IMPLEMENTATION OF A QUALITY PROCESS

Implementation of a quality process within the industrial environment is growing in popularity and necessity. Railroads must begin giving strong consideration to a

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[11] Ibid

[12] Ibid

[13] Ibid

[14] Available from Snap-On Tools, Railroad Dept., Kenosha, WI

[15] Olympus Corporation, Lake Success, N.Y.

formal quality process to keep in step with the competitive transportation business. At least one major railroad has adopted and put in place such a process. This was done with the help of one of several consulting agencies that specialize in this area. These consultants can provide the tools necessary to implement the lasting cultural change required for an effective quality process.

The first step in developing a quality process is to have the commitment and support of the highest officials. They provide the needed direction and resources to initiate and perpetuate this cultural change.

Many things come to mind when one considers quality, but quality is defined as conformance to requirements. The critical elements of the quality improvement process include identification of the cost of quality and development of a corrective action system. The quality improvement team is a key element in the success of the entire quality improvement process.

The cost of quality is a management tool used to determine areas needing corrective action, and to measure quality improvement. The cost of quality consists of two elements:

* The price of conformance (POC) or the total dollars spent to assure conformance and to prevent nonconformances, and
* The price of nonconformance (PONC), the total dollars spent due to the unnecessary expenditure of labor or material.

The price of nonconformance is a measurement of quality. It serves as a valuable management tool at the department level and for the local quality improvement team, which is responsible for helping to implement the system.

At the department level, the price of nonconformance focuses management's attention and helps develop the proper management perspective by placing quality on the same level as cost and schedule. It identifies major areas of concern requiring corrective action and provides a basis for tracking improvement within the company.

In addition to providing overall departmental direction, the price of nonconformance calculated at the local level is a valuable implementation tool for the quality improvement team. Local PONC's provide the basis for the quality improvement team to prioritize their quality improvement efforts, provide direction for measurement, provide a basis for determining where the most lucrative corrective action opportunities reside, and act as a gauge by which progress at the local level can be measured.

The PONC system is comprised of three basic elements:

1) Work group identification
2) Identification and Documentation of PONC's

3) A reporting system comprised of:
   * Data collection processing
   * Report distribution.

Work group identification:

The work group is the building block upon which the system is built since it solicits input and concentrates attention on those individuals actually experiencing the hassle — namely, the employees doing the work. It forms the link between the work actually being done, the PONC's being incurred, and the corrective action measures that may be generated. The work group also provides a natural structure for organizing a pyramiding reporting system.

Since the entire PONC system revolves around the work group, the first step involved in setting up the PONC system involves the identification of work groups by each quality improvement team. A work group is defined as a supervisor and a group of employees, or a group of supervisors, whose activities are directed towards a common goal. Everyone within the department belongs to a work group based on his or her specific job or function. It is important to include everyone when forming these groups. General work activities for a given area and activity assignments should be based upon supervisory responsibilities.

It is imperative that each quality improvement team apply the same basic guidelines when it initially determines its work groups, and that it carefully document the membership of each group. This will ensure uniform reporting systemwide, minimize duplication of reporting within a quality improvement team's jurisdiction, and minimize questions regarding the constitution of each group.

Identification and documentation of PONC's:

Once the work groups have been established, the next step involves the identification of major PONC's found by each work group and accurate documentation of each PONC. The quality improvement team assists the work group in these efforts. It is important that the work group understands what to look for when identifying these activities.

It is also important that each PONC entered into the system be carefully documented to ensure consistent handling systemwide, reliability in the event of questions concerning PONC description, how the PONC is being measured, and how the PONC is being costed.

Reporting system:

The overall objectives of the cost of quality step are to develop a system that reports the price of nonconformance on a regular basis, in an easily understood way, and to ensure that management uses the price of nonconformance as the one true measure of quality.

The entire PONC reporting system has been computerized to simplify documentation and reporting and to provide a "paperless" system which is easier to use.

One of the purposes of the quality process is to eliminate the problems that create "hassle" and unnecessary cost. The secret to eliminating these problems is to provide everyone with the tools needed to address the problems and resolve them forever. The corrective action system is designed by the quality improvement team to document problems at the local and headquarters level. It is this system that brings problems to final resolution.

The corrective action system has three key elements:

* Corrective action request form (CARE)
* Corrective action committee (local and departmental)
* Corrective action teams (CAT).

Each of these elements plays a critical role towards the ultimate solution of a problem.

Corrective action request form (CARE):

The corrective action request form (CARE) is a means to formally document a problem that requires the formation of a corrective action team at the local quality improvement team level. This form can be used to communicate a problem to headquarters that a local corrective action team cannot solve, and to track the progress being made on a particular problem that has been entered into the system. The corrective action request form is also a means to notify the corrective action committees that a problem is under investigation by a corrective action team.

Corrective action committee:

The corrective action committee is comprised of the individuals assigned to corrective action. Whether at the local quality improvement team level or the headquarters level that has been assigned the responsibility of dealing with departmental problems, the function of the corrective action committee is strictly administrative in nature. The corrective action committee monitors the CARE forms to ensure that problems are properly logged into the system, that the corrective action team formed to deal with the problem is making progress, and that there is no duplication of effort.

The corrective action committee furnishes status reports so that corrective action efforts can be prioritized, and lends technical assistance to corrective action teams to insure that the proper steps of problem elimination are followed.

Corrective action team:

The corrective action team (CAT) is a group of individuals brought together to solve a particular problem. Once corrective action has been implemented and has proven to be successful, the team is disbanded. The team members are selected based on the nature of the problem identified and the expertise required to resolve the problem. The chairman is the individual who is most affected by the problem and is therefore most interested in finding a solution.

The corrective action team chairman or his designee is responsible for keeping the CARE form up-to-date and for closing out the form once the necessary corrective action has successfully resolved the problem.

Once the quality improvement system is in place and people have been educated on how the process works, the cultural change can begin. Everyone knows how quality is defined, how to measure and report nonconformance, and how to resolve the problems through a corrective action system. This gives all individuals the tools and support they need to ensure that the quality process happens in their own work place.

IV.
A QUALITY TRACTION MOTOR SHOP

Introduction

Recently a major Eastern railroad recognized the need to improve its traction motor rebuild shop. The original shop was a collection of small work areas which contributed to the end product: the rebuilt traction motor. These work areas lacked continuity and depended heavily on overhead crane for lifting and moving. This caused congestion in some areas while others were waiting for motors or subassemblies. Shop supervision, Facilities Planning, and Locomotive department staff personnel visited other facilities and prospective suppliers to gain insight on the latest technological advancements. From these trips a plan was developed and construction began on the new traction motor shop early in 1984. By the end of 1985, capital improvements in excess of three million dollars were complete.

Objectives

A series of meetings and discussions lead to a number of design criteria for the new traction motor rebuild shop. These included the following:

A. Locate the new shop in the 27,000 sq ft bay adjacent to the present facility.

B. Design a facility capable of rebuilding 24 traction motors in a two shift (16 hr) period.

C. Utilize an assembly line process where one work center feeds the next.

D. Improve the tear-down process.

E. Reduce the overall labor component.

F. Minimize the need for manual movement of traction motors or subassemblies on the line.

G. Eliminate delays while shopcraft personnel wait on overhead crane.

H. Purchase state of the art equipment with a proven track record.

I. Improve the insulating material and process used on field coils and armatures.
J. Improve the quality of the end product.
K. Improve interior and exterior cleaning.

Planning

An extensive planning and approval process was undertaken. Suffice it to say that the objectives mentioned above were examined completely to insure that the related goals were attained. The final plan was approved and the monies appropriated. During this process the economic aspects became the driving force, both in the short term labor savings and the long term savings through improved quality. This commitment to quality can be found in every piece of equipment purchased for the line.

Operation

The basic layout of the shop is linear from south to north. The armatures are removed from the frames at the south end and travel north on the west side of the aisle while the frames continue north on the east side. Power conveyors are used extensively for frame movement, while armatures are moved by overhead crane and manual conveyor. The two lines rejoin near the north end, via an air float and monorail, where the traction motor is reassembled, tested and prepared for shipping.

The general steps in the line are shown below.

A closer examination of each of these work centers reveals the following:

Pretest - The traction motors are funneled into the shop through the Store department from all major running repair and maintenance facilities. Upon arrival they receive a series of checks to verify defects, assess extent of damage, and categorize the motors. This pretest insures that motors have been diagnosed correctly and that

1. Pretest
2. Exterior cleaning
3. Tear down

(Frame)	(Armature)
4. Interior cleaning	4. Cleaning and vacuum drying
5. Electrical test and coil stripping	5. Vacuum impregnating and bake
6. Qualifying (Mechanical)	6. Commutator turn and undercut
7. Rebuild or repair	7. Armature test
8. Insulation flood	8. Dynamic balance
9. Bake and cool	9. Bearing application
10. Reassemble	10. Reassemble

11. Test
12. Shipping.

the rebuild line receives the proper mix of motors. Mix on the line is critical to maintain an efficient operation by balancing the work load for each center.

Exterior Cleaning - The traction motor is given an exterior wash in a large Proceco washer, which is also used to wash locomotive truck frames. The wash removes the road dirt and grime, allowing workers and the shop to maintain a much higher state of cleanliness. This machine, along with the other washers in the shop, uses an industrial grade dishwashing soap. The cleaning cycle lasts 30 min. and washes three or four motors per cycle.

Tear Down - The traction motor enters the line at the south end by being placed on a special fixture, which stabilizes the motor while it is moved and worked. The pinion is the first item removed. This is accomplished with a standard induction heater. Next the pinion end bearing assembly is removed hydraulically and the bearing pressed out of the housing. The motor is advanced by power conveyor to the upender, where the motor is tilted 90 degrees, and the armature is pressed out and lifted out by monorail hoist. Next the commutator end bearing assembly is removed from the frame and the frame is tilted back to horizontal position. The armature is placed in a rotating device which revolves it 180 degrees, after which it is loaded into a four-position container, where it remains for the three steps.

At this point the frame and armature separate. We will follow the frame and return to the armature later.

Interior Cleaning - The frame is advanced by power conveyor to a two-stage Proceco washer for internal cleaning. The machine is a tunnel-type with a wash, rinse and vacuum drying cycle. Each cycle takes 35 min. and the frames are automatically advanced to the next stage.

Electrical Test and Stripping - All frames are electrically tested and are either sent to the coil stripping if they fail or on to mechanical qualifying if found electrically sound. The stripping area is designed to remove the clutter and debris from the building area. The traction motors are delivered to the machine via conveyor and transfer shuttle. The coil strip machine can rotate the motor to any attitude that enhances the removal of field coils and other internal parts. A motor can be completely stripped in 35 minutes.

Mechanical Qualifying - The stripped frames advance to the Brown and Sharp computer-controlled gauging machine. The operator places the frame in position and makes eight manual measurements to develop an envelope. Once the computer accepts the envelope, it automatically makes 45 measurements which produces a read-out that checks every critical dimension on the traction motor frame. This process takes approximately 45 min. Should a frame fail, it is sent out to a vendor for repair. Coiled frames are also gauged using a different computer program.

Rebuild - The frame repair center, while the most labor-intensive area in the line, is capable of handling anything from repairing a lead to a complete recoil. The frame is removed from the conveyor by jib crane and placed in one of 12 specially designed carts. These carts roll on V-grooved casters along any one of the 3 repair tracks in the work center. Each of these tracks is equipped with the correct tooling and a turntable to facilitate movement on and off the track. The carts are also equipped with an airpowered turning device allowing the workmen to rotate the frame for ease of repair. Material is delivered by small roller conveyor directly to the work station eliminating the need for workmen to leave the area to secure their own material. Once repairs and the necessary checks are made, the frame is returned to main conveyor for movement to the next process.

Insulation Flood - Each repaired or rebuilt frame is advanced from rebuild to insulation flooding station. At the station the frame is upended on a donut-type seal. The operator then pumps insulating varnish inside the frame, stopping the flow when all the field coils are covered. The varnish level is maintained for one minute, then pumped out and the frame is allowed to drain. Finally, the frame is rotated to a horizontal position and moved down the line.

Bake and Cool - The frames are delivered from the flooding machine via power conveyor to a Proceco tunnel-type curing oven and cooling chamber, where they are baked for 3½ hrs at 325 degrees F. The oven and cooling chamber have six positions each that automatically advance every 35 minutes. The system takes on and sets out a traction motor on each move.

Now we return to the armature reconditioning sequence.

Armature Cleaning and Vacuum Drying - The armature four-pack is placed in the armature washer staging area by overhead crane and then is loaded on the washer turntable with a hydraulic five-ton jib crane. The turntable swings back inside and a 20 minute wash cycle is run. Next, the four-pack is lifted from the turntable to the vacuum dryer for a 45 minute cycle.

Vacuum Impregnating and Bake - The armature four-pack is delivered by overhead crane to the vacuum-pressure impregnator. The operator closes and seals the chamber and draws a vacuum, extracting both moistue and air. Next, the insulating varnish is drawn in and the vessel is placed under pressure at 90 psi for two

hours, filling every void with varnish. Then the excess varnish is returned to the holding tank and the armatures are allowed to drain. Finally, the armature four-pack is placed on a four-wheel cart and pushed into the oven for an eight hour curing cycle at 325 degrees F.

Commutator - The armatures are placed in cradles on a manual conveyor. From the conveyor they are lifted by jib crane to turn and undercut the commutator. The commutators are turned on a standard engine lathe while the Mica between each bar is undercut on an automated undercutter, allowing the operator to work more than one station. Each of these operations takes 25 minutes.

Armature Test - The armatures are placed in position on the test machine. Then the computer-controlled Baker test machine takes over and tests each bar in the armature for grounds, shorts, open circuits and other defects by performing a high voltage surge test, current leakage test, and a high current high resistance test. The computer analyzes and displays the results, noting anything it considers a defect on a CRT monitor. The data are reduced to a hard copy at the completion of the test.

Dynamic Balance - Armature balance is checked and corrected as necessary. The armature is placed in the balancer by a jib crane and spun at 200 and 400 rpm. A computer read-out indicates when, where and how much weight should be added or removed.

Bearing Application - The armature is moved across the aisle on an air float to the bearing table where new bearings are fitted and applied, using standard rebuild tolerances and specifications. When this is complete, the armature is moved by conveyor to the assembly area and is ready to be applied to a frame.

Assembly - The armature and frame line rejoin at final assembly. The armature is lifted from the armature conveyor with a special lifting device that balances the armature horizontally. This allows the operator to assemble the traction motor on the line without upending the frame. Next the bearing assembly is torqued, the pinion applied and the brush holders inserted. Finally, the necessary adjustments and checks are made and the motor is sent to test.

Test - Each repaired motor, whether patch or complete rebuild, receives a running test on the GE test consoles. These machines are the "Inspector 12" of the traction motor line. "It's not a traction motor until they say it's a traction motor." The test consoles monitor and furnish data on rpm, vibration, load and bearing temperature. These machines are not a substitute for quality workmanship, but the test allows the operator an opportunity to ferret out and repair defects before the unit is placed in locomotive service, eliminating waste at both the building and using facility.

Shipping - Anything can be damaged in shipment, even a traction motor. After each traction motor is tested and capped, the leads are tied up and all openings covered. Then it is placed on a pallet and banded ready for shipment to the customer. This little extra effort has saved many hours that were spent repairing leads and damage caused by foreign objects on the commutator.

Conclusion - New technology by itself is not the answer to improved productivity. Rather, it is a combination of technology, willing or motivated labor, and sound management practices that will eventually bring railroads to the productivity level needed to prosper.

These qualities have made it possible for this traction motor shop to meet all the design goals mentioned earlier. For example, the overall manhours have been reduced by some 30%, while quality has improved steadily. The test consoles, by themselves, have significantly reduced infant failures, while the other new machines and processes have produced long term gains through extended traction motor life.

V.
WHEEL TRUING MACHINE TECHNOLOGY

The purpose of this section will be to re-familiarize you with the different types of underfloor wheel truing machines, their operation and the latest available technological advances. We are not attempting to theorize which method is better or recommend a particular method or machine, only to present you with facts pertinent to wheel truing operations. Each type of truing system has its own merits and drawbacks. It will be up to each of you to evaluate these systems and determine which is most suitable for your own operations.

Underfloor lathe type truing machine

Both of the types of turning equipment being described are known as the "underfloor" type. The turning machine is located under the tracks and the locomotive is driven or pulled over the top of it. The lathe type of machine uses the same basic principles found in common turning centers. The wheelset becomes the rotating workpiece, and cutting tools move across the wheel surface as it turns, creating the new profile. The lathe principle uses a lesser amount of cutting inserts, typically having only two cutting inserts per cutting head or a total of four cutting inserts. The correct profile is obtained through the use of tracing templates, with the cutting heads following the contour specifically outlined on the template. Different variations of wheel profiles can be obtained by changing templates. It is possible to have a large number of different required wheel profiles available in a template magazine mounted on the machine. Also, the templates can be made to compensate for varying wheel widths. The accuracies obtainable with this type of machine are typically in the range of .005 to .010 in.

The lathe type of machine has three different, distinct methods cf centering the wheelset prior to commencing the re-profiling operation. These are:

1. Bearing box centering. The bearing boxes are positioned on a fixed machine support and hydraulic clamps are placed on top of the box to exert the downward pressure required to place sufficient weight on the drive roller system. This type of centering eliminates the need to remove the bearing axle caps. An axial roller system places pressure on the interior of the wheel flange to insure that the wheelset does not move in an axial direction during the re-profiling operation.
2. Tailstock centering. This method of centering uses the axle center hole to hold the axle and apply downward pressure.
3. Flange centering. This method of centering uses the flange of the wheel itself. The drive rollers and axial guide rollers provide the centering forces. It should be noted that this type of centering requires the flange of the wheel to be concentric and free of major defects.

The double column design typical of the underfloor lathe machine also offers the following:

1. A large working envelope for the operator.
2. Easy access and view of the cutting tools.
3. Simple application of hydraulic hold down attachments to provide increased contact pressures on the drive rollers.
4. Ability to have the cutting operations performed by a single operator.

New developments in lathe type equipment

Probably the single most important advancement in the technology of the lathe type wheel truing machine is the addition of computer numerical control systems for machine operation. In the case of the lathe type machine, all machine movements are controlled by computer through programs that have already been defined with any number of required wheel profile contours. Automatic assessment of the amount of metal to be removed is made by electromechanical wear probes. These probes measure the wheelset and determine the necessary amount of metal that must be removed in order to obtain the correct wheel contour. This information is automatically input into the numerical control system. Tool settings, including depth of cut and the number of cuts required to restore the correct wheel contour are selected and performed based on wear input received by the probes.

In addition to enchancements added through the use of the com-


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puter control system, lathe type wheel truing machines have also had the following improvements made:

1. Digital diameter measurement systems can verify the accuracy of cuts between the wheels on any given turned wheelset to within a few thousandths of an inch. This measurement is especially critical to the rapid transit industry. A digital tape printer can be provided to record the measuring results and identify the vehicle number, wheelset number, date, shift and operator.
2. Electrical components now reflect the latest advancements in solid state technology.
3. Coordination of the development of improved cutting tools has led to superior chip breaking capabilities and improved removed metal disposition.
4. Self-diagnostic packages have been added which greatly aid in the correction of machinery faults.
5. Improvements have been made to mechanical components such as bearings, ways, hydraulic systems and various other wearable parts, increasing machine longevity.

Over the past years, the above items noted as well as numerous other advances have been added to improve the overall operational quality, operator safety and production capabilities of this type of wheel truing machine.

Underfloor milling type truing machine

The second type of wheel truing operation uses a milling process. In this operation, the wheel is passed rather slowly over the faster turning milling cutter. The milling cutter performs the reprofiling of the wheelset through the removal of materials. The cutter is equipped with ten separate cutting blades each of which contains 11 cutting inserts. There are a total of 112 inserts on each cutting head or a total of 224. These inserts, as well as the inserts on the lathe type of machine are indexable. The correct wheel profile is obtained through the configuration of the cutting insert holder. Each different wheel profile will require a new set of cutting blade holders.

Centering on the milling type machine is normally accomplished through the use of the axle centering holes. Typically, the axle bearing caps must be removed to access these holes with the machine centers. Some bearing caps are equipped with a center access hole with a removable plug which allows access for the machine centers to the axle center hole. It should be noted that special machine centers are required for this application. If your total fleet of locomotives is not equipped with this access hole, it will be necessary to change centers each time a bearing box cap is encountered that is not equipped with this modification.

In addition, unmounted locomotive or freight wheelsets may be turned through the use of the machine centers and hydraulic hold-down cylinders provided with the machine.

Milling type machine new developments

The addition of new computer systems has been perhaps the most significant new development for the milling type machine. One computer system for digital readout, known as DRO, continually supplies the operator with a number of important dimensional parameters including the following:

1. Current machining diameter - The display shows the actual diameter that the wheel truing machine is cutting at any given time. This diameter may be shown in inches, millimeters or in tapes.
2. Total cut depth - This register displays the total cut depth or in-feed of the milling cutters.
3. Service metal remaining - This display indicates the amount of tread metal remaining on the wheel during and after the wheel truing process.
4. Finished diameter calculator - This calculator is provided to assist the operator in determining the required finish wheel size for any given wheelset on the locomotive. This helps the operator stay within allowed variances between wheels of a wheelset and wheelsets of the same truck.

In addition to the computer upgrade, new milling type wheel truing machines have had the following improvements added:

1. High speed cutters - Modifications are now in the process to accommodate the use of a new, 16 insert high speed cutter for use on the milling type machine. These modifications include increased cutter drive horsepower and the use of tapered opposed to cylindrical inserts on the milling cutter assemblies. These modifications have been made to correct problems experienced by previous high speed cutter systems. The manufacturer indicates that production increases of approximately 24% may be obtained with the high speed modification. The first of these newly modified machines will be delivered to a railroad at the end of this year.
2. Power cutter alignment - The "C" frame assembly no longer floats with the wheelset gauge. Both cutting heads are now movable and hydraulic motors are used to power the cutting heads into the correct position and wheel gauge prior to cutting. This new addition is probably the next most significant upgrade, making alignment operations much easier and increasing production capabilities.

3. Emergency tool retract - This option allows instantaneous termination of cutting operations and retraction of cutting heads away from the wheelset.
4. Data acquisition programs - This optional computer package enables the operator to record information pertinent to the wheelsets that he has turned.
5. Automatic cut depth control and cutting cycles - Included in the standard computer control package, this system automatically feeds the cutting heads into the wheelset at the required increments and retracts the cutting heads when the correct profile has been achieved.

Other design and operational changes made to this type of machine include:

1. Relocation of the operator to further displace him from the cutting operation has improved safety.
2. Operator work intensity and responsibility have been decreased.
3. The overall operational complexity of the machine has been reduced.

Since the introduction of the milling type of in-floor wheel truing machine, the improvements mentioned previously as well as numerous other design changes and modifications have led to improved operator safety, increased production capabilities and greater machine longevity.

As we previously stated, it is not our intention to try to evaluate which type of underfloor wheel truing machine is the best. Based on past history, it would seem that the production rates for both machines are fairly equivalent. The equipment you select should be based on your own individual requirements and situations. We will say that both of the major competitive companies supplying information and illustrations for this section are very competent and have an excellent product. Each will stand behind its machinery with both technical and replacement part support. The important fact is that this equipment offers you an excellent method of performing necessary wheel truing operations to your locomotives. The choice is yours.

SHOP EQUIPMENT COMMITTEE
Six-Year Index

Southwestern Railway Club

Started in 1946, the Southwestern Railway Club this year is celebrating its 41st 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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Monday, September 14, 1987

10:00 A.M.

REPORT OF THE COMMITTEE ON NEW DEVELOPMENTS

Pre-Convention Presentation: Southwestern Railway Club

May 21, 1987
Hilton Airport Plaza Inn
Kansas City, MO

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1987 TOPIC:

MAJOR CHANGES AROUND THE CORNER

PERSONAL HISTORY

MARK A. COLES

Mark was born in Rocky Mount, North Carolina. Most of his early years were spent in the northeast, where his family finally settled in Rhode Island. Following high school, he attended Franklin Institute in Boston, Mass. where he studied automotive technology. He then attended the University of Rhode Island where he earned a bachelors degree in Mechanical Engineering.

He started his railroad career when he entered the Missouri Pacific's Management Training Program in June of 1976. Later that year he was assigned to the position of Assistant-to-the-Mechanical-Superintendent at North Little Rock, Arkansas. In 1977 he was assigned as a Locomotive Foreman at the Fort Worth, Texas Diesel Shop, and then returned to North Little Rock in 1978 where he was promoted to the position of District Diesel Supervisor. In 1979, he was promoted to the position of Road Foreman of Engines and was stationed at Falls City, Nebraska. At the end of 1980, he was transferred to Railroad Headquarters at St. Louis, Missouri, where he was assigned as Facility Planning Engineer, and worked on the design and construction of the Downing B. Jenks Locomotive Heavy Repair Facility at North Little Rock. In 1985, he was promoted to the position of Supervisor of Locomotive Equipment, which he held until the consolidation of the Missouri Pacific and Union Pacific Mechanical Departments in 1986. His current position is Engineer Mechanical Equipment - Locomotive, Union Pacific Railroad, Omaha.

Mark, his wife Susan, and three children now reside in Omaha, Nebraska.

MAJOR CHANGES AROUND THE CORNER

I.

ELECTRONIC FUEL INJECTION SYSTEMS

In the early 1970's, companies which supported the trucking industry began developing experimental electronic controlled injection systems for use in combustion studies. The outcome of these early studies demonstrated the feasibility of electromagnetically controlling the fuel injection process at the nozzle. The attractiveness of this concept stemmed from the fact that mechanical linkages could be totally eliminated, critical initial timing would become less critical, associated service adjustments which had to be made to compensate for mechanical wear would become a maintenance problem of the past, and injection timing could be changed instantaneously to compensate for operating conditions (with use of the microcomputer). Today the electronic fuel injection system is being developed and tested by several manufacturers in the U. S., for application in the medium speed diesel engine (800-1100 RPM).

The "Advanced Fuel Delivery System" which the New Developments committee analyzed for this year's LMOA meetings, consists of the electronic engine control system and an electronic fuel injection system. In this paper, we will attempt to provide an overview of the electronic fuel injection system and discuss some of the advantages and disadvantages of applying this system to locomotives.

To begin with, people in the diesel engine manufacturing industry have common opinions regarding the desirable characteristics for fuel injection systems of the future. These characteristics are:

1) High injection pressure
2) Short injection duration
3) Reliable engine starting
4) Precise & variable injection timing
5) Controlled engine torque
6) Electronic controls
7) Pressure & temperature compensation
8) Optimized emmissions & economy
9) Acceptable cost
10) High durability
11) Fail-safe features
12) Built-in diagnostics.

As can be seen from the list, many of the desired characteristics of a fuel injection system of the future have been long sought after in the standard fuel injection systems of the past and present. Most companies who are currently developing electronic fuel injection systems are attempting to design the majority of these characteristics into their systems. In a few cases, companies are using all of the characteristics as goal objectives for their products.

One system being developed today has five major components. These components are listed below and will be discussed in some detail.

1) Accumulator type nozzles
2) Solenoid valve
3) Pressure intensifier
4) Common rail fuel supply module
5) Electronic control module

Accumulator Nozzle

The accumulator nozzle is not a new concept. In 1926, Guy Bell developed an accumulator nozzle (patented) which injected at the end of the pump stroke, rather than during the pump stroke. In 1929 and 1931, patents were granted for enhanced designs of the accumulator nozzle with a spring operated accumulator plunger. The accumlator nozzle plays an essential role in the electronic fuel injection process. The accumulator's ability to store energy allows a distinctive time separation of the pumping energy and the actual fuel injection event. The advantage of having this separation process is that demands upon the fuel pressure supply are substantially reduced. Since pressure can be generated continuously, as opposed to very brief periods of fuel injection, less stress is placed on the fuel pressure supply. With these nozzle characteristics, another important feature then, is that the injection event becomes independent of engine speed. This allows very high pressure and very short duration injection cycles at any speed, including starting. Timing of the fuel injectors is dependent only on the beginning of injection since the end of the injection period is controlled by the nozzle itself. This concept of fuel delivery makes it feasible to control the injection event with a single solenoid electrical signal per injector.

A motorized gear pump, producing up to 1450 psi, is used to charge the accumulator nozzles. Injection energy is stored by pressurizing liquid fuel within the body of the nozzle and the injection process occurs upon opening of the spill port. In contrast, the injection process in a conventional unit injector begins upon the closing of the spill port. See Figure 1 for a comparison of the two systems.

Solenoid Valve

The solenoid valve is a three-way ball poppet valve, shown in Figure 2. The valve was designed to provide durability, easy maintenance, low power consumption, sturdiness, and predictable timing.

The solenoid's role in the fuel injection event is as an intermediary device that is activated to operate the pressure intensifier. When the intensifier is activated (via the solenoid), fuel is transferred into the accumulator nozzle to a demanded level. Once the desired pressure level of fuel is transferred to the nozzle, the injection event occurs when the solenoid valve is de-energized.

Pressure Intensifier

The pressure intensifier consists of a plunger and bushing with a 15:1 area ratio between the high pressure plunger and low pressure piston. The solenoid valve operates up to approximately 1450 psi while feeding the low pressure piston. The pressure intensifier's role in the fuel injection process, then, is to transform this 1450 psi into 21,750 psi in the accumulator nozzle. See Figures 4, 5, and 6 which show the pressure intensifier's role in various fuel injection stages (load, pressure, and fire).

Common Rail Fuel Supply System

The common rail fuel supply system pressure typically varies from 435 psi to 1450 psi. This pressure is supplied by the positive displacement gear driven pump. The rail pressure is varied to control the delivery of the nozzles. As stated earlier, output for injection is directly related to the rail pressure, in that the rail pressure is intensified 15 times (15:1 area ratio) in the accumulator nozzle.

Another component of the common rail fuel supply module is an

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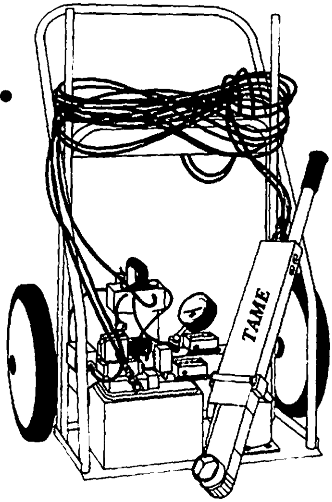

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TAME, INC., Chattanooga Valley Drive, P. O. Box 53, Flintstone, GA 30725 electronic pressure regulator. This regulator utilizes the same type of solenoid valve that is used with the accumulator nozzle. The regulator's function is to control rail pressure by a digital pulse-width modulated signal from the electronic control module. The element that achieves actual control of rail pressure is a variable bypass valve for a fixed displacement pump or a controlled stroke element for a variable displacement pump.

Electronic Control Module

The electronic fuel injection system is designed to interface with the electronic control module to achieve a more efficient, better controlled diesel engine. The electronic control module is discussed in another paper.

Additionally, the electronic fuel injection system is designed for direct digital electronic control of fuel injection. The intention of this system is to maximize control of both quantity of fuel used and timing of the injection event. See Figure 3 for a schematic of the system.

How the System Operates

The injection process begins with the fuel supply system. The system ensures that fuel pressure is generated equally throughout a common rail to all injectors on the engine. Again, this pressure varies between 435 and 1450 psi. An important part of the system is the pressure regulator, which can be operated in a variety of methods. Manual, mechanical, or electronic techniques can be utilized to operate the system. Technically, the pressure regulator controls engine speed and load and provides the energy source for the fuel injection event.

The pressurization process begins when the electronic control module energizes the solenoid operated flow control valve. The control module sends its signal to energize the solenoid when a position signal is received from the crankshaft. Once the solenoid has been energized, the rail pressure is applied to the primary piston. The primary piston is directly connected to a plunger of approximately one-fifteenth of the primary area. The appropriate volume of fuel is transferred to the accumulator by the high pressure plunger. The pressure within the accumulator is raised from the previous injection event needle closing pressure, to the level required for injecting the quantity of fuel being demanded.

The pressure inside the accumulator is forced to build to the desired level as long as the flow control valve solenoid is energized. At this point in the injection process, the accumulator chamber is separated from the intensifier cavity by a check valve. During the process of fuel transfer to the accumulator, needle valve lift is prevented by the intensified inlet pressure applied to the top of the needle valve system.

Injection is initiated when the flow control solenoid is de-energized. The two intensifier pistons are allowed to retract which causes a pressure unbalance on the needle valve. With this unbalance situation, the needle is forced to lift very rapidly. The check valve remains seated during this time and fuel is forced out of the nozzle and into the combustion chamber. See Figures 4, 5, and 6 which depict the fuel flow before and during injection.

This system allows injection to be initiated at a very high pressure since the energy is already stored in the nozzle at the time of needle opening. The quantity of fuel injected is a function of the pressure drop between opening and closing. One strong point of this concept is that the pressure can be set at higher values than with conventional systems. This is accomplished since needle seating velocity is controlled by the rate of decay in accumulator pressure. Injection duration is simply a function of the pressure drop within the accumulator and the nozzle orifice area.

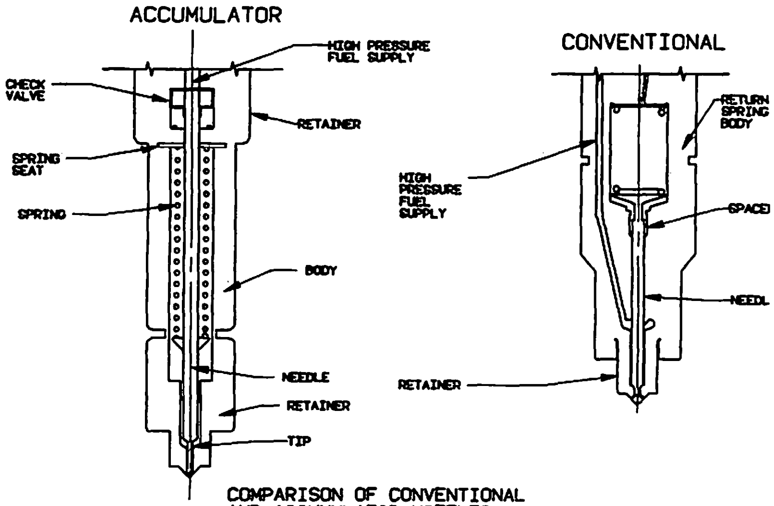
Advantages and Disadvantages

Since this system treats fuel injection as an "event" the process is not dependent on cam lift velocity. Depending on the timing of the solenoid energize and de-energize functions, the injector will fire on a time basis rather than on a resolution of the cam shaft. The combustion process will be improved through use of the accumulator nozzle. This device allows high injection pressure during short time periods of injection. Since the injection event is separate from the supply pump, peak power demands on the engine are reduced. High injection pressures and rates are restricted to the accumulator nozzle area.

Some possible drawbacks to this system are increases in noise, peak cylinder pressure, nitrous oxide emmissions, at medium and lower speeds. On the bright side of this problem, the ability to adjust the timing of the injection event (via solenoid time intervals) should smooth the injection event out. It is the preliminary feeling of most of the developers of this system that the net effect of using this system will be on the positive side. For example, there are some strong indications that very short injection duration will have a net benefit at all speeds and loads. Additionally, designers believe that the problems of fuel contamination and quality of fuel can be compensated for electronically. If this turns out to be the case, substantial benefits could result, in that we would not have to be so particular about fuel purchased for our locomotive fleets. There are obvious cost advantages of being in this situation.

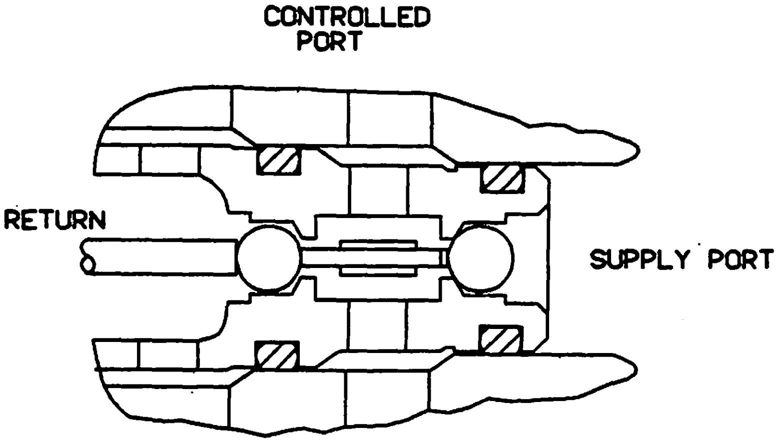
This year, an electronically controlled fuel injection system will be applied to a 12 cylinder EMD turbocharged engine. Southwest Research Institute, which is under contract and guidance of the AAR, will conduct tests to determine performance and reliability characteristics of the electronically controlled fuel injection system. It is hoped that at the conclusion of the test period comprehensive engine efficiency and cost data will provide guidelines for considering retrofit of this system to locomotives. Preliminary examination of the literature available indicates that electronic fuel injection systems may be a viable alternative to the mechanical fuel injection system.

Figure 1



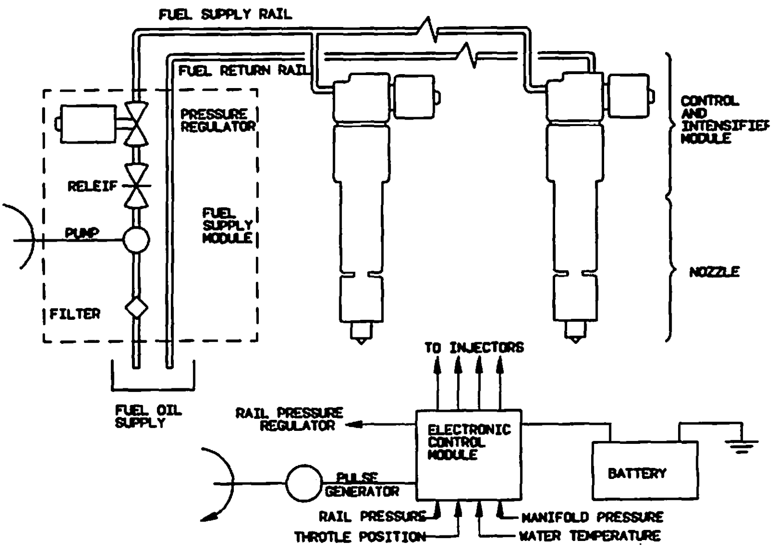
COMPARISON OF CONVENTIONAL AND ACCUMULATOR NOZZLES

Figure 2



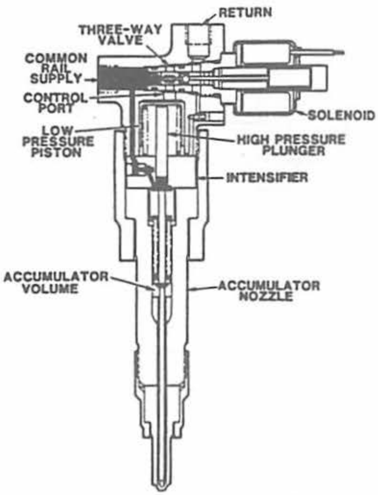
3-WAY BALL POPPET VALVE

Figure 3



Electronic Injector Schematic Diagram

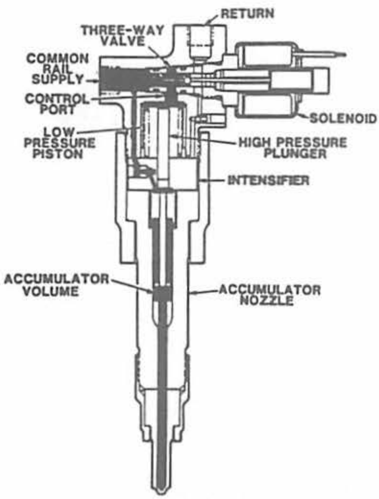
Figure 4



ELECTRONIC FUEL INJECTION - LOAD STAGE

(Note: Solid darkened areas depict fuel flow)

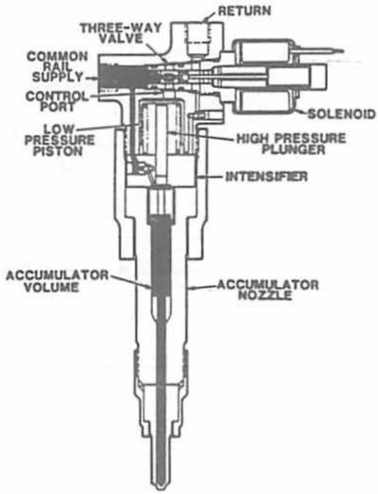
Figure 5



ELECTRONIC FUEL INJECTION - PRESSURE STAGE

(Note: Solid darkened areas depict fuel flow)

Figure 6



ELECTRONIC FUEL INJECTION - FIRE STAGE

(Note: Solid darkened areas depict fuel flow)

II.

UPDATE ON ELECTRONIC GOVERNORS

Caterpillar "PEEC" (Programmable Electronic Engine Controller)

The Caterpiller entry into the locomotive electronic governor field is called the "Programmable Electronic Engine Control" or PEEC. This governor is currently available only on Caterpillar locomotive engines. Early in the PEEC governor's development, a digital electronic system, rather than a mechanical governor, was chosen. Cost, serviceability, and reliability were the prime design considerations. (Caterpillar chose to use a microprocessor-based electronic governor because of its ability to better control fuel economy and better utilize the engine's operating range.)

System Diagnostics

A block diagram of the PEEC locomotive system is shown in Figure 7. The PEEC system is integrated into the locomotive system to provide total system power output control. The primary operator input into the system is the notch lever controller. The control can be configured to handle up to 16 notches, each of which corresponds to a particular output power level specified by the customer. However, the typical North American application of eight power notch settings plus idle is most common. The ramp rate of the traction generator (or alternator) output power under transient conditions between notches is controlled by a yard/main switch which selects one of two customer-defined acceleration rates. This extends the versatility of the locomotive by providing optimum power ramp rates for both yard operation and main line operation. For yard operation such as "kicking cars," the power ramp rate should be steep and consistent with the available traction on the locomotive. On main line operation, good controlability is required to minimize stress on the rolling stock and to make the unit compatible with the existing fleet.

Each notch position corresponds to a pre-set power output which is specified by the customer. Since power output and not speed is the critical parameter, the engine load and speed at each notch setting can be set at the lowest fuel consumption condition. A Caterpillar 3612 fuel consumption map (Figure 8) illustrates how the engine operating conditions can be tailored for optimum fuel consumption conditions.

The PEEC governor is designed to be used in single or multiple unit operation. Since the ramp rates for both yard and main line applications can be programmed and changed, it is easy to match the ramp rates with other locomotives in a consist. The locomotive electrical system can be interfaced with the PEEC governor through an external derate module. This module interfaces with the locomotive's wheel slip signal. Using the signal, the governor controls wheel slip by reducing excitation until the wheel slip condition passes. Engine speed remains constant. Then, the excitation is ramped back slowly to avoid recurrence of a wheel slip. Wheel slip ramp rates, both up and down, are customer tailored according to the application.

Like wheel slip, dynamic braking can also be incorporated with the PEEC governor. Both wheel slip and dynamic braking signals are a 0 to 50 volt analog signal digitally encoded by the derate module to provide for good electrical noise immunity.

Other functional inputs to the control system are:

— Rack position sensor signal
— Magnetic speed sensor signal
— Generator output current signal
— Generator output voltage signal
— Generator "load/no load" control input.

The rack actuator drive signal is a 0-200 milliamp current signal which drives an engine-mounted electro-hydraulic actuator. This actuator controls the engine rack. The generator excitation control signal is a 0 to 50 volt signal which is used by the generator excitation system to determine the main generator excitation current. The unit can provide up to 10 amp of excitation current.

A cab-mounted warning lamp is provided to indicate when a fault has been detected. Detected faults are displayed using a group of LEDs on the front face of the PEEC unit. The display provides an indication of the following faults:

— Derate module
— Personality module
— Engine speed sensor
— Rack position sensor
— Generator voltage
— Generator current.

The main PEEC circuitry is in a sealed aluminum housing for environmental protection. The plug-in personality module is bolted to the main housing and is also sealed. The personality module contains:

— Customer-specified software
— Serial communication link software and connection
— Engine low idle speed adjustment
— Operation parameters specific to the application.

The personality module also contains customer-specified operating parameters tailored to customer requirements. These include the following for each notch:

— Desired engine speed
— Desired rack position (fuel rate), usually notches 4-8
— Desired absolute traction motor power, usually notches 1-3
— Generator voltage limits
— Generator current limit
— Excitation control signal limit
— Engine speed governing control gain constants
— Generator excitation control gain constants
— Yard/main switch power ramp rates
— Dynamic brake settings.

The speed and load of the engine are controlled independently with the PEEC locomotive system. Engine speed control has priority over load control. Conventional rack position control systems tend to increase excitation current when the proper rack feed back signal is not achieved. This can lead to a prob-

lem that the engine is not able to support the load and could possibly cause the engine to stall. The PEEC locomotive system reduces the excitation current to the generator to maintain engine speed. Thus, the engine is not in lug condition or overloaded in an undesirable operating condition if the rack position sensor is faulty or not calibrated correctly.

Barber-Colman, DYNA System

Barber-Coleman's entry into the electronic locomotive governor field is called the DYNA system. Like other new electronic controls, it is a speed/load control. The DYNA system can be applied to any diesel electric system, either a.c. or d.c., which provides power for electric traction alternators. The governor system performs three major control functions:

- Basic engine governing
- Speed setting
- Load control

Optional features include oil pressure alarm, water pressure alarm, and smoke limiting. Standard features of the Barber-Coleman governor allow it to be applied to a single engine for a multiple-unit locomotive operation. This governor does not have a need for hydraulic piping or oil supply; thus maintenance is minimal. The DYNA system can be easily retrofitted to existing locomotives. The Barber-Coleman system also uses load control excitation of the generator exciter to control the output of the generator. Engine rpm governing is controlled throughout the command speed range by controlling rack position. The system is solid-state with adjustable loading and unloading ramp schedules.

Speed control is from the notch level on the control stand. Input signals from notch 1 through notch 16 are available if customer required. In addition, the engine speed setting can be set by a pressure signal to a pressure transducer. The resulting electrical signal is processed on the speed setting module. A third control method uses a 5000 ohm potentiometer to the speed setting module or utilizes a d.c. input voltage.

Wheel slip control is an optional function. The wheel slip signal which is provided by the locomotive system interfaces with the DYNA governor. Wheel slip unload ramp rates are adjustable.

Basic components of the governor include a card assembly, a speed setting module, two speed governing modules, a driver module for actuator power and generator excitation control, and load control module. In addition, optional features can be added to the governor specified by a using railroad. These are

- Oil pressure alarm and/or engine shutdown
- Water pressure alarm and/or engine shutdown
- Fuel limiting as a function of manifold boost pressure.

System Description

Figure 9 is a functional block diagram of the typcial diesel electric locomotive control. The blocks represent plug-in modules which are housed in a card cage assembly. The block function of each module is indicated by the individual block. Each plug-in module has a built-in test feature which allows functional testing. This feature is called "BITE" or Built-In Test of Equipment.

The sequence of operating and interpreting the testing is described on the inside cover of the controller's card cage assembly. The purpose of this built-in test function is to assist maintenance personnel in quickly troubleshooting and isolating any problems to a given plug-in module. This will help minimize down time associated with the Barber-Colman controller because once the faulty module has been located, it can be easily removed and a new unit installed.

Load control function is provided by one of the plug-in circuit modules housed in the card cage assembly. The inputs are actuator position (fuel lever position) and engine rpm. Figure 10 shows a graph of a typical characteristic which is generated within the load control module. Adjustments are provided within the load control electronics to establish a slope and offset of load control characteristics.

Earlier, three optional hardware functions were discussed:

— Oil pressure
— Water pressure
— Smoke limiting.

Each of these three options requires a sensing transducer.

Engine Oil Pressure Alarm

The engine oil pressure alarm and/or engine shutdown is a function of a particular engine speed to known normal oil pressure conditions as a function of that engine speed. The alarm level is programmed below the normal minimal oil pressure levels. Figure 11 describes this characteristic when a typical engine oil pressure is a function of engine rpm and the oil level is shown beneath the normal oil pressure characteristics. This alarm level or shutdown level is factory set on the oil pressure circuit module.

Engine Water Pressure Alarm

The water pressure alarm or shutdown as a function of engine speed is functionally the same as oil pressure. The characteristics are shown in Figure 12 with a typical curve of water pressure and engine rpm. The alarm level curve is shown beneath the normal water pressure operating characteristics. The alarm level and/or shutdown level is adjustable.

Smoke Limiting

This function provides smoke limiting if manifold pressure boost is not sufficient for command fuel setting. A typical engine characteristic is shown in Figure 13 with a limit line above the typical boost pressure characteristic. The boost pressure limit line is adjustable to meet the required characteristics of a user's engine.

With the DYNA system, the locomotive engineer can select the horsepower he needs simply with standard throttle control in the cab. The selected notch and engine rpm are governor controlled. Excitation level is automatically set so that the engine operates on its optimum hp curve for that selected rpm.

Woodward Governor, Menu-Oriented Editing Program Governor

The third electronic governor currently available to the North American railroad market is produced by Woodward Governor. This governor is known as the "MOE" or Menu-Oriented Editing Progarm Governor. One member railroad is working with Woodward to develop this locomotive governor control system. The Woodward governor is being developed based on railroad requirements tailored to individual railroad needs. Limited information is avialable about the governor at this time; however, it is known that the locomotive control will monitor lube oil pressure, water level, and temperature and is capable of locomotive control similar to the Caterpillar and Barber-Colman governors. Wheel slip control with an input signal, fan control, and generator excitation are also part of the Woodward package.

There is little doubt that the future electronic locomotive governors and related control equipment will continue to be developed for the railroad industry. Microprocessor technology is an everyday fact on new locomotives. Microprocessors used to replace mechanical governors are already proving they can save fuel, interface with the wheel slip signal and some also interface with dynamic brakes. Electronic microprocessor governor controls can also monitor such functions as inlet air restriction, lube oil pressure, coolant level and temperature, and brake pipe air. Actually, electronic governors can monitor almost any function required by the railroad customer.

The future of microprocessor-based locomotive governors is bright. Undoubtedly, additional governors will be developed for new locomotives as well as replacement packages for existing equipment.

Figure 7

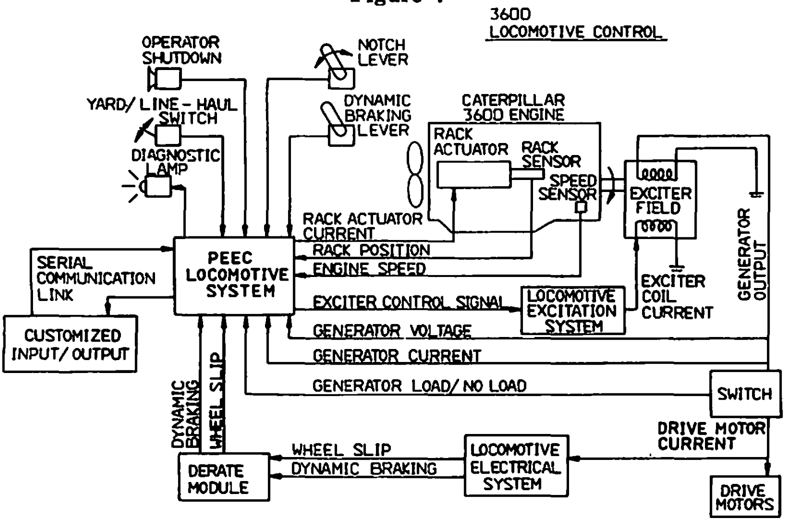


Figure 8

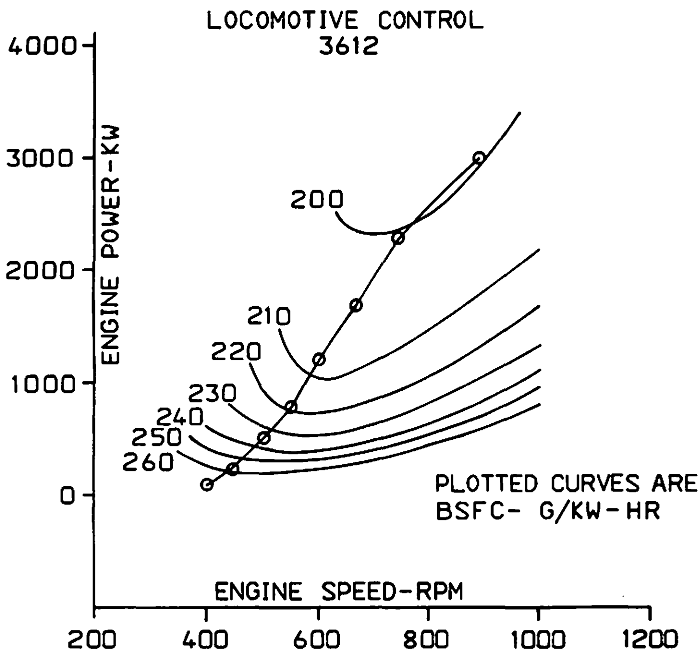
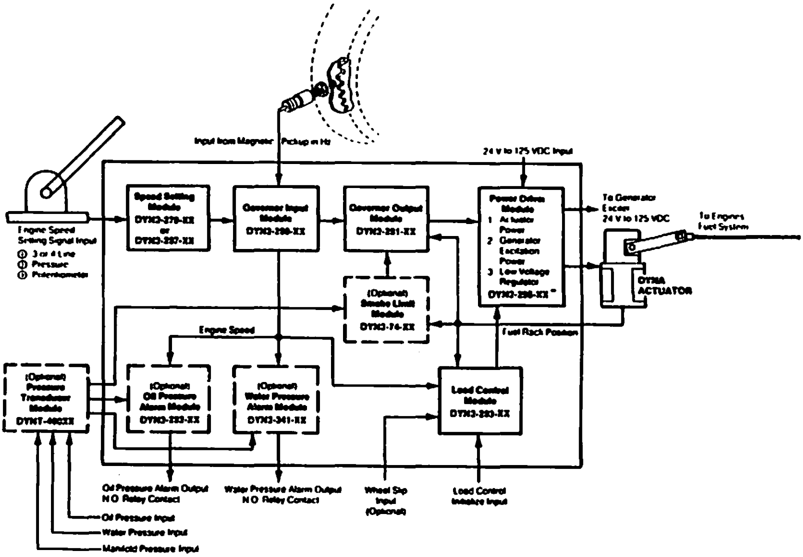


Figure 9



FUNCTIONAL BLOCK DIAGRAM For DIESEL ELECTRIC CONTROL

Figure 10

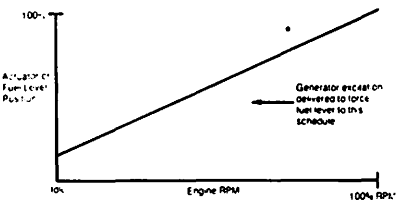
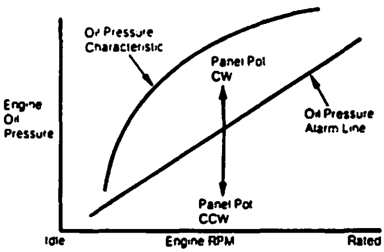
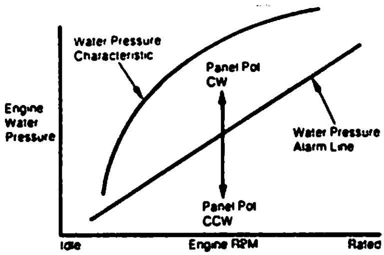


Figure 11



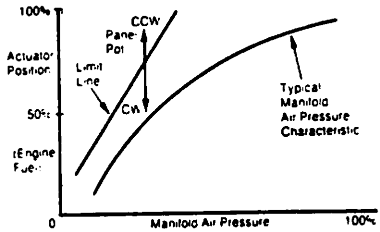
Typical Engine Oil Pressure As A Function of Engine RPM

Figure 12



Typical Engine Water Pressure As A Function of Engine RPM

Figure 13



CAL Engine Fuel As A Function Of Manifold Boost Pressure

III.

RECENT ADVANCES IN STEERABLE LOCOMOTIVE TRUCKS: THE EMD 4-AXLE, 4 MOTOR HT-BB ARTICULATED TRUCK

Steerable Trucks

Recent studies at General Motors' Electro-Motive Division indicate that locomotives may be responsible for 10 to 25 percent of the overall rail wear expense born by North American railroads. In addition, flange wear on locomotive wheels produces an expense for Mechanical departments as well as an implicit expense for Transportation departments through out-of-service unavailability. Recent work has proven the benefits of rail lubrication (either through onboard-locomotive application or hi-rail truck application) in reducing flange-to-railhead contact and resultant friction, and also of various radial freight car trucks which reduce flange contact through steering action.

EMD has been involved in studying locomotive curve negotiation for over 20 years. A recent program has centered on the development of the 4-axle radial and articulated locomotive truck aimed at reducing wheel and rail wear.

An experimental 4-axle, 4-motor articulated truck, designated the HT-BB model, was produced and tested by EMD in cooperation with a major western railroad. Based on field tests which verified computer simulations of the truck's performance, the HT-BB truck appears to offer significant advantages over current 3-axle, 3-motor locomotive trucks, including:

* Leading wheel lateral forces which are about 30 to 35 percent lower than for 3-axle trucks.

* A wheel flange wear factor which is about 40 percent lower than for 3-axle trucks.

* Projected adhesion capability which is 8 to 10 percent greater on curves of 10 degrees or more as compared to 3-axle trucks.

Interest in the HT-BB articulated truck was expressed by two railroads in the Western United States and Brazil. The latter is a meter-gauge railroad in Brazil engaged in unit train movement of iron ore; its locomotive fleet includes 82 DDM45 locomotives built by EMD between 1970 and 1976. The DDM45 is an SD-45-equivalent (3600 horsepower) riding on meter-gauge DD-type 4-axle, 4-motor non-articulated trucks. (Similar standard gauge trucks were used under 89 DD-type locomotives built in 1964-1971 for two other western U. S. railroads.)

While the American railroad involved in this test does not and has not owned any 8-axle locomotives, it does operate a major fleet of 6-axle locomotives through numerous areas of highly-curved track in the western United States.

In addition to wheel and rail wear, track curvature of 10 or more degrees creates a significant degradation of locomotive wheel-to-rail adhesion, resulting in reduced tonnage ratings. The latest EMD locomotives equipped with "Super Series" adhesion controls, for example, are rated at 24 percent adhesion on curves as sharp as 6-to-10 degrees; adhesion levels as high as 29-to-30 percent are achievable under certain conditions on tangent or slightly-curved track (less than 6 degrees). Where one railroad with low curvature can handle a given train with two locomotives, another with severe curvature and the same grades will require three due to the loss of adhesion in curved track territory.

Although the EMD HT-BB truck was designed as an alternative means of reducing wheel and rail wear expenses, the 4-axle 4-motor design also serves as the basis for future locomotive designs incorporating traction horsepower ratings in excess of 4000 per unit. A study of the feasibility of an "HT60" locomotive, utilizing two HT-BB trucks underneath what otherwise was a 3800 horsepower SD60 locomotive, was undertaken. Such a locomotive could have application as a replacement for older power in low-speed drag service (such as replacing two 2000 horsepower SD38s). If additional horsepower were available through application of a higher-rated diesel engine and electrical transmission, locomotives of 4500-to-5000 horsepower on two HT-BB trucks could be applied in services now requiring greater numbers of 3000 horsepower locomotives.

The test railroad agreed to supply EMD with a stored SDP45 locomotive for application of a pre-prototype HT-BB articulated truck, with the modified locomotive made available to EMD as a test locomotive, and to operate it in test service.

HT-BB Truck Design

The HT-BB truck is a 4-axle, 4-motor articulated truck It consists of two interchangeable truck frames, each containing two powered axles. The two truck frames are joined together in the center by steering linkage assemblies. An alternate arrangement using pin-and-spherical ball bearing joints has also been designed by EMD. (Figure 14 depicts the general arrangement of the HT-BB pre-prototype truck design.)

Each truck frame uses conventional pedestal liners, journal boxes, composition brake shoes and journal springs. The pre-prototype HT-BB truck is equipped with 42 inch wheels. The two traction motors in each truck frame are arranged back-to-back, as in an EMD GP-type truck. The pre-prototype HT-BB articulated truck was manufactured using two SD Flexicoil-type 3-axle trucks, each having the single-motor end removed. Production HT-BB trucks would have provision for traction motor roller support bearings.

The two truck frames support and are connected by a large span bolster; each end of the span bolster rests on two secondary bolster springs on each truck frame. The span bolster includes a conventional center bearing which mates with the underframe center plate.

The span bolster carries primarily carbody weight; all tractive and braking forces are transmitted from the truck frames into the underframe through traction rods, one on each side of each truck frame, for a total of four. A stanchion assembly, welded to the underframe on each side, anchors the inboard end of each of the traction rods. The outboard end of each traction rod is connected to a bellcrank which is mounted on the bottom of each truck sideframe. Each bellcrank is supported by an "AP" cartridge bearing fitted over a vertically-mounted pin pressed into the truck sideframe; this arrangement allows the bellcrank to pivot about a vertical axis.

The two bellcranks on each truck frame are interconnected by a lateral tie rod between the traction motors. This arrangement of lateral and traction rods allows the two truck frames to turn while negotiating curves, and also provides a rigid force linkage between the truck frames and the underframe.

Four primary and four secondary shock absorbers are also provided on each HT-BB truck to dampen vertical motion.

Modifications to Locomotive For HT-BB Truck

Field testing of the pre-prototype HT-BB truck was done on a 3600 horsepower SDP45 locomotive built in 1967 for dual freight/passenger service. As built, the locomotive was equipped with two 3-axle, 3-motor SD Flexicoil trucks, 5000 gallon fuel/water tank and had a total loaded weight of 396,000 pounds.

The test railroad shipped the locomotive to EMD in early 1984. After receipt at the LaGrange plant, EMD made the following modifications:

1) The rear platform was removed and replaced with an underframe extension and new rear platform; the extension added 31 inches to the locomotive's overall length. (See Figure 15.)

2) The 5000 gallon fuel tank was replaced with a shorter 4000 gallon tank.

3) A welded stanchion assembly was installed on each side of the rear underframe center plate, to provide an anchoring connection for the four traction rods; the original underframe rear center plate was retained (45'0" truck center spacing).

4) The pre-prototype HT-BB articulated truck was installed at the rear position.

5) In order to maintain 6 traction motors on the modified locomotive having 7 axles, the number 2 motor was removed from the remaining SD Flexicoil truck, resulting in an A1A-B+B wheel/motor arrangement.

6) Traction motor ducting and cabling were modified to accommodate the new motor arrangement.

7) In order to maintain fully-loaded axle weights at about 60,000 pounds, additional ballast was placed on the rear end of the underframe to increase total loaded weight to 419,719 pounds. (Figure 15 depicts the general arrangement of the test locomotive after modification and application of the HT-BB truck to the rear truck position.)

No change was made to the locomotive's wheel slip control system, which was the original IDAC installation. Use of that correcting-type wheel slip control limited the locomotive to about 18 percent adhesion, even with the HT-BB truck. Retrofitting the locomotive with EMD's Super Series controlled-creep control system would have permitted higher adhesion levels, but would have required major modification of the locomotive's main alternator and controls (to achieve permanent-parallel motor connections and radar speed-based creep control).

Field Testing

Field testing of the HT-BB truck was to occur in territory with sufficient curved track to verify the articulating, self-steering ability of the design. By June 1984, modifications to the locomotive were adequate to enable EMD to make non-powered curving tests on yard trackage within the LaGrange plant. All modifications were completed August 30, 1984, and the locomotive was shipped to the railroad's yard in Cicero, Ill. The locomotive, along with EMD's SD45X experimental locomotive 5740 and the EMD 840 test car, was then shipped west to the railroad's shop near Seattle.

In early September 1984, EMD engineers installed instrumented wheelsets and instrumentation on the locomotive. The test consist was modified by including an SD38-2 (to provide additional dynamic braking effort, along with EMD 5740).

In early August 1984, railroad representatives selected the main line between Auburn and Yakima, Wash. for testing the HT-BB truck. The main line was selected due to the heavy concentration of curves, proximity to a locomotive shop, and lack of traffic due to the diversion of all revenue trains to other routes.

The specific test site chosen was nine miles long, where the line is on a 2.2 percent compensated grade uphill. Those nine miles include 34 curves, from 0.25 to 10.50 degrees curvature. Testing commenced on September 13, 1984 and concluded on September 22, 1984. The locomotive was then sent back to a nearby shop, where the instrumented wheelsets and instrumentation were removed. Afterwards, the unit was sent back to EMD for inspection of the HT-BB truck, and new wheels and remanufactured traction motors were installed. The unit was released to the railroad in late December 1984 for general service; it reportedly remained in service until late 1986, when the HT-BB articulated truck was to be removed and shipped back to EMD.

Instrumentation for Field Tests

Three of the four wheelsets on the HT-BB truck under the locomotive (all were 42 in. with 1:20 tapered narrow-flange profiles) had instrumented plates to provide continuous measurement of lateral and vertical wheel loading on the rail. Those wheelsets were installed at the numbers 1, 4 and 6 positions on the unit. The wheel plate instrumentation consisted of strain gages transmitting strain signals through an end-of-axle slipring, with signals transmitted by cable to the EMD test car. A total of 26 test signals were monitored on the test car, including:

* Lateral wheel loads
* Vertical wheel loads
* Wheel L/V ratios
* Angle of attack for the SD Flexicoil truck
* Angle of attack for the HT-BB truck
* Vertical displacement between the HT-BB truck frames
* Force on the steering links
* Locomotive speed
* Drawbar force behind the unit
* Armature current
* Sand application.

The computer on board EMD test car 840 monitored tractive effort for both the SD Flexicoil and HT-BB trucks; the effective adhesion level for each truck was also calculated (adjusted for weight shift). The nine-mile test area was divided into 18 test segments for data acquisition; segments were based on representative curvatures.

The locomotive was tested in traction mode (pulling the two braking units) and in coasting, all at constant test speeds. The HT-BB truck was tested using several different conditions of axle free lateral clearance, and with and without the steering links installed.

Weather conditions in the test area during September 1984 test runs were generally clear skies with 50 to 70 degree F temperatures and light rain on two days.

Test runs were made at speeds of 15, 20 and 26 MPH.

Test Results: Curving Forces

In a maximum 10 degree curve, the HT-BB truck reduced the net lateral load 30 to 35 percent at full power and 35 to 40 percent while coasting, as compared to the SD Flexicoil truck. Typical net lateral wheel loads in 10 degree curves were approximately:

* 18,500 pounds for the SD Flexicoil truck
* 12,000 pounds for the leading HT-BB truck frame
* 6,000 pounds for the trailing HT-BB truck frame

at a two-inch unbalance speed on the superelevated curves.

At balance speed on the 10 degree curves (see Figure 16), the net lateral wheel loads were approximately:

* 17,500 pounds for the SD Flexicoil truck
* 11,750 pounds for the leading HT-BB truck frame
* 6,000 pounds for the trailing HT-BB truck frame.

Average adhesion demand on the wheels during those tests was 11 to 15 percent.

Looking only at the leading wheel on each truck, the lateral forces on the HT-BB leading truck were 37 percent lower than on the leading wheel on the SD Flexicoil truck while coasting at balance speed through a 10 degree curve (10,500 pounds versus 17,400 pounds). During those tests, the HT-BB truck had average lateral free clearances of 0.24", whereas the SD Flexicoil truck average lateral free clearance was 0.44". (See Figure 17.)

Test Results. Steering Link Force

Strain gages on the steering link rods measured steady-state forces in the rods under power and coasting conditions throughout different curve radii. Typical dynamic forces measured in the steering link rods were 3,000 to 5,000 pounds peak-to-peak, at frequencies of 1 to 2 Hertz. Dynamic forces while entering curves and at track irregularities were measured as high as 8,000 pounds; the maximum force measured was 21,000 pounds.

EMD found that the steering link had a mean tension load of about 3,500 pounds while under power (and 2,000 pounds while coasting) on tangent track. That unexpected loading was subsequently determined to be caused by a steering link being too short, based on post-test measurements. An almost constant net lateral wheel load of 3,000 to 4,000 pounds was also observed at the No. 6 right wheel (right front of the trailing HT-BB truck frame).

The SD Flexicoil truck was found to have little difference in net lateral wheel load in 10 degree curves between power and coasting conditions. Initially, the SD Flexicoil truck had a maximum of 0.38 in. of longitudinal free clearance per journal due to worn pedestal liners; that free clearance permitted some self-steering of the SD Flexicoil truck's wheelsets. After the Flexicoil liners were changed, free clearance was reduced to about 0.12 in. per journal. The HT-BB truck's liners had very little free longitudinal clearance.

Test Results: Axle Free Lateral Clearance

It was found that the net lateral wheel load of the HT-BB truck was reduced by about 29 percent when the free lateral clearance in the Hyatt journal bearings was reduced from an average of 0.48 in. to 0.24 in. That was determined to be the approximate minimum total free lateral clearance in an HT-BB truck necessary to significantly reduce curving force, as compared to the SD Flexicoil truck. EMD concluded that tapered cartridge journal bearings would be advisable for future HT-BB articulated trucks in order to tightly control the necessary lateral clearances. (See Figure 18.)

Test Results: Operation Without Steering Link

The steering links were removed during one day's testing to determine their effect. The HT-BB truck still produced about 23 percent less net lateral wheel load than the SD Flexicoil truck in power condition; thus, the independence of the two 2-axle truck frames in the HT-BB truck accounts for about two-thirds of the wheel load improvement over the SD Flexicoil truck. (See Figure 19.)

Test Results: Angle of Attack of Leading Wheels

Motion sensors were applied during testing to measure the angle of attack of the Numbers 1, 4 and 5 wheelsets, to measure the rotation of the truck centerlines relative to the underframe. It was assumed in calculating angle of attack that the axles would remain parallel within their truck frames on constant-radius curves. Angle of attack measurements were made at adhesion demand levels of 0, 7, 10 and 18 percent.

Angle of attack was higher for both the SD Flexicoil and HT-BB truck while in coasting mode as compared to any of the power tests; lateral creep of the wheel across the railhead is reduced during curving by the presence of traction force. (See Figure 20.)

During power testing, the lead wheelset of the HT-BB truck had 25 to 30 percent less angle of attack than the leading wheel of the SD Flexicoil truck.

Test Results: Calculated Wheel Flange Wear

EMD constructed a simple wheel flange wear index: FWI = (Wheel flange force, pounds) x (Angle of attack, deg.)

Test results showed that the leading wheel wear index for the HT-BB truck should be about half that for the SD Flexicoil truck, substantially reducing flange wear through curve contact.

Test Results: Adhesion

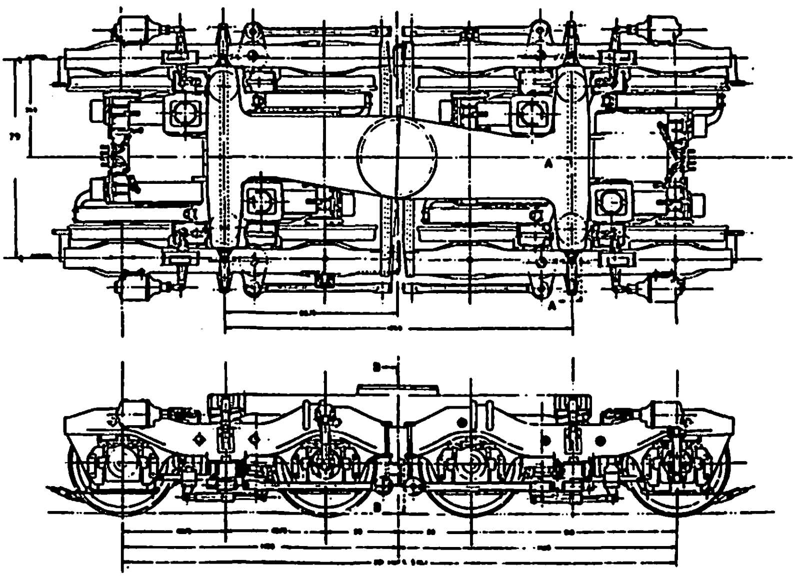
Adhesion levels were monitored based on continuous readings of traction motor currents for each powered axle. Vertical displacement of the two HT-BB truck frames was also recorded; the actual vertical displacement (to be expected as each truck frame attempts to tilt) was less than the predicted value. The actual displacement between the two truck frames ranged from about 0.38 in. to 0.90 in.

EMD predicted that the HT-BB truck would have an adhesion efficiency of 91.5 percent at the 25 percent adhesion level, compared to 80 percent for the 4-axle, 4-motor non-articulated DD truck used under previous DD-type locomotives. The actual vertical wheel loads measured were very close to the predicted values. The small difference in wheel loads corresponded to minimal differences in tractive effort at each wheelset, implying high adhesion efficiency throughout the truck.

Test Results: Ride Stability

The HT-BB truck was also tested at speeds as high as 60 MPH on wet rail, to determine its hunting characteristics without the steering link in place. The ride characteristics were described by EMD as "satisfactory." With the steering link in place, the yaw motion of the two truck frames within the HT-BB truck are coupled, and any hunting is further reduced.

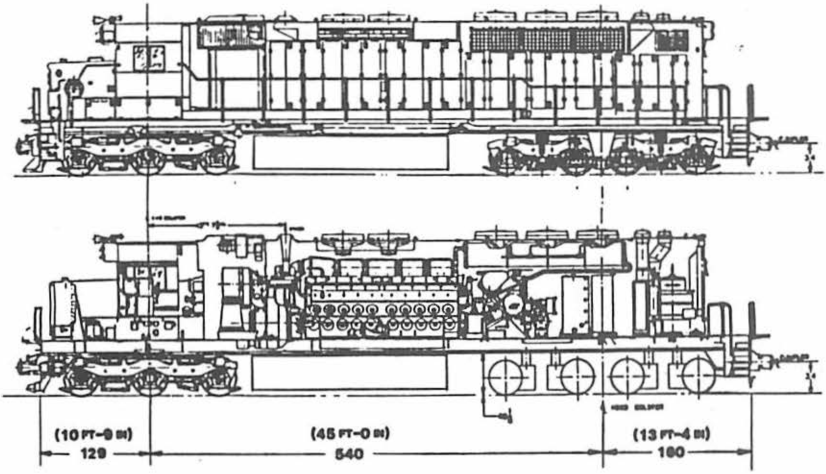
Figure 14



HTBB TRUCK

PRE-PROTOTYPE DESIGN

Figure 15



MODIFIED SDP45 LOCOMOTIVE

Figure 16

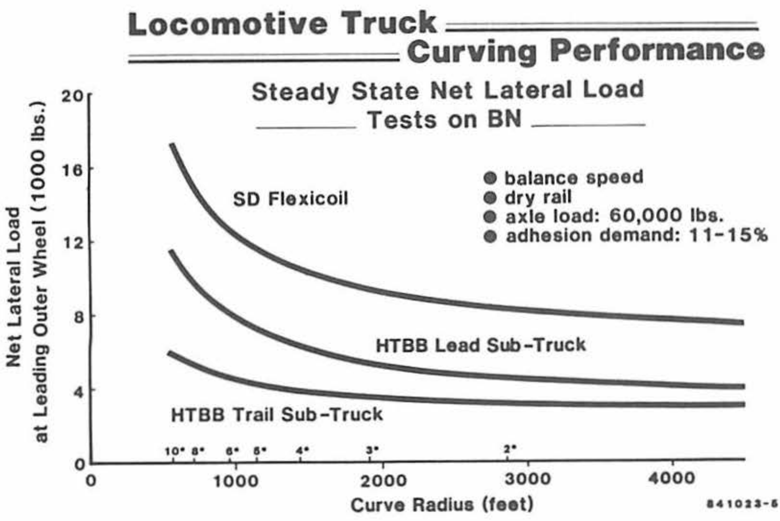


Figure 17

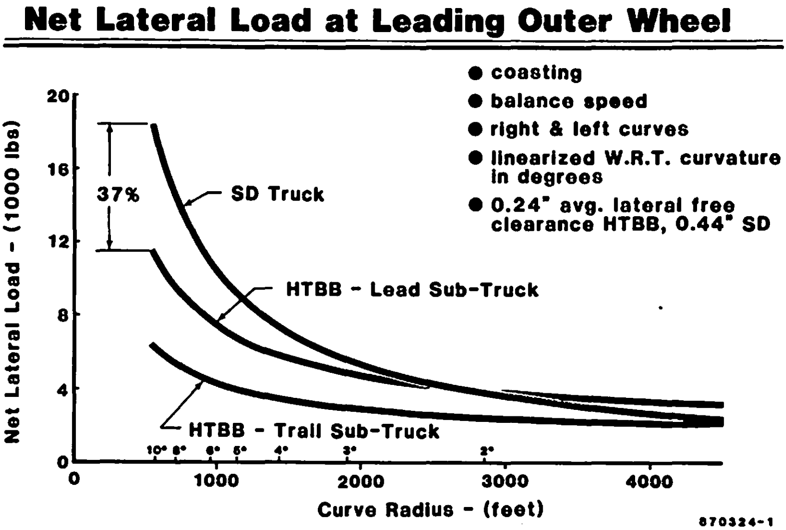


Figure 18

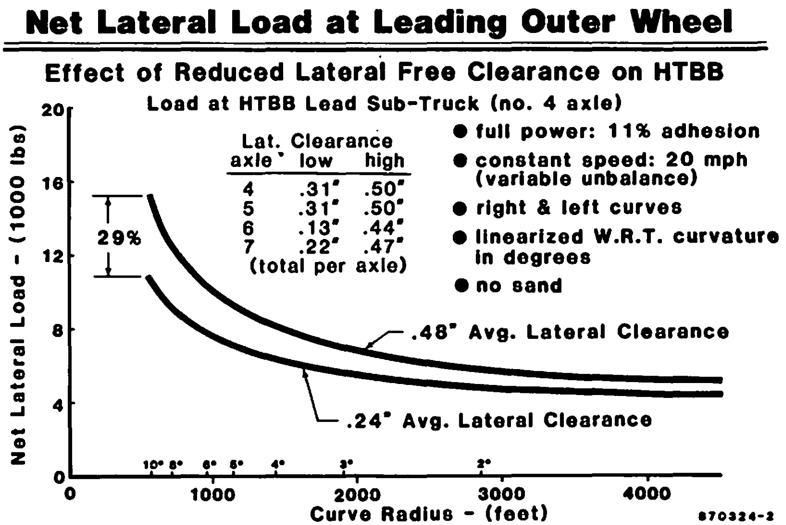


Figure 19

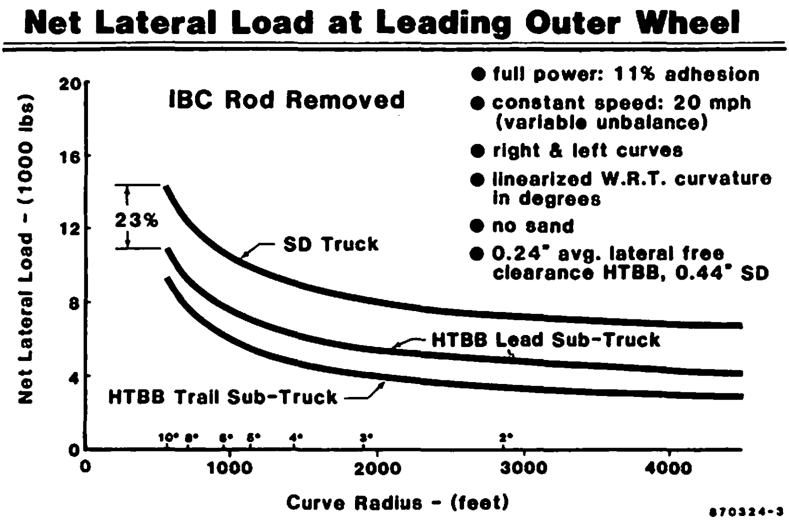
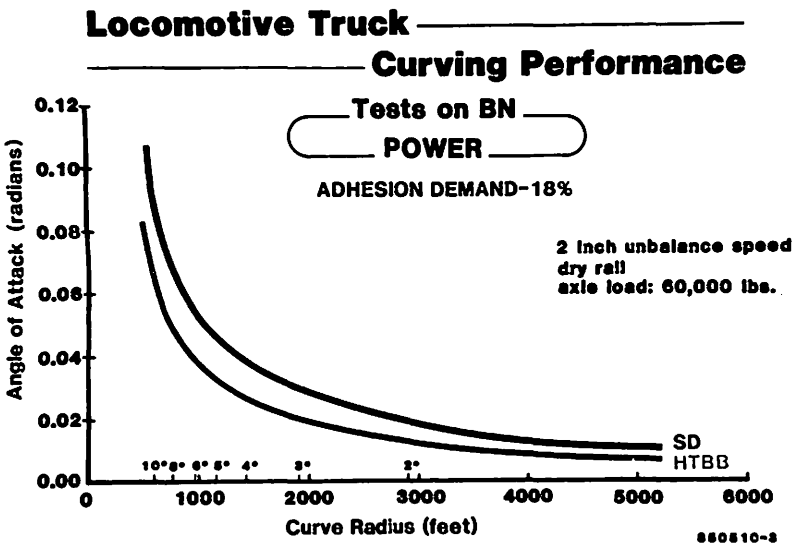


Figure 20



IV.

CONVERTING AN F40 LOCOMOTIVE TO AC TRACTION MOTORS

In 1985 Amtrak initiated a project to retrofit an existing F40 PH class locomotive to A-C drive. Engineers from Brown Boveri, Inc. (hereafter shown as BBC) advised that the necessary A-C control components would fit into an existing F40 carbody if additional space could be made available. It was agreed that the traction motors would be truck mounted and power transmitted to the wheels through a quill drive (See Figure 21). The existing 2-axle F40 truck with inclined rubber suspension, was modified to accept the A-C traction motor.

Carbody: The F40 is 56 ft. 2 in. over the pulling face of couplers with an enclosed full-width carbody approximately 54 ft. long. Most of the long hood is occupied with engine components plus a headend power gear box and 3-phase alternator.

Amtrak's engineers confirmed that the existing carbody room was inadequate for adding the A-C inverters, additional cooling air ducts, etc. With help from Amtrak's Beech Grove shop personnel, the carbody was lengthened 24 in. In addition, the lube filter rack was raised approximately 12 in., thus permitting the HEP gear box, alternator and air compressor to be moved forward nine inches to provide 33 in. additional space between the air compressor and the rear carbody wall. Figures 22 and 23 illustrate the F40 carbody before and after space for A-C inverters was provided. Additional changes to the carbody include:

1. Increasing the width of the traction motor air duct 30 in. to provide additional cooling air to the inverters, d.c. choke and interconnecting buss bars.
2. Move the 1800 gallon fuel tank forward 8 ft. 6 in. to counterbalance the added weight being added to the rear of the locomotive.

Electrical: Electrically, unit 202 will be similar to the A-C power and control installed in CP Rail locomotive No. 4744. A block diagram showing the electrical circuit is illustrated in Figure 24 and the basic control concept for the BBC-3 phase system is diagrammed in Figure 25.

Electrical components added to the F40 locomotive in addition to the four A-C traction motors are:

* 3 D-C/A-C inverters
* 2 current transformers
* 6 voltage transformers
* 1 3-phase choke
* 1 D-C choke
* 1 electronic control cabinet
* 1 protection circuit

Trucks: As stated previously, the F40 truck is being retained. The traction motor will drive the wheel through a flex drive and quill that will be bolted to the plate of the wheel. The wheels (supplied by Edgewater Steel) are 42 in. in diameter and have a flat or vertical plate. The larger diameter provides an additional inch of ground clearance for the gear box as well as additional clearance between the axle and hollow quill. This drive arrangement provides a fully sprung suspension of the traction motor, thus lowering the unsprung weight on the rails. It is similar (in concept) to the GG-1 electric locomotive.

Cooling: Cooling the inverters, chokes and interconnecting buss bars is the most formidable problem to be solved. Primary cooling air will come from the traction motor blower. A six-axle traction motor blower is being used in place of the four-axle blower common to the F40. The air duct to the rear of the locomotive was widened 30 in. to improve air volume. The rear deck forms a plenum chamber with outlets feeding cooling air to Nos. 3 and 4 traction motors and the inverters. A ply-metal partition will be constructed at the rear of the air compressor to separate the main engine compartment from the rear compartment to reduce ambient temperatures around the inverters.

BBC advises that ambient air temperature around the inverters should not exceed 45° C (113° F). If the partition fails to maintain proper ambient temperatures, a supplemental blower will be installed in the roof of the locomotive.

Completion and Testing: Amtrak estimates the F40 A-C locomotive will be ready for testing in October, 1987. After initial operating tests are conducted between Indianapolis and Chicago, a test program to evaluate performance as a passenger locomotive will be conducted at the AAR test center in Pueblo, Colorado. These will include:

* High speed runs to 100 MPH.
* Dynamic braking
* Observing vertical axle movements to ensure proper quill/axle clearance
* Operation with other F40 locomotives in multiple mode
* Speed-time runs with trains of various sizes.

Information gathered will include:

* Inverter switching multiples
* Motor currents
* Response to controls
* Adhesion in motoring and braking modes
* Operation of protection circuits.

As with the CP Rail No. 4744, the A-C traction is a BBC design with components manufactured and assembled in Germany.

Amtrak believes the elimination of traction motor commutators will reduce traction motor failures and improve locomotive reliability. Amtrak has also experienced high maintenance costs associated with traction motor support bearings and will closely monitor the benefits of operating with the quill drive.

Amtrak considers unit 202 an experiment and not the forerunner of converting all or part of its F40 fleet to A-C drive. If unit 202 performs as intended, it will be the first step in supporting the acquisition of new A-C drive locomotives in both diesel electric and straight electric locomotive configuration. The New Developments committee will continue to monitor efforts to develop and manufacture A-C drive locomotives in North America.

NOTE: For discussion on A-C traction motors for locomotives see 1984 New Developments paper, p 147, "Appraisal of the AC Traction Locomotive."

Figure 21

Traction motor, gear and drive of E 120 locomotive with wheel set

Traction motor

1 Stator core
2 Stator winding
3 Rotor core
4 Short-circuited winding
5 Shaft
6 Cylindrical roller bearing
7 Pulse disk
8 Casing
9 Air inlet
10 Connecting cable
11 Air outlets
12 Mounting eyes

Gear

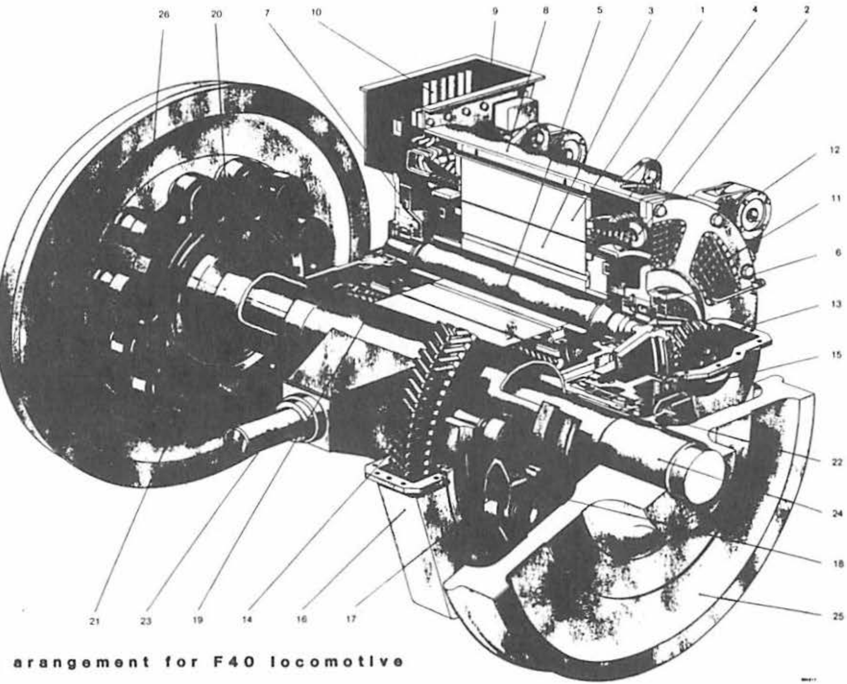
13 Pinion
14 Gear-wheel
15 Gear-wheel bearing
16 Gear box

Rubber joint cardan drive

17 Linkage coupling
18 Hollow shaft spider
19 Hollow shaft
20 Fork spider
21 Linkage coupling
22 Hollow shaft casing
23 Supporting arm

Wheel set

24 Wheel set shaft
25 Disk wheel
26 Disk wheel with driving bolts



BBC arangement for F40 locomotive

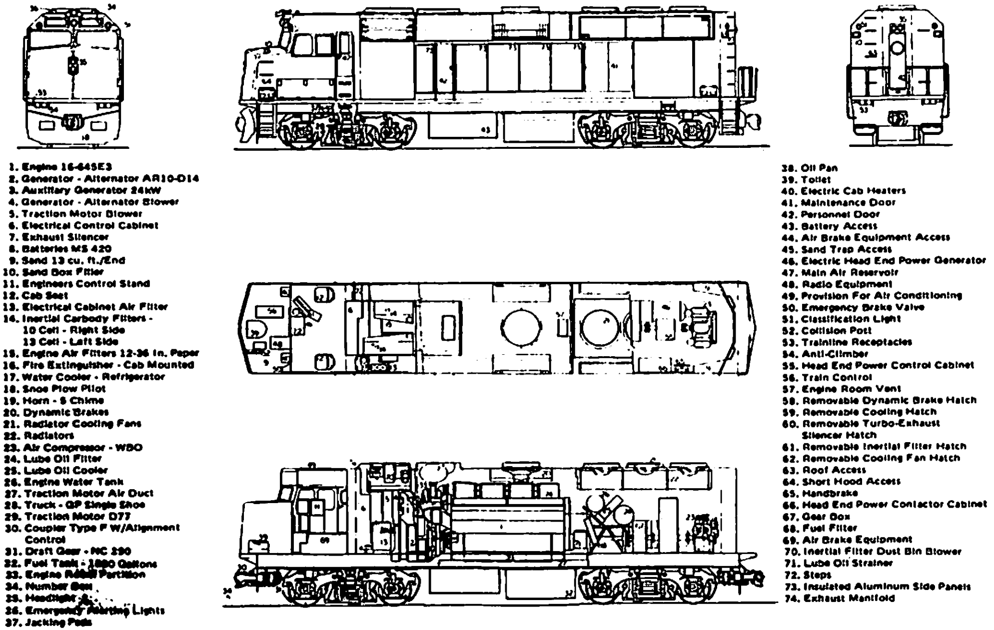
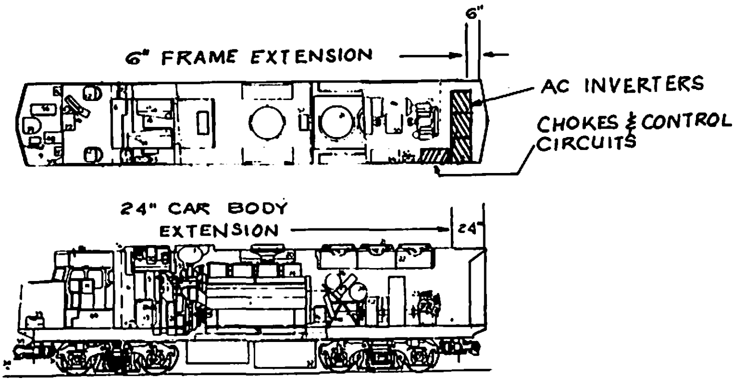


Fig. 0-1 – Model F40PH - 3000 HP Four Motor Diesel-Electric Passenger Locomotive

Figure 23



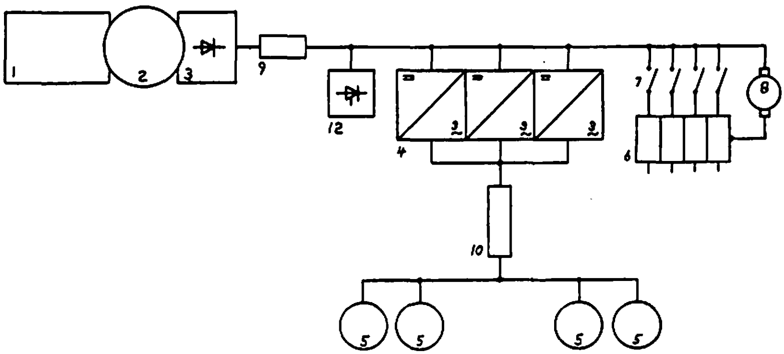
CARBODY MODIFICATIONS FOR AC DRIVE

Model F40PH - 3000 HP Four Motor Diesel-Electric Passenger Locomotive

Figure 24

LEGEND

1. Diesel Engine
2. Main Alternator
3. Rectifier
4. 3-Phase Inverters
5. 3-Phase Traction Motors
6. Dynamic Brake Resistors
7. Dynamic Brake Contactors
8. Dynamic Brake Blower Motor
9. DC Choke
10. 3-Phase Choke
11. Choke By-Passing Contactor
12. Protection Circuit



Electrical Circuit for BBC 3-Phase Locomotive Traction System

Figure 25

LEGEND

Equipment

1. Diesel Engine
2. Alternator
3. Rectifier
4. Inverter
5. Traction Motor
6. Control Electronics
7. Operator's Controls and Indications
8. Load Control Potentiometer
9. Woodward Engine Governor
10. Alternator Excitation
11. Voltage Transducer
12. Current Transducer
13. Traction Motor Speed Sensor

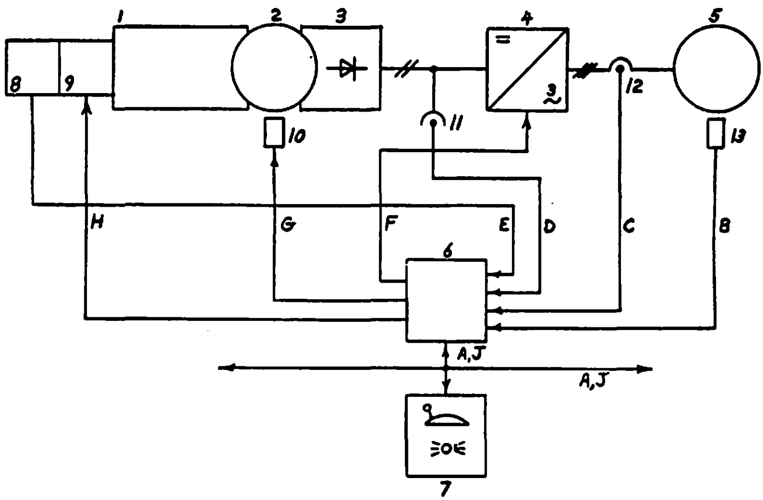
Signals

Input to Control Electronics:

A. Operator's commands from local controls or via trainline
B. Traction motor speed
C. Traction motor current
D. Intermediate circuit voltage
E. Load control potentiometer value

Output from Control Electronics:

F. Inverter firing commands
G. Excitation command
H. Engine speed command
J. Indications, alarms to operator



Basic Control Concept for
BBC 3-Phase Locomotive Traction System