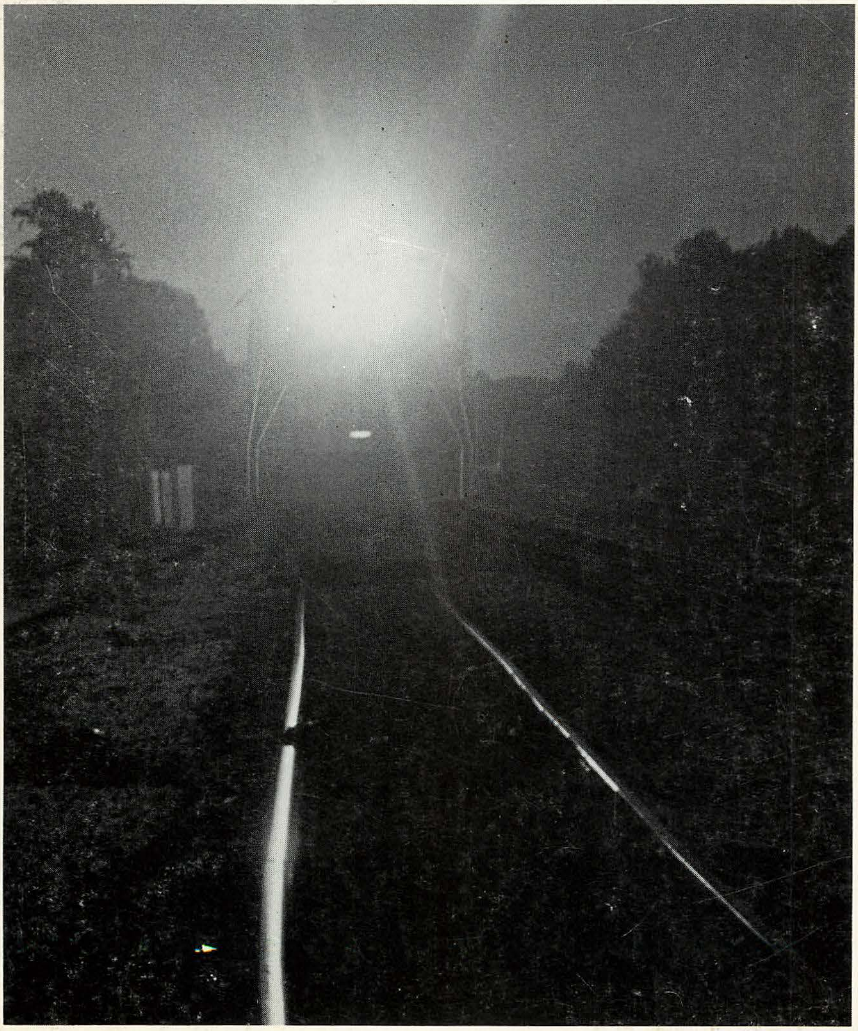
LMOA

Locomotive Maintenance Officers Association

Proceedings of the 53rd Annual Meeting
Chicago, September 16-18, 1991



1991 ADVERTISERS INDEX

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TECHNICAL PAPERS

WILLIAM J. WATT
Associate Adminstrator, FRA
Speech to the Coordinated Associations Technical Conference
Chicago, Illinois
September 16, 1991

Since my experience in transportation involved police--not the nitty-gritty of railroad equipment and operations--I won't pump hot air at you on these matters. Instead, I'll comment on a few transportation policy issues now being considered in Washington, along with observations about issues and trends in transportation safety. These subjects are interrelated, so I'll take up the safety themes first.

The development of safety regulatory policy...and the manner in which it is carried out...is influenced by a number of factors: safety trends, mandates by Congress, public concern, media accounts of safety problems or practices, the impact upon the regulated industry and its customers, disputes between management and labor, and even the budget deficit. Therefore, the political process that leads to regulatory policy can be influenced by perceptions as well as facts. Despite these pressures, FRA tries to build regulations and enforcement programs around the concept that they should be credible and effective deterrents to unsafe practices.

Another objective of FRA regulatory strategy is that it ought to provide opportunities for FRA to play a positive role in working with the industry to promote safety. That may involve evaluations of existing practices and companion recommendations for improvement, informational or training sessions, research and testing of new technologies, or programs targeted to the public in areas such as highway grade crossing safety.

The underlaying safety trends in general are very encouraging. There have been dramatic improvements in rail safety in virtually every category since the 1970s. That's a reflection of a number of developments. Deregulation improved as financial vitality of the industry, which permitted capital investment in new and safer operating structures and equipment.

Better technology in track, equipment, signaling and communications also made major contributions. The effectiveness of the federal government's and the industry's own safety monitoring efforts also improved during this period. The cost of insurance coverage, multi-million dollar lawsuits, and risk management efforts were catalysts for increased management attention to safety. Action by government and industry toward making the railroad environment drug-free represented another important factor.

In recent years, statistics show a tapering off of the annual pace of safety improvement. Obviously, the safety gains associated with investments such as converting from jointed rail to welded rail reflect a one-time improvement, and that conversion on the nation's Class I mainlines is all but complete. However, as America's railroads have upgraded the quality of their operating hardware--thereby reducing accidents attributed to defects in track and equipment--the role of human factors stands out more starkly.

In train accident statistics for 1990, human factors accounted for the single largest cause of accidents--38 percent. Therefore, in the coming years you can expect FRA to place a a high priority on human factors issues, in terms of both safety research and safety enforcement. An increasing percentage of our safety research budget is being allocated to human factors projects. Meanwhile, the provisions of the 1988 Rail Safety Improvement Act which allow penalties against individual railroad employees provides a level of personal accountability that didn't exist in the past. Historically, FRA cited railroad companies. Now, individuals--management and labor--are subject to the civil penalty provisions--which can include substantial fines or disqualification from a safety-sensitive position.

America's railroads appear to be making real progress in the effort to eliminate substance abuse from the transportation workplace-- which also should help curb the extent of accidents attributable to human factors. Random drug testing for 1990 showed a positive rate slightly above one percent. Post-accident testing showed that the incidence of alcohol or drug abuse was half that of three years earlier.

Although highway grade crossing fatalities showed a significant improvement in 1990 from the previous year--from 801 to 691, these accidents, as you well know, continue to represent a highly visible and worrisome problem. A related issue--trespasser fatalities--showed a 20 percent increase.

Federal Railroad Administrator Gil Carmichael and his staff are working on additional strategies to combat grade crossing deaths. One initiative likely will involve working with state and local officials to encourage the outright closing of a number of grade crossings. Mr. Carmichael has said publicly that as many as 25 percent of the nation's grade crossings could be closed. This would promote public safety and reduce the accident risk to the railroad industry. Previous efforts of this type have met with only minimal success, because the public perceived that only the railroads were the beneficiaries. Somehow, we've got to establish that there are other "winners" in this equation--the public, the affected communities, and so on.

Having said all this, there are a few things we need to recognize. What was good enough for the 1980s will not be good enough for the 1990s. The public and its representatives are setting higher standards of performance and accountability--for railroads, shippers, and government regulators. Your own senior managements are holding you to higher standards as well, because of the substantial cost in both human and economic terms of accidents, of safety lapses.

One of the public policy decisions under consideration right now in Washington involves the periodic reauthorization of the federal rail safety program. I don't know what the final version will look like, but it probably will leave FRA with less discretion in determining whether or not a given safety issue will result in a new regulation. Furthermore, other provisions in the new law may specifically add to FRA's regulatory responsibilties, which in turn may affect your operations.

In recent years we have seen how a single accident or series of incidents can set in motion a process that leads to more stringent law and regulation. The Amtrak accident at Chase, Maryland, generally is considered to have been the catalyst for the Rail Safety Act of 1988. The recent subway accident in New York City has escalated Congressional and Adminstration awareness and concern about substance abuse in the

transportation industry--alcohol as well as drug. The two recent hazmat derailments in California may prove to be catalysts as well for amendments to the safety bill now before Congress.

I noted that both the industry and FRA would be held to a higher standard of accountability during the 1990s.

Just as railroad personnel have been forced to make adjustments to deal efficiently with changed circumstances, FRA is working to improve the efficiency of its day-to-day administration of safety programs. We are seeking greater consistency among our eight regions in inspection and enforcement practices and priorities. We've had some critism--and deserved it--about earlier inconsistencies. FRA is completing the development of its new national inspection plan that ties these priorities to a list of critical inspection points, based upon an inventory that is being conducted at this time. A new training program will help keep FRA's inspection force current with technological developments that relate to safety.

FRA is reducing its backlog of violations and will be testing new ways to streamline the enforcement process. That may have an unpleasant short-term impact upon the carriers, because the dollar volume of fines you pay this year will be higher than normal as a greater number of cases are settled within a shorter time frame.

However, the speed of this process is, we believe, important to the agency's goal of promoting safety. If there is a lag of many months or years between the violation and the fine, it won't have as much impact. As people are transferred, promoted or retired, accountability tends to diminish. The faster FRA resolves the violation, the stronger the safety message we send. That's important to those railroads which go beyond paying fines out of some account at corporate headquarters, but which penalize the budgets of the responsible officials down at the division level. Under the old system, local operating managers would suffer from the practices of their predecessors.

FRA also realizes that a safety program built solely on the concept of writing violations and collecting fines won't be fully effective. Safety evaluations or training efforts may be effective supplements. Additional technological innovation may be equally important, and the agency is taking steps to assure that its regulatory policies do not impede the inauguration of technology that will contribute to the efficiency and safety of the nation's rail carriers.

Another policy issue now being determined in Washington centers on the direction of the nation's surface transportation investment and maintenance program for the coming five years. Although commonly referred to as a "highway bill", the legislation has impact upon other transportation modes and upon each of you as motorists, taxpayers and voters.

The Senate has passed a version that represents a meaningful departure from earlier reauthorization legislation. This fact suggests that the senators, or at least a majority of them, want to take the country in a new direction in which alternatives to new highways are given more consideration. However, while promoting that general theme, the Senate ends up sending mixed signals in the way that it deals wth funding formulas. The House version has not yet been approved by the full body, and its intentions are more difficult

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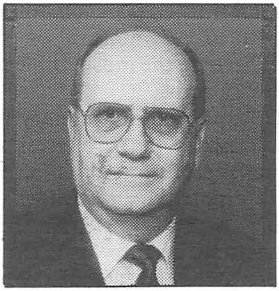

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to read, particularly since the proposed motor fuel tax increase and the "so-called" demonstration projects have become the most visible political lightning rods.

Transportation Secretary Skinner has observed that Congress and the Administration do agree on two important policy issues. One is that the future highway program needs to concentrate on improving the performance and efficiency of the highway system that now exists. Second is the notion that state and local governments should have more flexibility in spending transportation dollars.

However, in Secretary Skinner's words: "But there is one major area in which we disagree, and that's how much money state and local governments need to come up with to match what the federal government invests in projects of primarily state and local interest. The House and Senate appear bent on decreasing state and local matching requirements from current law, when we know that all levels of government and the private sector must invest more in our transportation infrastructure."

Secretary Skinners' other question centers on the House proposal to increase the motor fuel tax by five cents. Again quoting the Secretary: "A bill which proposes a gas tax increase will be vetoed."

The Administration opposes a motor fuel tax increase for the following reasons: It violates the budget agreement. It will empede economic recovery. A federal tax increase is not needed to meet federal responsibilites in transportation. If the states determine that additional revenue is needed, they are in a better position to allocate that revenue individually and internally than under a federally-imposed formula.

The Administration also is concerned about the extent of demonstration projects in the House proposal, which in percentage terms tie up three times the amount of money proposed in a 1987 surface transportation bill which President Reagan vetoed.

At this point, it seems questionable whether Congress will be able to complete action on this legislation--which is a key element of the President's domestic agenda--before it adjourns this autumn. An temporary extension of the existing law could be passed. It may be early next year before we get clear signals as to how the nation intends to modify its focus on surface transportation investment.

There doesn't seem to be much momentum for expanding longer combination trucks. The railroads have had some success in promoting a freeze at current levels. While that's obviously a key issue for the railroad industry, you should be watching other developments, too. Most participants in this process are talking about giving state and local governments more flexibility in the use of trust fund money for transportation alternatives--commuter rail and transit, rural railroad assistance, advanced technology systems, and the like. They may also be given more flexibility to seek private sector participation in surface transportation projects.

I would expect that state and local govenments will get more flexibility. Will they use it once they get it?

The answer to that question more than any other factor--will determine the extent to which America charts a new course in transportation, one in which railroads could take on more prominence. Thank you.

Past President Darrell Walker, Norfolk Southern, left, presents Past President's Pin to Outgoing President Don Hudgens, Union Pacific, while Past President, Tom Harley, Trailer Train (retired), looks on.

Group Photo - Standing - left to right - Chairman of the Board Bill Brown, Burlington Nothern; Jack Kuhns, CSX (retired); Past Presidents Don Ward, Burlington Northern, Paul Hoerath, Conrail (retired); Dale Propp, Burlington Northern, Darrell Walker, Norfolk Southern; Tom Harley, Trailer Train (retired). Seated left to right: Secretary-Treasurer, Ron Pondel; 1st Vice President, Weylin Doyle, Union Pacific; newly elected President, Allen Keller, Amtrak; Outgoing President, Don Hudgens, Union Pacific; 2nd Vice President, Mark Coles, Union Pacific; 3rd Vice President, Glen Peters, AT&SF.

MONDAY, 1:30 P.M.
SEPTEMBER 16, 1991

DON HUDGENS' PRESIDENT'S SPEECH

As president of LMOA, I wish to warmly welcome all of the LMOA members and guests who are in attendance today and will be in attendance this week. This is the 53rd year since founding of the LMOA and I think getting close to our 50th meeting. (I understand there were no meetings of the LMOA during World War II.) I am very happy you are able to attend our meeting this week and especially happy to extend a warm welcome to our many Canadian friends who are here, as well as to Allen Constable, who has come all the way from Auckland, New Zealand, and Tony Fields from London, England. I also am pleased to see past presidents Dale Propp, Darrel Walker, Don Ward, Bill Brown and Paul Hoerath.

We come together here this week to meet with our peers—to discuss different ideas; to hear reports from our standing committees; to meet new people. I know you will find our meetings rewarding. I know you will take home with you some valuable information, insights and understandings as well as renewing some old friendships and making some new ones.

Last year in my acceptance remarks I referred to an author who questioned the business of railroads ... He concluded that we were in the civil engineering and construction business. Of course we really know that we are in the transportation business. We really know that the shipper is the one who provides the revenue (or cash flow) and is the one that must be completely satisfied with the service he receives in order for us to remain in business.

We do have some inherent advantages over other modes of transportation, provided by the physics of the steel wheel on steel rail. We also have an advantage of being a high density mode and we will see a very large advantage over competitive modes when it comes to impact on the environment.

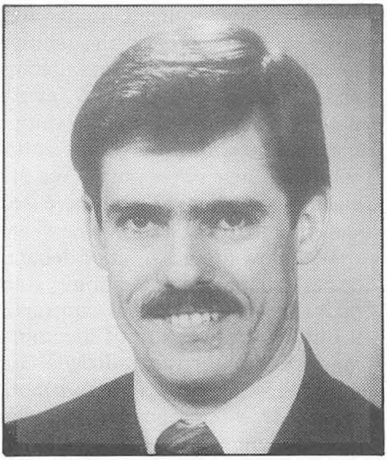
Railroads are large, complex organizations and locomotive maintenance is but a part of such organizations; albeit a very important part ... much more important than, say, the executive department! In any case, all departments within our railroads must work harmoniously together, and our ultimate focus must be on serving the shipper. Locomotive servicing, maintenance and repair are probably invisible parts of our service to the shipper, but no one within our organizations can deny their importance. We must ensure that when a locomotive is put out on line it will perform flawlessly.

We know there is a lot of debate in upper management about doing maintenance in house or contracting it out. Will the future of locomotive maintenance on the railroads come down to basic servicing of our motive power? Or will it continue to include light repairs, heavy repairs, major overhaul and component rebuilding? We certainly must be able to handle the basic maintenance and dispatch failure free locomotives. That is an absolute necessity! But beyond that, we must continue to prove we are able to overhaul locomotives and build components in a quality manner and do it economically.

OUR OFFICERS

President
DONALD D. HUDGENS
Mgr.-Research & Development
Union Pacific Railroad
Omaha, NE 68179

1st Vice President
MR. K. ALLEN KELLER
Supt. Loco. Maint.
National RR Passenger Corp.
Philadelphia, PA 19104



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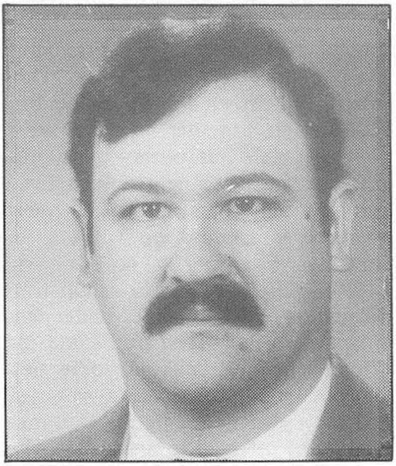

3rd Vice President
MR. MARK A. COLES
Mgr. Loco. Maint.-Mech.
Union Pacific Railroad
Omaha, NE 68179

Our work force must be made to understand what its part is in the big picture and how vulnerable its jobs are. At times our workers seem to be so bound up in their contractual rules that they are missing what is happening around them. They must be brought to realize that their livelihoods are tied to the railroads' success and that they are the very foundation of any of our maintenance programs. The consequences of their failure to realize this will be job reductions. Railroads are businesses and must make a profit in order to continue in business. I believe a part of that business should be maintaining a strong, comprehensive maintenance and rebuilding program in house. I believe that if we fail to do so we will become vulnerable to increased costs further down the line as we lose those capabilities.

I believe the LMOA helps strengthen individual railroad maintenance programs by providing a meeting ground where maintenance officers from various railroads as well as those in the supply industry are able to come together and discuss common problems and share ideas which are mutually beneficial. All of us who have been involved with this organization for any period of time know how valuable it is to have a network of peers whom we are able to consult when we are stymied by a particular problem.

We must provide our managements with the best information possible on maintenance, repair and rebuilding of our locomotives so that they can get the very best return for their investments, remain competitive in the transportation market and help move freight off of our tax supported highways and waterways. We can make a significant contribution in this direction.

Our customers, our shippers, don't want to hear excuses about why their deliveries are late. They have every right to expect that the service they pay for will be provided. We in the locomotive maintenance end of the business do play a large part in fulfilling that expectations of our final customers, the shippers. When a delivery is late because of a locomotive failure we have failed in our job, and no explanation or excuse is really acceptable. Our product, an efficient reliable locomotive, is the expectation of our operating departments and we should continuously strive to provide it without fail. Fulfilling our responsibility can be made easier by having a network of experts that we can call on. The LMOA provides that network. I personally have benefited from my association with the LMOA and my company has benefited from my association with this organization.

Our industry's shrinkage during the past decade is directly reflected in our association; and yet, I think that the need for our association grows as the industry shrinks. The modern locomotive is more reliable than its predecessor, but the advancing technology makes repair and maintenance more challenging. The need for locomotive maintenance has not disappeared simply because the number of personnel employed by the railroads has shrunk—there are still thousands of locomotives on our nations' tracks and they will continue to need routine maintenance, repairs, modifications and overhauls. Maintenance departments in essence expand their staffs by backing organizations like ours, where we can make those valuable contacts and save valuable time in solving problems.

Finally, I want to thank the many people who have made the past year so easy for me to be your president. The offices in the LMOA seem to get

OUR OFFICERS

President
DONALD D. HUDGENS
Mgr. - Research & Development
Union Pacific Railroad
Omaha, NE 68179

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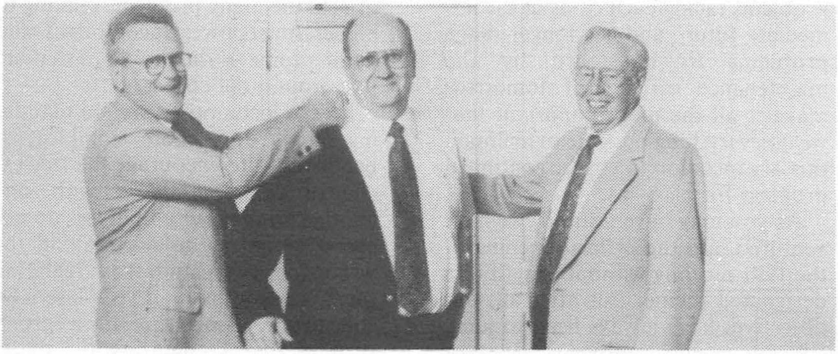
1948	113	295	1183	1591
1949	134	595	1789	2521
1950	123	595	2101	2822
1951	125	626	2912	3663
1952	135	510	2747	3392
1953	118	597	3288	4003
1954	118	545	2943	3606
1955	81	434	3235	3750
1956	110	419	3257	3786
1957	100	423	2678	3201
1958	82	350	2320	2752
1959	90	387	2395	2872
1960	98	393	2302	2793
1961	101	348	2201	2650
1962	118	316	2291	2725
1964	138	273	2345	2756
1965	155	289	2372	2816
1966	163	464	2368	2995
1967	180	408	2327	2915
1968	200	321	2575	3096
1969	192	335	2173	2700
1970	184	345	1929	2458
1971	140	283	1621	2044
1972	132	343	1777	2252
1973	108	345	1563	2016
1974	124	384	1735	2243
1975	103	326	1579	2008
1976	109	314	1610	2033
1977	114	317	1508	1939
1978	125	363	1367	1855
1979	120	391	1251	1762
1980	112	405	1200	1717
1981	114	445	1143	1702
1982	102	440	1261	1803
1983	92	386	1025	1503
1984	95	400	1116	1611
1985	90	386	1006	1482
1986	90	320	702	1112
1987	75	221	615	911
1988	79	226	420	725
1989	70	225	415	710
1990	67	215	402	684

easier as you progress thru the chairs in this organization. The committee chairmen and all the committee members are of course the ones that have done the lion's share of work thru the preparation of the papers. I am proud of the fine job they have done this past year. I don't want to forget the executive committee which has provided our association with the core leadership to keep us on track and moving forward, and the various supply people who serve on our committees and help us in so many different ways! A very special thank you should go to our secretary-treasurer, Ron Pondel, who does such an excellent job of taking care of the business end of our association; and to the railroad clubs around the U.S. and in Canada who hosted our pre-convention presentations. All of these people have made it easy for me and I thank all of you for your support.

I am deeply honored to have served as president of the LMOA over this past year and deeply appreciate the trust that you, the membership, have placed in me to hold this important post...Thank You

Past President Don Ward, Burlington Northern, left, presenting General Desk set to Outgoing President Don Hudgens, Union Pacific. Chairman of the Board Bill Brown, Burlington Northern, witnesses the ceremony.

Outgoing President Don Hudgens, Union Pacific, left, gives gavel to newly elected President, Allen Keller, Amtrak. Past President Paul Hoerath, Conrail (retired) looks on.



Past President Dale Propp, Burlington Northern, assists newly elected 3rd Vice President, Glen Peters, AT&SF, with his LMOA blazer. Jack Kuhns, CSX (retired), also lends a hand.

Allen Keller's Acceptance Speech September 17, 1991

Ladies and gentlemen, officers of the Association, and chairmen of all the technical committees, it gives me great pleasure to serve as your president for the next year. This position not only brings with it a great deal of responsibility but also the potential for personal satisfaction.

I am honored that membership has seen fit to elect me to this position. I first became a member of LMOA in 1963, a year in which the industry was just getting into the peculiarities of the maintenance of second generation power. We are now probably two generations more advanced from the power of that day, but some of it as well as the first generation power is still with us.

Many of us have been part of this organization for a long time, and, in fact, for most of our managment careers. We realize full well the benefits presented to us over the years by our activities on various committees and the informal discussions that took place in those after the formal committee meetings. The problems facing each of us in the immediate future and the longer range problems to be faced by the maintenance officers of tomorrow make it all the more important that we do everything possible to maintain this organization to ensure continued progress for all of us.

As you may have noticed, we have ventured into the official opening of the 1991 meeting without benefit of a designated theme. But after all, our objectives have always been to identify our mutual problems, endeavor to find solutions to those problems, and then freely exchange those solutions with each other. Our industry does not seem to be lacking in mutual problems to identify. Our organization's members have always been in the forefront when it comes to gaining solutions to those problems. The challenge to this organization is now to encourage the free exchange of these solutions among its members.

Some of the problems looming on the horizon are as follows:

1. Environmental concerns about locomotive emissions;
2. The continuing need for fuel efficiency and the need to continue to explore the feasibilities of alternate fuels;
3. The information explosion on board locomotives with microprocessors and computers everywhere; and
4. The continued increase of regulations in the industry.

This association is blessed with tremendous resources of talent and many of these talented people have voluntarily accepted positions of responsibility as technical committee chairmen, vice chairmen, and members of technical committees. Their combined efforts have prepared a program this year which will thoroughly investigate and discuss the many problems relating to higher horsepower locomotives and discuss some of the problems that are just around the corner.

As the locomotives we are maintaing grow ever more complex, it behooves us to encourage the free exchange of these ideas with one another so that our employees do not spend countless dollars making the wrong decisions and then regreting them six months or a year later. By collectively associating in a group such as this, recognizing the mutal problems and providing solutions to these problems, we can overcome the adverse situations as they arise. Then we will have made a genuine, tangible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contribution to the well being of our industry and the country which it serves.

Adversity has not been a stranger to members of this organization in the last 20 years. The economic cycles of this country and the railroad industry have produced plenty of ups and downs for our organization. Adversity necessarily calls for reaction, and your officers and chairmen have been doing plenty of reacting over the past year. Our need to react to adveristy will continue in the coming years. You heard the report of our membership committee chairman, Mark Coles. (Mark reported a 28% decline in membership in the last three years). With the downsizing that is continuing in the industry, our membership rolls are going to continue to be challenged in the coming years. One area where there are opportunitites to grow and be of further service in the coming years will be the shortline and regional railroad field. Your officers recognized several years ago to there is room for membership growth in this area, but we have yet to identify how we may best serve this particular segment of the industry. In the meantime, we are encouraging our membership from the regional and shortline railroads to become active on committees and reach out in their world and secure additional membership from their co-workers.

I am grateful for having had the opportunity to work with this association for many years. It has been extremely helpful, interesting and informative. It most certainly will be an honor to serve as your president this coming year and I thank you for having put that challenge in my hands. The very fine help and cooperation of all of you (railroad management and the supply fraternity) has been most gratifying and is appreciated. With the help of our most able executive officers and committee chairmen, who have agreed to serve this coming year, we expect to continue to make LMOA an organization which will be in the forefront of providing solutions to our common problems.

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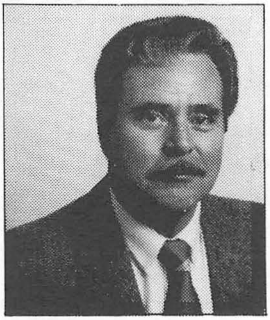

WILLIAM A. BROWN
Gen. Forman-M & E
Burlington Northern RR
West Burlington, IA 52655

DONALD L. WARD
Ass't. General Foreman
Burlington Northern Railroad
Springfield, MO 65083

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

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

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

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

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

The Board of Directors
The Chicago Railroad
Mechanical Association

REPORT OF THE COMMITTEE ON DIESEL ELECTRICAL MAINTENANCE

Monday, September 16, 1991
10:00 A.M.

Pre-Convention Presentation Chicago RR Mech. Assn.

April 18, 1991 Union League Club Chicago, IL

(Photo Not Available)

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

Vice Chairman
R.J. VASQUEZ
Supvr. Loco. & Car. Maint.
AAR-ITC, Pueblo, CO

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PERSONAL HISTORY

Don Gezon

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

I. LOCOMOTIVE REBUILDING SOMETHING OLD SOMETHING NEW

Presented by: Don Gezon

Rebuilding locomotives has become an integral part of locomotive replacement programs. The number of rebuilding schemes past and present has generated interest in our committee to provide an overview of various projects that represent a variety of different configurations. The Diesel Electrial committee has undertaken a collaborative effort to give a short descriptive review of several of these rebuild programs.

Rebuilding as differentiated from overhauling implies changing or substantial upgrading of mechanical, electrical and/or car body components.

Some rebuilds are rebuilt intended primarily to extend locomotive life. Usually in these cases the rebuilt locomotive is designated to perform the same type of service as the unit had been performing. Examples of this type would be the ICG, GP8, 10 and 11 programs and the Santa Fe CF7 program.

Other rebuilds are intended to enhance the locomotives' ability to perform an alternate service such as switching instead of mainline. The NS and BN Caterpillar rebuilds of GP9's are in this category.

Still another type of program is to create a new medium horsepower unit out of older units that are no longer economical to operate. BN's GP39-2 units are examples of this kind of program as are EMD's BL-20 units.

The last type of program is a modernization and upgrading which advances the technology of an existing unit, such as Montana Rail Link's SD40 upgrade, DMIR's SD9 program, GTW's GP9 project and GE Super 7 series.

There are common attributes of rebuild programs regardless of the changes incorporated. Rebuilds are designed to not only extend the life of the locomotive, but also to improve reliability, cost less than a new locomotive and increase the utility of the unit.

From a historical perspective railroads have been rebuilding diesel locomotives since the 1950s. Going back in the archives of many rail fans we came up with these examples of early rebuilds that were notable for their variety rather than for their success. Who can forget the Baldwin freight unit repowered with an Alco 251? Lima-Hamiltons were probably the worst diesel engines ever used in a locomotive and hence the Lima-Hamilton-EMD. Then there was the Fairbanks-Morse-EMD and the Wabash Fairbanks-Trainmaster with a 251 Alco. A more successful repowering/rebuilding was the RS-3 conversions with 12 cylinder EMD engines. While not done in large numbers, some of these are still in service.

These rebuilds are of interest only in the historical sense. They obviously were not very successful, only done in limited numbers and had no impact on future programs.

A. Santa Fe

One of the most successful and earliest rebuild programs was done by Santa Fe. Santa Fe deserves credit for the first successful large rebuild program. They had enough need for branch line locomotives that they rebuilt F-7's that were replaced in mainline service into CF-7's. This was a major reconstruction of the car body. While the power plant and control system was not radically changed, the car body was completely reconstructed.

The Santa Fe conducted a study to

tive to buy GP type locomotives or to convert the F-7's to a GP type configuration. The conclusions of that study was the birth of the CF-7 remanufacture program at Cleburne, Texas. The remanufacture program started in 1970 and concluded in 1978. The 233 CF-7's produced were numbered from 2417-2644.

Topeka shops and engineering were responsible for all design work, fabricating much of the car body, and addressing weaknesses in the F-7 design. The dynamic braking was eliminated as well as the Safety device pedal and rear marker and number lights. Alertors and electric sanders were added to the CF-7 design.

Cleburne was responsible for the manufacturing phase of this project. The project did not always proceed smoothly. A number of modifications were implemented as a result of feedback from the operating crews and Mechanical forces throughout the eight-year project. The lessons learned during this project was used to improve other remanufacture programs implemented by the Santa Fe; namely the GP-7, GP-9, SD40, SD40-2, SD45, F45, FP45, GP30, GP35, GP38, GP39-2, SD26 and SDF40-2 remanufacture programs performed at Cleburne and San Bernardino.

The CF-7 program was a very successful venture for the Santa Fe. But time and changing needs spelled the end of these units. The 24RL air brake equipment and other components made them to costly to maintain in both material and labor resources. The Santa Fe has sold or scrapped all of these locomotives.

This is not to say the CF-7 has outlined its usefulness. Many of these locomotives are still in active service on a number of short line railroads.

B. Illinois Central

The Illinois Central Gulf between 1967 and 1981 rebuilt 109 GP7's into what they called a GP8, 327 GP9's into GP10's and 54 GP9's into GP11's. To date this is the largest group of units rebuilt. The GP8 and GP10 programs did not change much of the mechanical or electrical systems. More extensive rework was performed on the car body by lowering the short hood.

The GP11 units have the distinction of being the first units to use the Dash-2 type electrical system, first used by EMD in the GP15-1 locomotives. Since then many others have followed in upgrading GP9's.

Like Santa Fe's CF-7, Paducah built GP8, 10 and 11's have continued in service after being sold by ICG to many short lines and regional railroads. Also, the ICG continues to use rebuilds in mainline service and thereby proves the success of the program.

C. Norfolk Southern

The two examples given were of rebuilds in kind. The next rebuild is an example of alternate service, the Norfolk Southern's TC-10. This major rebuild scheme is now used by the BN and the Soo Line as well as the NS. Because the NS rebuild is a radical change a detailed description of this unit follows.

Norfolk Southern saw the need for a low horsepower locomotive to be used for switching and other service. It wanted a locomotive with an engine that could be shut down in cold weather and easily restarted by the operator. The TC-10 was the result.

TC-10 stands for transfer type locomotive, Caterpillar power and 1050 horsepower.

After 25 or more years of faithful service, the original NW road-switcher fleet reached the point of either requiring heavy rebuild or

replacement. In the early 1970's, the NW looked at the feasibility of heavy rebuild of the fleet and ran one prototype unit through Roanoke Shops.

A decision was made to have four additional units completely rebuilt by an outside contractor. In 1978, four locomotives were sent out and rebuilt essentially "in kind" but with the most modern switch gear and other electrical components. Considerable attention was also given to rebuilding the operator's cab. These rebuilds proved very successful; however, the desire to minimize fuel consumption led the NS to explore the possibility of repowering with a smaller, high-speed engine, which would use antifreeze in the cooling system and could be shut-down in freezing weather.

Discussions were held with the various engine manufacturers and NW learned that the Grand Trunk Western had repowered several 1000 horsepower Alco switchers with Caterpillar D-398 engines. The GTW Cat's were being operated with antifreeze in the cooling systems, had modernized electrical systems and were well received by operating crews. With the GTW's experience in mind, the decision was made to pursue the repower of a GP-9 with a Caterpillar engine in the 1000 to 1200 horsepower range.

A number of parameters were set when the TC-10 design was put together:

(1) The diesel engine must be capable of shutdown and **unassisted** restart with ambient temperatures down to +10 degrees F. (Unassisted means that glow plugs, ether injection and stand-by heaters will not be used.)

(2) The electrical control system and engine starting motors must operate at voltages compatible with conventional locomotive systems.

(3) Lubricating oil specifications must permit use of a multiple-viscosity crankcase oil. The engine, however, must also be able to live with accidental addition of conventional locomotive lube oils.

(4) Filter change and other engine maintenance items must mesh with Federal Railroad Administration mandated periodic inspection cycles.

(5) The locomotive must be capable of operating between servicing locations and duty assignments in regularly scheduled trains.

The engine chosen for the TC-10 is the Caterpillar model 3512 which in the NW application provides 1050 horsepower for traction. Several factors contributed to the decision to use this engine.

First, the engine design permits two power take-offs on the front of the engine to drive the auxiliary generator and the auxiliary alternator.

Second, the unit fuel injector would minimize fuel leaks as compared to other systems.

Third, the cylinder head to liner design is such that engine coolant would not leak into a cylinder and cause hydraulic lock in the event of seal failure.

Fourth, engine replacement parts are stocked at a number of parts centers around the country.

And finally was the Cat's PEEC governor. PEEC stands for "programmable electronic engine control," and incorporates engine speed control and traction alternator excitation control in one package, simplifying the locomotives electrical system.

In order to simplify the high voltage system, a Kato traction alternator and rectifier assembly was

chosen. The alternator has a continuous rating of 4200 amps and a peak rating of 6000 amps after rectification. This machine is a brushless design and permits full parallel motor connection with no motor field shunting. The alternator is a single bearing machine and bolts directly to the engine.

The TC-10 construction starts by stripping a retired GP9 down to the underframe and rebuilding from there up.

In order to make up for the weight loss when the old engine and generator were removed, slab steel ballast was placed in the recesses in the GP9 platform. It generally requires about 40,000 lbs. of ballast to reach the design weight of 255,000 lbs.

One of the most important items NS has found in salvaging a GP-9 frame is to reinforce the frame at several points to reduce chances of buckling in event of a hard coupling.

The TC-10's compressor is a three-cylinder air-cooled machine driven by a 25 hp three-phase Siemens-Allis motor. The compress/motor package has its own mounting base which is attached to the locomotive platform. The deep sump air compressor crankcase is a real plus in extending the time period that the TC-10 can remain at a duty station without servicing.

NS has always been convinced that not only does the direct-driven air compressor waste fuel, but also an unloaded compressor beats itself apart. A motor driven air compressor, which can be shut down when there is not demand for air, is one of the first items included in the design package and was something not offered by the two locomotive builders until recently.

A number of items have been incorporated into the TC-10 to reduce fuel consumption and improve reliability.

A 150kw auxiliary alternator manufactured by Kato provides AC for the traction motor blowers, air compressor and radiator fan. Traction motor blowers are turned off when there is no need for cooling air.

Several items such as a 2350 gallon fuel tank and large sand boxes do much towards keeping the TC-10 at a duty station for extended periods. In fact the current TC-10's have worked some assignments for as long as 28 days without requiring fuel or sand.

The auxiliary alternator and generator are mounted on the engine rail package. This permits the engine supplier to mount and align all engine-driven components and pretest the system completely before installation in the locomotive. This also reduces misalignment problems that might occur if the auxiliary machines are mounted directly on the locomotive platform.

The TC-10's electrical cabinet contains the latest design switch gear, and since alternator excitation is handled by the PEEC governor, the electrical cabinet is relatively bare. The TC-10 has an adhesion control system designed in-house which takes advantage of the wheel creep concept to gain additional tractive effort. It also uses an in-house design wheel slip control system which corrects wheel slip whenever possible without giving the locomotive engineer a wheel slip signal.

The TC-10 has spent the last five winters working around Chicago, Detroit and Cleveland. The operating crews shut the engine down at the end of their tour duty and restart it when they report for their next tour of duty.

During the past five winters, they have not had an incident where Mechancial department forces were called to help the operating crew start

the locomotive.

The cab layout on the TC-10 has been extended to utilize part of the short hood end of the locomotive. It provides additional room for seating all crew members in the cab of the locomotive when necessary.

Two other TC-10's which were built by Roanoke Shops have been in service for approximately three years. These two locomotives have also been assigned at points where the NW expects them to receive the most severe weather conditions. During 1986, two additional TC-10's were constructed at outside shops and are now in service.

Norfolk Southern deserves the credit for conceiving the TC-10 package. Now BN and Soo Line are using similar units built by Generation II in Minneapolis. These later units are using a bigger Cat engine, the 3516, which provides more horsepower.

The total population of TC-10 type units is not yet large. Now let's look at the largest program to date.

D. Burlington Northern

Burlington Northern Railroad embarked on the latest in a series of locomotive rebuilding programs in the late 1980's The rebuilding program was driven by the need for reliable, medium horsepower (2000-3000 horsepower) locomotives to replace the aging branch line and regional service fleet.

The candidates for rebuilding were EMD GP30 and GP35 class locomotives, where these locomotives would be upgraded to EMD Dash 2 technology. With a detailed list of specification, BN requested bids on the project. After reviewing bids from a number of locomotive rebuilders, vendors and from internal facilities, three companies were chosen: EMD, Morrison-Knudsen, and VMW.

With GP30 and GP35 locomotives provided by BN, EMD & MK produced GP39 locomotives. The final product is comparable to an original EMD GP39-2 locomotive. The diesel engine is a 16 cylinder, 645D3A turborcharged power plant. Changes in rack settings and/or RPM schedules limit horsepower to the 2300 range. The DC main generator has been replaced with an AR10 and standard Dash 2 excitation and control systems are used. With the installation of an AR10, the locomotive is capable of operating in a parallel traction motor configuration, thus eliminating the failure prone transition control and motor field shunting equipment. The GP39 locomotive is equipped with EMD rebuilt D77/D78 traction motors that are monitored by EMD's IDAC (WS10) wheelslip system. Dynamic braking and self load test are standard equipment. The cab and cab equipment have been upgraded to AAR standards with 26L air brake equipment, and electric cab heat to enhance the working environment for operating crews.

A significant clause in the rebuilding contracts with all three companies is a comprehensive warranty and performance guarantee. Each locomotive carries an extended warranty as well as a guarantee to perform at specified levels. Should the locomotive fail to perform as promised, the rebuilder is penalized. Thus, the locomotive rebuilders are motivated to produce a quality product.

To date, 200 locomotives have been rebuilt under this program, with more scheduled. The locomotives have performed beyond expectations, to the point of providing the unexpected benefit of main-line service for the BN.


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E. Electro-Motive

EMD gained experience with its participation in the BN GP39E program and has come up with a rebuilt unit which is designated BL20-2. These units are being developed as an alternate to continued use of GP7 and 9 units, at a moderate cost (compared to new), that will provide 15 to 20 years of reliable service life at a time when older four axle units are in need of replacement. The BL20-2 maintains as much equity from the old locomotive as possible while incorporating reliable, proven upgrades.

The GP7 and GP9 hulk is used to begin the process. It is stripped of its older components and parts and a Dash 2 control system is built in. A Supercharger is engineered into a rebuilt 567 engine to bring the originial 1500 or 1750 horsepower of the engine up to 2000. It provides 18-24% better fuel economy than the GP9.

New are the cab, carbody, electrical cabinet, AC cabinet, cabling, piping, engine supercharger and increased strength front hood collision posts. Rebuilt are engine components, AR10/D14 alternator, trucks and components, underframe, fuel tanks, fans and motor.

This is a new offering from EMD and has not yet had time to be tested in the marketplace. However, it is similar enough to other programs that are successful to be optimistic about its acceptance.

F. Montana Rail Link

The last type of rebuild to be examined is a modernization and upgraded technology applied to units to prolong their life in current service.

Three examples of this type are given.

First is the Montana Rail Link program. Montana Rail Link, as a new regional railroad, began operations with locomotives surplus to BN and other roads, which required it to address motive power rejuvenation early on.

In 1989, MRL began rebuilding its SD40-2 locomotives. The work scope is extensive. The unit is stripped to the frame and a new locomotive evolves. Among the specifications for this program was the installation of a new "X" style Dash 2 high voltage cabinet and "clean cab" concept control stand. The high voltage cabinets had exceeded their intended service life and required considerable attention. Reworking the existing cabinet to accept module control and motorized switch gear would be cost prohibitive. The obvious benefit was a highly reliable locomotive but a by-product was produced. Each locomotive rebuilt left its dirty forerunner, a cabinet and control stand with little value or use. Options for this material are limited. Perhaps scrap...but these relics are not worth a great deal especially when shipped from a remote location like Montana. Possibly strip them for components...but how much switch gear is practical to inventory, not to mention the expense of rebuilding it. Neither solution was a desirable recourse.

MRL continued to rebuild its SD40 fleet in 1990 and a sizable quantity of cabinets and control stands was accumulating. Late in the year, a program was initiated to rebuild the roads aging GP9 locomotives. One of the program criteria was standardizing components with the high horsepower fleet. With a portion of the fleet new rebuilds (SD45-2/SD40-2) and the remainder dating as far back as the late 1950's (SD/GP9's), an extremely diversified inventory was required.

Material levels were becoming a serious concern with standardization beneficial and monetarily necessary.

During the design stage of the GP9 rebuild, the circuits were arranged for maximum reliability with an eye to utilizing the growing number of scrap SD40 cabinets and control stands. The basic design of the SD40 has a proven record of dependable service and the components are easily obtained. While it was not feasible to rework the SD40 cabinets for Dash 2 components, it was practical to upgrade a GP9 to SD40 standards. This course of action would also address material standardizatin while simultaneously depleting the growing number of scrap cabinets and control stands. These items could be economically returned to efficient service.

In November of 1990, an SD40 high voltage cabinet and control stand were sent to a locomotive cabinet facility in Chicago. The prototype cabinet was stripped, cleaned, and some fabrication alterations made for GP9 height restrictions. Air ducting to accomodate five modules, and a molded circuit breaker panel were installed. Essentially, the switch gear area, relay panel, and engine control panel were to remain the same. The basic SD40 component list has a historically low incidence of failure, allowing a majority of the material to be reused. The high voltage switch gear was rebuilt and the control relays were cleaned and qualified. The work was extensive but replacement components were minimal. These measures produced a "like new" pressurized SD40 cabinet for GP9 application. By starting with a six motor cabinet, there was a sufficient quantity of material to reload a four motor cabinet with a surplus pool to replace failed components. When the project is completed, any remaining material of value may be reclaimed to inventory with only a minor level increase.

The SD40 control stand underwent a similar face lift. It too was completely stripped and cleaned. The mechanism was rebuilt, switches and terminal boards qualified, rewired and reloaded. A framework was fabricated to replace the top of the air brake portion with a "clean cab" enclosure to house the built-in Spectra radio pack. This required minimal fabrication changes while remaining within the clean cab guidelines.

The incorporation of the old with the new has produced a modernized, dependable central nerve system for the GP9 rebuild. The demonstrated longevity of the SD40 controls is anticipated in this new production model combined with a considerable cost reduction. The expense of this endeavor versus new fabrications is about half, while utilizing material cascaded from another program. Antiquated GP9 material inventory will be phased out and only a supply of Dash 2 and SD40 material will be maintained. Locomotive availability increases while material levels decrease...a no lose proposition.

G. Duluth, Missabe & Iron Range

Another example is that of The Duluth, Missabe & Iron Range SD9 program.

During the period from 1957 through 1960 the DMIR and other US Steel owned railroads retired their steam power in favor of diesels. The DMIR was equipped with SD-9 and SD-18 locomotives, which remain in iron ore hauling service today. After 30 years of service these units obviously needed rebuilding. Rebuilding began in 1979, but only two units were completed before the steel industry troubles of the early 1980's stopped spending on most capital projects.

The rebuild program was restarted in 1988, continues today, and is projected into the next several years.

The only two units completed in the 1979 program were complete "frame up" rebuilds. These units received all new wiring and contactors, and all mechanical systems such as prime mover, air compressor, and trucks were completely rebuilt. Renumbered 301 and 302, they returned to ore service in 1980 with several notable and modications. The short hood and cab configuration was changed to allow better visibility and more light into the cab. The fuel tank capacity was increased to 2400 gallons from the original 1200 gallon capacity. A less obvious modification was the changing of the excitation system to static electronic using EMD GP-15-1 components. This allows for better wheel slip control and enhances Pacesetter operation. Also, all traction motors were exchanged for D-77 models. These motors were built to handle much more than these 1750 horsepower units can dish out, and seem almost indestructible in this service. The rest of the package rounds out with such things as an AC auxiliary generator, 10,500 watts of electric cab heat for Minnesota winters, and various electronic retrofits such as a speed information system and dynamic brake regulator.

By the time the heavy overhaul/rebuild program was reinstituted in 1988 the remainder of the 1957-60 vintage fleet was getting a little ragged. To this point 20 more units have been completed. They too were torn down to the frame, although the rewiring is less extensive, with some circuits qualified, and only redone if necessary. Carbody changes include the expanded fuel capacity and the lowering of the short hood end as in phase 1, with crash posts installed to protect the cab space in the event of a collision. Traction motors were all upgraded to D-77, and the main generator was overhauled by an outside vendor. All other electrical rotating equipment was reconditioned in house. During the overhaul, care is taken to remove any component containing asbestos or PCB's. The electrical equipment added includes the usual solid state devices common to the industry today such as a digital speedometer and an event recorder transition control panel, DBR, and caboose off/end of train equipment. The high voltage contactors were upgraded to Dash 2 vintage equipment. A new control stand was designed and built in house to serve our particular needs. Several modifications of DMIR's own design were included such as a "hostler circuit" to allow engines to enter and leave the building without running the prime motor. This is accomplished by powering one traction motor with battery current. Another modification was added to rectify a problem relating to cooling fan failures. In the cold Minnesota winters the #2 cooling fan seldom, if ever, runs. Then when spring and summer weather require it to operate, the #2 fan failure rate is significantly higher than the heavily used #1 fan. This phenomenon is eliminated with the addition of a reversing switch and two hour meters. The new switch allows the sequence of operation to be reversed, and the hours of operation of each fan kept somewhat equal by balancing the hours on the meters. One more circuit was added to increase the throttle position to number 3 position if engine water temperature falls to 120 degrees and the locomotive is "tied up" and in neutral and isolated. It returns to normal idle when water temperature reaches 145 degrees, or the engine is put on line and a direction is selected. Finally, these engines were equipped

with a 18kw auxiliary generator and 10,500 watts of electric cab heat.

H. General Electric

Our last example is the General Electric Super 7 program. Like EMD's BL-20-2 and GP39E projects, GE's Super 7 rebuild offers a like new locomotive incorporating recent advances in locomotive design at a considerably lower cost than a new locomotive.

GE starts with either a U series or Dash 7 locomotive. After stripping, a new cab and car body are supplied.

The Super 7 series incorporates the best features of the service proven Dash 7 systems with an updated car body design. It also incorporates some of the latest design components from the Dash 8 as well as a remanufactured structure and components. This was accomplished through a totally integrated systems engineering effort that combined these proven results with the latest design updates.

The Super 7 design philosophy focused on increasing reliability while keeping maintenance costs at a minimum. This was achieved by conservatively rating the components and using simple, time tested systems. But this does not mean out of date technology. The Super 7 included the following technological advances:

- GE Sentry wheelslip control system (1981)
- GE CHEC II excitation system (1986)
- GE Motor Thermal Protection (1983)
- Full-Time motor parallel connections (1981)
- Eddy current clutch auxiliary load reduction (1979)
- Separate dynamic brake package with hi-capacity grids (1979).

The Super 7 high productivity traction system consists of a GTA 24 alaternator driving 752 traction motors with parallel motor connections and alternator transition. GE's state-of-the-art Sentry wheelslip provides high adhesion coupled to the MTP motor thermal protection system to safely utilize the motor's maximum tractive effort capability.

Propulsion Equipment is a mix of remanufactured major and new components. This includes the following:

- Dash 8 style dynamic brake package
- GTA 11 alternator remanufacturing to GTA 24
- Remanufactured auxiliaries
- New rectifiers using proven Dash 7 design with simplified packaging
- Remanufactured 752 E8 traction motors.

Control equipment consists of all new components except for remanufactured power contactors and reverser/braking switch. These components are repackaged in highly accessible compartments to ease maintenance. This is accompished by borrowing some of the updated carbody features from the Dash 8. The new battery box is equipped with a low maintenance battery. The new Dash 8 style operator, cab houses low voltage control equipment (such as Sentry and CHEC II panels) previously located behind the operator's cab. A new control stand is also provided. All new wiring and cabling is used throughout the locomotive. The large high voltage cabinet containing the power contactors, REV and BKT switch has a removable top and sides.

I. Summary

In summary, the electrical committee has presented an overview of several rebuild programs. The programs differ based on the intended use of the rebuilt unit. By no means is this an all-inclusive list of rebuilds. It

is a compendium of different schemes, all of which share the common characteristics of prolonged life, improved reliability, upgraded technology and lower cost than purchasing new units.

The success of rebuilding is evident in the increasing number of programs and units being rebuilt. Rebuilding locomotives will be a big portion of activity at railroad, contract and builders shops in this decade. The railroad industry is fortunate that we have suppliers, fabricators, contract shops and OEM manufacturers able and willing to support rebuilding needs.

Together this infrastructure is meeting the needs and requirements of our industry for essential locomotives.

NOTE: Contributions made by;

TIM JOHNSON — DM & IR
JOHN NIXON — ATSF
GARY PARSONS — BN
DAN SMITH — MRL
CHARLES WILKERSON — NS

II. STANDARDIZATION OF ELECTRICAL EQUIPMENT

Presented by: Brian Hathaway

How many times have you gone to the storehouse to get an electrical component for the so called "older power" and received this familiar quote, "it's obsolete and not manufactured any longer", or "back ordered?" The storehouse cannot possibly supply all the components neccessary for a 30 year old plus locomotive, a large percentage of which no longer exist. Locomotives are held out of service for material, train movements are hampered, and revenues lost. Alternatives are essential for those of us dealing with aging equipment

As railroads are continuously working for a way to improve service and the reliability of their power, one must realize that the solutions to this scenario are vast, and there is no one correct answer. Attempting to rebuild or repair an obsolete component is time consuming and counterproductive. You are only postponing the inevitable....the component must go.

This objective may be accomplished in several ways. Retire the locomotive and purchase new, or perhaps rebuild the locomotive and upgrade it to a more reliable, easily maintained unit. These may be realistic possibilities to some, but to a small carrier they are not feasible. The revenue and car loadings are not there to justify an expenditure. Purchasing obsolete stock may be a stop gap solution until one considers the inventory increase, with no long term relief from the original dilemma.

Standardization of components is one course of action which will produce several advantages. First, it will result in more reliable locomotives. Second, obsolete inventory will be reduced and eventually phased out completely, and third, this avenue will not require large expenditures to accomplish.

The most desirable material for small scale upgrades are items stocked for newer locomotives like a GP38 or GP40. Some retrofits possible on a running repair basis might include relays. When a GP7 or GP9 is shopped for a relay failure and it is the old Vapor metal stack style, replace it with the current general purpose or "tower" relays standard in the new locomotives. Mounting and wiring are similar and down time on a locomotive is minimal. A similar direction may be taken for the old voltage regulator assemblies. It may be in your railroads best interest to replace these, when the newer static regulators used in GP40's are easily obtained and more reliable. Again, the wiring changes are minimal and this may be done on a running repair basis.

During annual or biennial inspections one could consider further, more extensive retrofiting the units. The maintenance of the battery charging contactor and reverse current relay would be eliminated with the application of the DC battery charging rectifier and resistor assembly, which is virtually maintenance free. With a high maintenance record one could consider the replacement of the round controller control stand with the AAR clean cab control stand assembly. This change would minimize maintenance, reduce inventory and standardize to the newer power. With modifications the stand could be arranged to accept the 24RL or 26RL brake system.

If the subject of modifying "older power" is favorable to you, remember that a modification must be justified and fully investigated so as to provide a change for betterment. Modifications must be effectively and efficiently applied to the locomotive. A modification of older power is one way to help in the reduction of inventory, and the industry as a whole wants inventory reduction.

This is not to suggest that the electrical components for the older power are not available, or cannot be repaird. However, these alternatives would aid in the standardization of material to be applied to locomotives, which would be helpful in the future of maintenance items and inventory control.

III. LOCOMOTIVE BATTERIES

Presented by: John Nixon

All railroads have experienced the financial strain brought on by increased fuel prices.

During the 1990 Mid-East crisis, the price of fuel went from 58 cents a gallon to $1.01 a gallon in a matter of a few short weeks. Obviously, fuel conservation is extremely important to the bottom line.

One method of fuel conservation is to shut the locomotives down when they are not needed and weather permits. With reduced on-line mechancial forces, it is crucial for the locomotive batteries to be properly maintained in order to implement this type of policy.

If the batteries are not maintained properly, locomotive crews may not be able to restart the locomotive. Poorly maintained batteries will end up costing the railroads more money than they can save by shutting their locomotives down. The purpose of this paper is to outline a policy that will ensure the batteries are properly maintained.

Battery Construction

There are two basic configurations of locomotive batteries. One is called the monoblock while the other is called unitized. It takes eight monoblock battery trays to make a complete set, while it takes just two unitized. Both configurations have their advantages and disadvantages, but most railroads prefer the unitized.

The lead-acid type of battery used by the railroad industry falls into two different maintenance categories. One category will be called routine maintenance batteries while the other will be called low maintenance.

The watering interval for the routine maintenance battery depends upon ambient conditions, charging rate, age of the battery and the duty cycle. Typically, a well maintained battery charging system allows a 92-day watering interval. The life expectancy is about eight years.

The low maintenance battery operating in a well maintained battery charging system will allow one year between watering intervals. This battery has a life expectancy of 12 years.

The low maintenance battery costs more but it does offer advantages which should not be ignored.

The issues which we all need to address in our operation are:

A. Storage handling procedures;
B. Recommended maintenance procedures;
C. Recommended repair procedures.

A. Storage Handling Procedures

Batteries can be stored in either of two states — dry charged or wet charged. Dry charged means the battery is stored without acid in the cells while wet charged means it is stored with the acid in the cells.

The dry charged battery can be stored up to two years with no special attention by the storage facility. The battery must be specially prepared by the manufacturer in order to store in this state.

The problem with this method of storage is the acid must be poured into each cell and receive an equalizing charge prior to placing the battery in service.

To store a battery in the wet charged state involves a whole different set of procedures. The batteries should be stored in a cool dry location per the manufacturer's instructions. If the ambient temperature is below 60°F, the battery can be stored for about four months before a freshening charge is required.

The higher the ambient temperature, the shorter the time interval between freshening charges.

The specific gravity of the battery should be checked regularly and the battery charged accordingly.

All railroads store their batteries in the wet charged state.

B. Maintenance Procedures

The following is the recommended minimum battery maintenance procedure for locomotive batteries:

On A 92 Day Frequency

1. Check the blocking to ensure it is in place and the battery is secure. Correct all defects.
2. Check the battery leads for loose, broken or burnt connections. Correct all defects.
3. Wash batteries when ambient conditions permit.
4. Check the specific gravity of a pilot cell or randomly selected cell. If found to be low, check the battery and voltage regulator. Correct all defects.
5. On routine maintenance batteries, add water on an as needed basis to each cell. Never overfill the battery cells.
6. Check voltage regulator setting and adjust as required (Most microprocessor equipped locomotives automatically adjust the charging voltage as a function of ambient temperature. The higher the ambient, the lower the voltage setting.)
7. Correct all defects found.

Twelve Month Inspection

To include all the 92 day requirements plus the following:

1. On low maintenance batteries, add water to each cell on an as needed basis. Never overfill the battery cell.
2. Check the specific gravity and voltage reading for every cell and take necessary action to correct all defects found.

C. Repair Specifications

Repair specifications are critical to ensuring your battery fleet is kept in optium condition. Repair specifications with facility audits will ensure proper repairs are made. The battery repair should ensure the battery will operate for at least one year without additional failures. The following is the committee's recommendations for a thorough repair specification:

1. Routine maintenance batteries should be scrapped if they are eight years old or older and low maintenance batteries should be scrapped if they are 12 years or older.
2. Scrap if the battery fails to make 80% of rated capacity test of 1.7 volts per cell criteria;
3. four or more cells to be replaced on unitized;
4. two or more cells to be replaced on monoblock.

Stage One — Qualify for Repair

1. Visual inspection noting all repairs required
2. All open cell voltages are checked and recorded.
3. All specific gravities are checked and recorded.
4. If the battery is found uneconomical to repair or if it meets any of the other scrapping criteria, then it is to be scrapped.

Stage Two — Qualify for Repair

1. Minimum of a three day charge is given to the battery.
2. Equalize the charge on all cells. Some batteries may require up to three additional days to be equalized because of the time allowed to stand in a discharged condition. Six days is the maximum time allowed for charging purposes. If the battery cannot be charged properly in this amount of time, then it is to be scrapped.
3. Acid adjust cells to 1.240-1.260

specific gravity.
4. Perform battery discharge test for three hours.
5. If the battery fails the discharge test, then it is to be scrapped.

Stage Three
Ready for Service

1. Replace bad cells with used cells from those batteries which were scrapped and which meet the 80% of capacity and are five years old or less. If used cells are not available, then use new cells for the repairs.
2. Recharge battery to full charge.
3. Clean the battery thoroughly.
4. Make all required repairs.
5. Mark battery with date repaired and paint positive red and negative black at the edges of the terminals.
6. Return battery to railroad storage facility.
7. Sticker indicating date charged.

The repair facilities should compile a quarterly report so management can assess the overall condition of the battery fleet. The report should include a code for the various defects. In this way one can determine if additional maintenance emphasis is needed to reduce the number of battery changeouts. An example would be if the number of batteries found discharged with no other defects is on the rise, then the voltage regulators may be in need of attention or battery handling procedures need to be reviewed.

Conclusion

Following the procedures outlined in this paper will increase the availability and reliability of the locomotive battery and the locomotive itself. This will increase the probability that the locomotive will start when it is needed. It will allow the railroad to take advantage of one method of fuel conservation and will allow it to be more competitive in the market place.

IV. AMTRAK'S AC TRACTION LOCOMOTIVES

Presented by: Edward Lombard, Mgr. of Performance & Test-Amtrak

Amtrak's Motive Power Engineering department has had an interest in AC locomotives that started in the late 1970s. The technology was starting to take hold in Europe and Amtrak had a desire to evaluate AC traction in this country.

In an AC lomotive's traction motors there are no commutators, brushes or brush holders. It is able to produce car electrical, or head-end power in lower throttle notches than our standard F40. With AC technology head-end power can also be produced by the rotating traction motors during dynamic braking, reducing fuel usage, noise and emissions. However, these advantages must be weighed against a more electronically complex locomotive.

In the mid-1980s Amtrak contracted with Brown Boveri (now part of ABB Traction) to supply the traction and control electronics for an AC locomotive to be built by Amtrak from a wreck-damaged F40. This unit was completed in 1987, and after serving four years in the Northeast Corridor has been loaned to the AAR in Pueblo, Colorado.

In the Spring of 1987, as part of an Amtrak order for nine F40s, EMD agreed to build two prototype AC locomotives for the benefit of both themselves and Amtrak. Siemens, one of the largest AC traction suppliers in the world was selected by EMD to supply the AC-related hardware and associated computers.

This discussion will focus primarily on a general overview of the locomotive. I will touch on the tests performed at the AAR's Transportation Test Center in Pueblo, and the over-the-road tests on Amtrak trains.

The F69 is essentially similar in its major dimensions to our F40s. It has four axles, is 58 feet long, 15½ feet high and weighs 262,000 pounds (Fig. 1). Like our F40, it has 3000 hp but produces 50,000 lbs. of continuous tractive effort, compared to only 42,000 with an F40. It has a 12 cylinder 710G3 engine turning an AR-7 main generator and does not have a rotating generator for head-end power.

The F69's AR-7 produces AC that is converted to DC (just as on a standard diesel). This DC is fed to three "inverters" where it is converted to three-phase AC. There is one inverter for the front truck, one for the rear and one for head-end power (Fig. 2).

Each inverter is controlled by its own Siemens-supplied computer. Two of these computers have the task of monitoring and adjusting both the voltage and frequency of the traction inverters as the load, speed, and other conditions change. The hotel power inverter is responsible for maintaining the three phase, 480 volts for car supply, regardless of the changes in demand.

In addition to these three inverter computers, there is a fourth computer that supervises the activity of the other three, as well as performing all of the control functions of the locomotive in general.

The unit has a slightly streamlined front end with racked-backed windshields. This gives us three major advantages: 1) it contributes to fuel savings, especially at speeds above 70 mph; 2) the frontal area of the windshields is reduced by the tilt-back thus reducing the effective velocity of any projectile that may hit it, and 3) the windshields are located farther away from the engineman, reducing his chances of being struck by glass.

The cab is of a modern console design with a 30CDW air brake valve and air operated seats.

To reiterate, the F69 is controlled by four computers. As previously mentioned, there is one for each truck, one for the hotel power and the control computer. Siemens supplied these computers as well as the software for the traction and hotel power. EMD wrote the software for the control computer.

Those four computers are in the cabinets behind the engineman. In a pre-60 series or pre-Dash 8 DC locomotive these cabinets house circuit cards and relays.

The master, or control computer intereacts with the engineman and maintenance personnel via a display and keyboard located directly over the engineman's console. The display alerts the maintenance or yard personnel of an open 480 volt trainline and on which side, and it is also the method by which the hotel power system is started and shut off.

In addition to over 300 operating parameters, the system displays the operating faults. These faults are prioritized and displayed to the engineman or maintenance personnel, and they can then use the display to reset them. The system will also archive these faults for later retrieval through the display or a laptop computer. In addition, self-load and subsystem checks are run using the display and keyboard.

The display diagnostic system is user friendly and requires no computer literacy on the part of the operator.

The heart of AC technology is of the gate drivers that are part of the traction inverters. These solid state devices receive firing pulses from the computers located in the cab and send turn-on turn-off pulses to the high power phase modules located out of sight behind the gate drivers.

The phase modules are the actual devices that take the DC from the main generator and convert it to three-phase AC for the traction motors. In the case of the hotel power, they convert the DC to a constant three-phase AC at 50 Hz and 480 volts. The phase modules produce a large amount of heat during normal operation and are cooled by an evaporative Freon bath.

From the early summer of 1989 until September 1990, both F69s were at the AAR's test center at Pueblo, Colorado. During this time both EMD and Siemens developed the locomotive and refined the control software.

Amtrak also ran a series of tests with this locomotive over instrumented, disturbed track to gather data on wheel-rail forces.

Following the Pueblo tests, both Amtrak and EMD started a three-month service evaluation. During this period both locomotives and the EMD test car were run as a set. One unit, the 450, had over 100 data channels connected to the test car for the entire over-the-road evaluation. This time was used to evaluate the locomotive, as well as the suitability of AC technology for passenger service.

Both units, and the test car, were run across the country between Chicago and the West Coast and between Chicago and Washington, DC. A number of hardware and software problems were identified and corrected.

With computer control, new chips can be made in the test car and installed in the locomotive during a station stop and the fix can be immediately evaluated.

During the revenue service evaluation we were able to gather fuel usage data from the F69s and compare it to the F40s that pulled the same train the day before. Fig. 3 is of a representative test and shows the results of a study on train #3, The Southwest Chief.

Along the bottom of the graph are

the segments of the run between fuel stops. The vertical axis is fuel used. The graph is for the one unit of a two unit consist that was producing the hotel power. Overall, during the fuel tests on train #3, The Southwest Chief, we measured a 15% saving between an F69 consist and an F40 consist hauling the same train on the same route on the previous day. (Actually the F69-hauled train had one extra car - the EMD test car.) This can be broken down to a 10.5% saving with the F69 producing hotel power and a 4.5% saving with the unit not producing hotel power.

Fuel savings with an F69 can be attributed to two sources: The first is due to the ability to run in a lower throttle notch when producing hotel power. An F40 must run in notch 8 at all times when developing head-end power in order to turn the generator at the correct frequency. An F69 does not have this constraint, it generates head-end power via an inverter that receives its input from the DC that is produced by the main alternator/converter. The prime mover has only to turn at a sufficient RPM to produce enough DC energy to meet the demand. This can be as low as the 4th notch.

The other reason for this saving is dynamic brake regeneration. During dynamic braking the traction motors - now generators - feed power back into the converters which convert the AC to DC. The DC is then applied to the DC bus that feeds the head-end power inverter; the remainder goes into the grids. So during dynamic braking we are able to produce hotel power with no power demand being made on the prime mover. A good example is train #5, the California Zephyr, which is in constant dynamic braking for about three hours traveling westbound into Roseville, Calif.

It is still too early to discuss maintenance history. The mechanical and electrical components are still new and, for the most part, have needed only inspections and adjustments. Of course, as with any new design we have had to start retraining our maintenance personnel and have had some "growing pains." The builder is actively supporting these units and has provided both formal, classroom training and day-to-day tutoring at our shops.

Our operating experiences have been good. Amtrak and the builder provided training to operating supervision while the units were still in Pueblo, which facilitated crew acceptance and eased the transition from F40s to the F69s.

The evaluation of these units is still in progress. The test car was removed in early December and each unit has put on approximately 100,000 miles in revenue service.

It is Amtrak's intention to pursue AC technology pending the successful outcome of these tests.

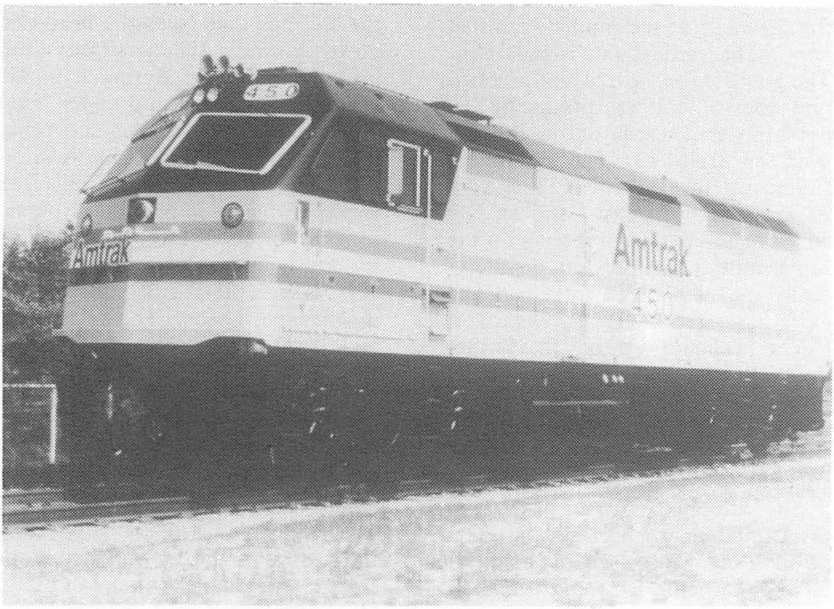

Amtrak
Amtrak

Fig. 1

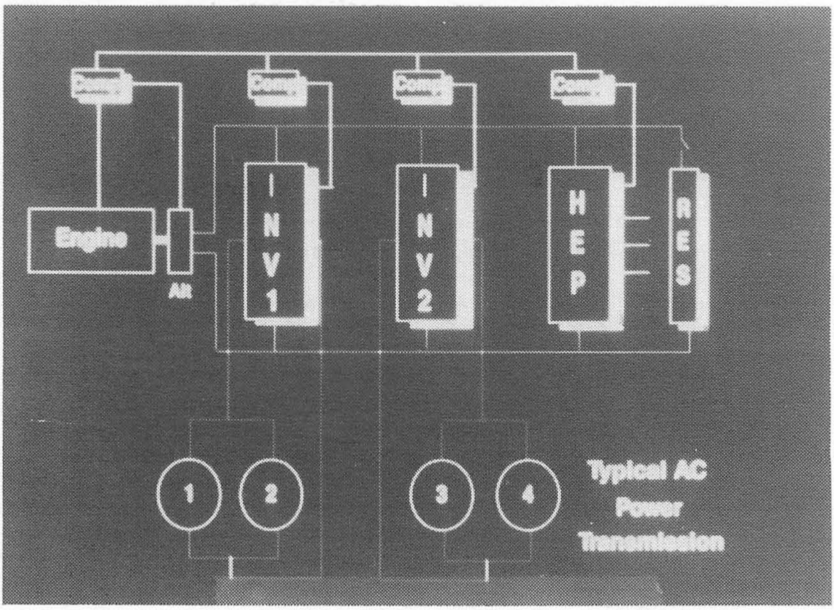

Engine
AR
INV 1
INV 2
HEP
RES
1
2
3
4
Typical AC Power Transmission

Fig. 2

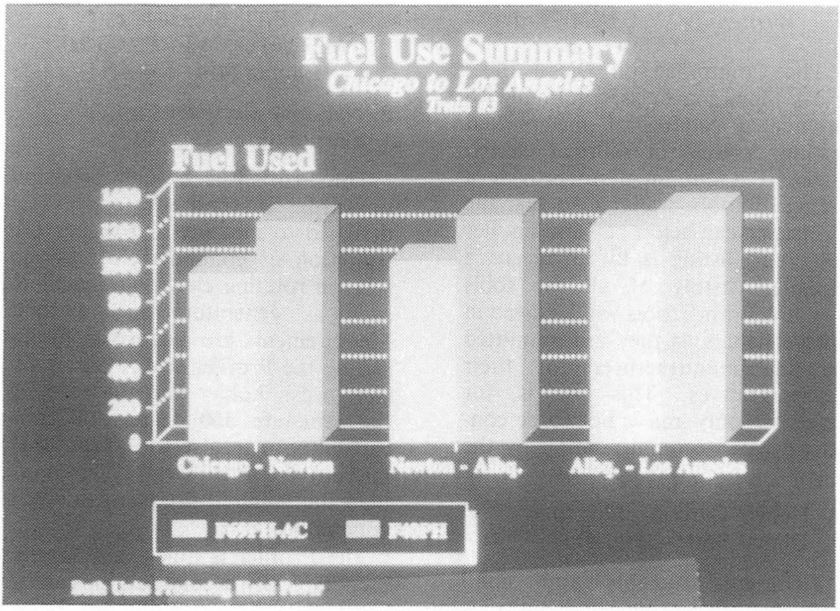

Fuel Use Summary
Chicago to Los Angeles
Fuel Used
Chicago - Newton
Newton - Albq.
Albq. - Los Angeles

Fig. 3

V. MODERN TOOLING FOR ELECTRICIANS

Presented by: Don Gezon
Written by Dick Blanchard

The Committee on Diesel Electrical Maintenance is continuing to provide a catalog of meters and testing devices for railroad electricians. It is our intent to provide a listing of tools available so that the electrician can better perform his/her job. This listing is by no means a complete listing of all the tools available, other tools will be listed in future papers as they are submitted by the manufacturers or their representatives. This list is for reference only and is not to be construed as a recommendation by the LMOA.

A. Helwig Carbon - Electronic Digital Scale - (Fig. 4)

Efficient, durable and small enough to fit in your hand, Helwig's Electronic Digital Scale is the convenient way to measure brush holder spring force. Simply attach the interchangeable strap or roller to the spring assembly and pull the scale taut by the comfort-grip handle. The measured force is clearly displayed in easy-to-read, ½ inch LCD numerals.

The battery-operated digital scale accurately reads force measurements of both spiral torsion springs and constant force springs up to 10 lbs. Convenient automatic zeroing ensures measurement of only the spring force, not the weight of the strap or roller, so that every reading is precise.

Fatigue can cause any brush holder spring to wear out and lose its rated force, resulting in unsatisfactory brush performance. The Helwig Electronic Digital Scale helps detect improper spring forces before excessive brush or commutator wear causes costly downtime.

For further information:

HELWIG CARBON PRODUCTS, INC.
8900 W. Tower Ave.
P.O. Box 24400
Milwaukee, WI 53224-0400
Phone: (414) 354-2411

B. National Electrical Carbon Corporation - (Fig. 5)

The Profiler is a high precision portable instrument especially designed to measure and record the condition of commutators and slip rings in rotating electronic machines such as generators and motors. Measurements are performed by inserting the Profiler sensor into a vacant brush holder and the rotating the armature 360 degrees. With a capability to resolve to .00004 in. (1 micron) the Profiler provides more than the required precision to check commutators.

The Profiler is quick and easy to use - typically a commutator can be checked in about five minutes. Being fully portable due to its battery operation (including printer) in situ measurements can be made with ease.

Having taken a measurement, the Profiler gives you TIR (total indicated readout), MBTB (maximum bar to bar) and even counts the number of bars. With its 8 kilobyte non-volatile memory it can store readings from 20 different commutators each having 2 tracks and 200 bars (approx.) The Profiler's easy to read printout makes commutator surface diagnosis quick and easy.

For further information:

NATIONAL ELECTRICAL CARBON CORPORATION
P.O. Box 1056
Greenville, S.C. 29602
Fax: (803) 281-0180

C. GE Electronic Services - Electronic Inverter - (Fig. 6)

GE Electronic Services has designed and built the latest in electronic inverters for use with your

locomotives. This state of the art inverter uses moden technology to invert standard 72 volt DC locomotive power to an adjustable high voltage DC output which can be used to set up and adjust your transition panels.

This new inverter offers many benefits over your old, obsolete MG sets:

* Safer to use
* Smaller and lighter
* Easier to use
* More portable.

Features:

* Up to 1,250 Volts DC output
* 0.5 amperes DC output current
* Safety ground connection
* DC output isolated from the in put power
* Protection circuitry provided for:
  * Over voltage
  * Over current
  * Over temperature
  * Input power polarity
  * Zero voltage start up
  * Digital metering for accuracy and durability
  * Rugged, lightweight, shock resistant design
  * Ability to parallel for increased current capacity.

For further information:

GE TRANSPORTATION OPERATION
2015 49th Avenue, North
Minneapolis, MN 55430
Phone: (612) 522-4396

Compact Size For Fast, Easy Readings
Efficient, durable and small enough to fit in your hand, Helwig's Electronic Digital Scale is the convenient way to measure brush holder spring force. Simply attach the interchangeable strap or roller to the spring assembly and pull the scale taut by the comfort-grip handle. The measured force is clearly displayed in easy-to-read, ½-in. LCD numerals.

Precise Spring Force Measurements
The battery-operated Digital Scale accurately reads force measurements of both spiral torsion springs and constant force springs up to 10 lbs. (+ or – 2 oz.). Convenient automatic zeroing ensures measurement of only the spring force, not the weight of the strap or roller, so that every reading is precise.

A handy way to improve brush life.

Helwig Electronic Digital Scale

Reduce Downtime Due To Inadequate Spring Force
Fatigue can cause any brush holder spring to wear out and lose its rated force, resulting in unsatisfactory brush performance. The Helwig Electronic Digital Scale helps detect improper spring forces before excessive brush or commutator wear causes costly downtime.

A Simple Way To Determine Proper Spring Force
Measure spring force. Calculate the spring pressure by using the formula listed below. Refer to Helwig's Recommended Range of Spring Pressures Chart to determine if the correct spring force is being applied to the application.

Warning: To avoid personal injury always disconnect the power source before inspecting electrical machinery.

Recommended Range of Spring Pressures*

Industrial D.C. Applications	4-5 P.S.I.
WRIM & Sync. Rings	3½-4½ P.S.I.
High-Speed Turbine Rings. Soft Graphite Grades	2¼-2¾ P.S.I.
Metal Graphite Brushes	4½-5½ P.S.I.
FHP Brushes	5-8 P.S.I.
Traction Brushes	5-8 P.S.I.

*For brushes with top and bottom angles greater than 25 degrees, an extra ½-1 P.S.I. is required to obtain recommended pressure at the brush contact face.

Formula

$$\text{Spring Pressure (P.S.I.)} = \frac{\text{Measured Force (lbs.)}}{\text{Brush Thickness (in.)} \times \text{Brush Width (in.)}}$$

Helwig's Electronic Digital Scale. A handy way to improve brush life.

HELWIG CARBON PRODUCTS, INC.
8900 W. TOWER AVE. P.O. BOX 24400
MILWAUKEE, WI 53224-0400
TEL 414-354-2411 FAX 414-354-2421
FAX 1-800-365-3113

Fig. 4

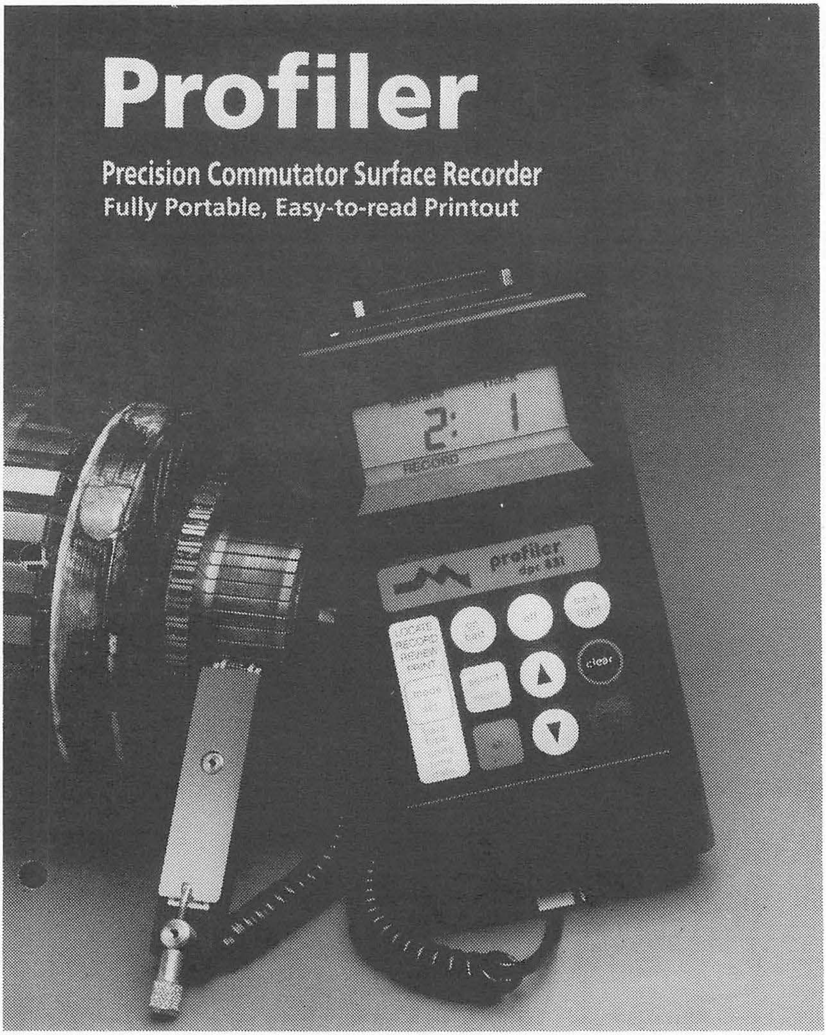
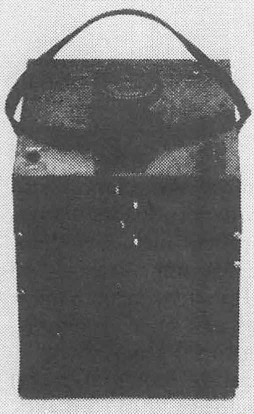

Profiler
Precision Commutator Surface Recorder
Fully Portable, Easy-to-read Printout
2: 1
RECORD
profiler
clear

Fig. 5

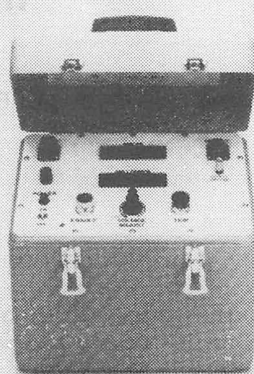
ELECTRONIC INVERTER
MODEL 17GP-1200

GE ELECTRONIC SERVICES has designed and built the latest in electronic inverters for use with your locomotives. This state of the art inverter utilizes modern technology to invert standard 72 volt DC locomotive power to an adjustable high voltage DC output which can be used to set up and adjust your transition panels.

REPLACE YOUR OBSOLETE MG TEST SET



WITH...



OUR NEW SOLID STATE TRANSITION TEST SET WEIGHS ONLY 19 POUNDS AND IS MUCH SAFER AND EASY TO USE.

This **new** inverter offers many benefits over your old, obsolete MG sets:

* Safer to use
* Smaller & lighter
* Easier to use
* More portable

ELECTRONIC SERVICES

Fig. 6

THE SOUTHERN AND SOUTHWESTERN RAILWAY ASSN.

717 Pinecliffe Drive
Chesapeake, Virginia 23320

PURPOSE

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

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

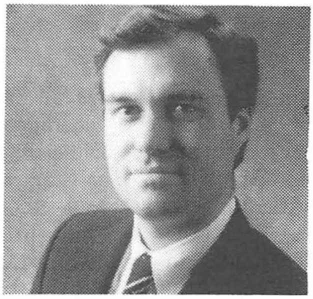
Please drop our Secretary a line for an application or further information.

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

REPORT ON THE COMMITTEE ON DIESEL MECHANICAL MAINTENANCE

Monday, September 16, 1991 2:00 P.M.

Pre-Convention
Southern and Southwestern Railway Assn.



April 9, 1991
Union League Club
Chicago, IL

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Senior Gen. Foreman
Norfolk Southern Corp.
Bellevue, OH

Vice Chairman
C.T. KUNKEL
Mgr.-Loco. Plng. Std. & Programs
Union Pacific Railroad
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T.H. Volkmann	Shop Mgr.-Loco. Shop	C&NW Transp.	Marshalltown, IA

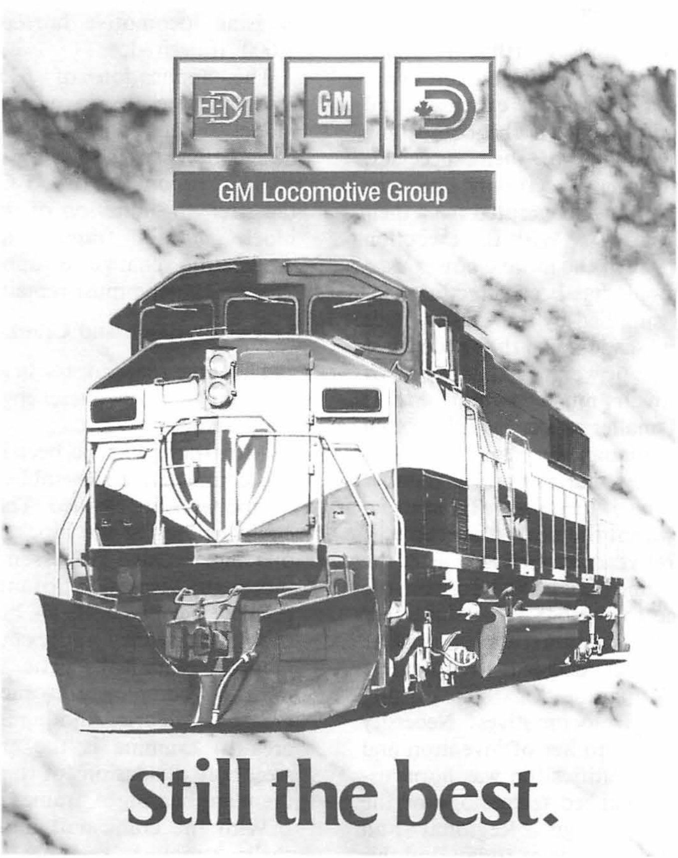
PERSONAL HISTORY

C. Douglas Corbin

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

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

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


GM
GM Locomotive Group
Still the best.

I. RECOMMENDED PRACTICES FOR UPGRADING 567 ENGINES TO 645 DESIGN

Presented by: Lee Oviatt

A. Introduction

Regional and Shortline railroads have had to be very resourceful over the years. Limiting expenses and overheads has been the compelling factor in many of their successes. Motive power is certainly one area where they have benefitted from their Class I partners. With the exception of a very few, the motive power used on regionals has been directly or indirectly supplied by the Class I roads as they cascade down their older, less efficient power. This type of locomotive is much more affordable for the smaller railroads and is often more available. In many cases the spin-off regional assumes a number of this type of locomotive from structuring within the deal to purchase.

Several years ago, shortly after the EMD engine design changed from the 567 type to the 645 type, the larger roads in conjunction with the manufacturer decided to pursue a type of upgrade for their existing fleet of 567 locomotives. Necessity became the mother of invention and a retrofit modification was born, using the advanced technology of the new 645 design. Regional and Shortline railroads of today find this still to be a viable alternative to purchasing newer, more expensive power, especially when it utilizes an already existing asset. In this paper we will briefly reiterate what has become a proven and economical method for improving older locomotives performance and longevity.

Upgrading a 567 engine to the 645 design includes much more than simply power assemblies. This paper will deal with the various component changes and variations of available material. The rationale for this change includes among other things economy, reduced inventory, standardization, and in some cases increasing locomotive horsepower to 2,000, if desired.

The application of 645 power assemblies results in a new engine model designation. The former 567 designation would become 645, i.e. 16-567C becomes a 16-645-C. Due to the strength limitation of the engine block and A frames, no letter designation change is appropriate, thus a C engine must remain a C.

B. Engine Block and Crankshaft

The upgrade process begins with the removal of the diesel engine from the locomotive.

After the engine has been removed, it is completely disassembled and the components are cleaned. This will include separating the block from the oil pan. Once disassembled, a thorough inspection of the components begins. Both air box drains should be cleaned and examined for blockage and leaks. The air boxes must be completely cleaned of all grease and debris. Another important area to examine is the crankshaft steel bore dimensions of the block or the main bearing A frames.

With the crankshaft and bearing shells removed, re-apply the main bearing caps and torque the nuts in two passes. On the first pass, torque the nuts to 350-400 ft lbs. On the second pass, final torque the nuts to 750 ft. lbs.

Check that the main bearing bore dimensions are within minimum and maximum limits. Take two sets of measurements at each bore, one set ½" in from the accessory end of the bore and one set ½" in from the generator end of the bore. If these dimensions are within tolerance, check the total length of the bearing bores for the proper line bore dimensions. Depending upon the severity of out of tolerance dimensions found, a line bore remachining may be necessary. Several reputable railroad vendors and Class I road backshops can offer this service, as well as crankshaft rework if required.

The crankshaft should be visually and dimensionally inspected for grooving, pitting, and straightness. Again, many vendors are capable of straightening and refinishing crankshafts. Normal crankshaft qualification usually include a Magnaflux process which will determine if there are any cracks in it.

The crankshaft is now ready for installation.

Apply the main bearing to the A frame bores and to the bearing cap, lining up the bearing tabs.

Carefully place the crankshaft in the A frame bearing shells and apply the two end and two center (16 cylinder) bearing caps to hold the crankshaft in place. Be sure to apply a generous amount of new oil to all bearing shells prior to application in the A frame. Tighten the nuts until they contact the bearing caps. Apply the remaining bearing shells and caps. Using a torque multiplier, all nuts are torqued to 350-400 ft. lbs. in a staggered pattern. After all nuts have been tightened to this torque value, final torque all nuts to 750 ft. lbs., again in the prescribed sequence.

C. Reassembly of Block to Oil Pan

A round silicon seal cord placed in a groove in the oil pan mounting rail effectively prevents any oil leakage at the junction of the crankcase and oil pan. Install the seals in the grooves without twisting or stretching and without lubricant.

Place the crankcase over the oil pan and use line-up guide pins in the four corner holes, then lower the crankcase onto the oil pan. Apply tapered dowel bolts and tighten, then apply all crankcase to oil pan bolts with washers and snug four corner bolts to about 100 ft. lbs. torque. Starting with the center bolt and alternating between bolts to the left and right of center, tighten bolts to a torque of 100 ft. lbs. After tightening bolts on both sides of engine to 100 ft. lbs., repeat the tightening sequence bringing bolts to a final torque value of 450 ft. lbs. After all bolts have been tightened to proper torque, cut seal cord ends to provide a seal protrusion from the face end plates of 3/32" +/- 1/64". This seal protrusion will seal the three-way joint of the oil pan, crankcase, and end housing.

D. Idler Gear Stubshaft Assembly

The new idler gear stubshaft assembly is installed at this time. This will effectively upgrade the idler gear stub shaft assembly and gears to current design for improved strength and dependability, as well as improved oil flow capabilities. The new design incorporates the following improvements:

On turbucharged engines - An oil flow that supplies filtered turborcharger oil to the lower idler gear stubshaft. This change includes replacement of the 2 GPM soakback pump and ¼ HP motor with a 3 GPM pump and ¾ HP motor to provide the increased oil flow required by the improved stubshaft bracket

On blower type engines - A new stubshaft with through-bolting similar to the current stubshaft design of turbocharged engines, with shrunk-on bushings and enlarged oil passages that are rerouted to increase oil flow and also minimize entry of oil-born debris.

The following steps are recommended when installing the new stub shaft:

* Place the new lower and upper idler gears on the stubshaft, checking to see that the backlash is .007" - .016" at the cam gear and crankshaft gear.
* Locate the centers for the new holes in the end plate by using the holes in the lower stub to pilot an 11/16" diameter drill. Drill only deep enough to provide centers.
* Locate centers for the three ½" -20 holes by using the three new holes at the top of the new stubshaft to pilot a 9/16" diameter drill. Drill only deep enough to provide centers.
* Remove the stubshaft bracket and thoroughly clean.
* On the four centers established, drill 37/64" diameter x 1-5/16" deep holes, countersink and tap 5/8" - 18 UNF x 1-1/16" deep.
* On the three centers established, drill 29/64" diameter x 1-1/8" deep holes, countersink and tap ½" - 20 UNF x 7/8" deep.
* Thoroughly clean rear end of engine removing all chips and debris.
* Apply stubshaft and dowels using 15 - ½"-20 bolts with hardened washers, torque to 90 ft. lbs. and lock wire. Apply the lower idler gear, thrust plate, and four 5/8"-18 bolts with hardened washers, torque to 90 ft. lbs. and lock wire. Apply the lower idler gear, thrust plate and four 5/8"-18 bolts with hardened washers, torque to 185 ft. lbs. and lock wire. This procedure will vary some between turbocharged engines and blower-type engines.

E. Camshafts and Gear Train

Qualify camshafts, or replace as desired, paying particular attention to the camshaft bearing inserts at all cam support locations. The 645 upgrade calls for renewal of all cam shaft counterweights.

F. Power Assembly Installation

At this point the user must decide what type power assemblies he wishes to use. Depending upon personal preference, any number of new or remanufactured components such as heads, liners, and pistons are available. Some Regionals and Shortlines may prefer to rebuild the original 567 type cylinder heads when they do not intend to increase the horsepower of the engine to 2,000. This is a substantial cost saving over purchasing 645 heads, if desired.

If the horsepower is increased no smaller than a circle or a diamond 3 cylinder head should be used.

If the original connecting rods are to be reused, qualify each one for length, twists, bore parallelism, and acceptable wear of the bearing cap serations. Qualify cylinder head water jumper inlet openings in the top deck of the block for excessive wear and cracks. Also, qualify the head seat surface of the block for wear and metal distress. It is recommended that the latest Viton type of head seat ring be used in an effort to deter oil migration into the cylinder. Apply the new power assemblies, rods, and connecting rod bearings according to OEM specifications and procedures. Torque the head to liner nuts to 140 ft. lbs. and the cylinder head crab nuts to 1800 ft. lbs. The original 567 type liner water jumpers may be reused after careful inspection for cracks or leaks. The cylinder liner oil supply lines or pee pipes must be of the 645 design to allow for fit up to the new liner. The opposite end which attaches to the pee pipe oil supply manifold is the same as that of the 567 and requires no modification. Along with the new 645 power assemblies, a different fuel injector is required. Substantial savings can be realized by upgrading injectors presently in use. These conversions consist basically of application of new low sac spray tip and calibration slide. Once the power assemblies are applied and torqued, the accessory "jewelry" is installed. Valve and injector timing should then be set according to manufacturer's specifications.

G. Engine Blowers - Roots Blown Engines

Most suppliers now offer the upgraded "567" ROOTS blower that is equipped with the "645" design oil drain line. The improved design must be used on this type of engine upgrade. If the horsepower is to be increased to 2,000, upgraded blower bearing and 29 tooth drive gear are required in addition to the drain pipe modification. This is also a good time to upgrade the original, less effective air intake system with a more modern baggy or paper filter system. Several suppliers offer these bolt-on packages at a reasonable price. This will further standardize the filters inventoried by reducing the number of different types that must be carried. There are several schools of thought relative to this modification's ability to improve air filtration, horsepower, and fuel economy; however, this paper does not make specific product recommendations. Suffice it to say that in most cases there will no doubt be some improvement over the old original air intake system if a new design is applied.

H. Miscellaneous Components

With the new assemblies now applied, a thorough check of other miscellaneous components should be accomplished.

* **Exhaust stacks** - Thoroughly clean out all threaded bolt holes in the block vee to be certain the threads are acceptable. If threads are not acceptable, oversized studs or thread repair kits can be installed. Check stack bases for being warped, clean mating surfaces and reapply stacks with new gaskets using the proper torque values and bolt tightening sequence. Qualify the welds of the stacks and the jointing bands, if used. Several more modern types of exhaust stacks may be applied which offer reduced maintenance, less back pressure, and are modified to take advantage of expansion joints between stacks.

* **Engine protector** - The low water/crankcase protection device should be renewed or qualified by the proper vacuum test procedure to determine its integrity.

* **Lube oil cooler** - The oil cooler should be removed, cleaned, and tested to ensure proper oil cooling and oil supply potential. Due to age, oil coolers in locomotives of the 567 vintage are sometimes found to be deficient and should be at least cleaned and tested. If the horsepower is to be increased to 2,000 an oil cooler closure plate must be applied to the inlet slot and the lube oil bypass valve must also be upgraded. It is also recommended that the oil cooler be converted to a mechanically bonded type for improved reliability.

* **Harmonic balancer** - The balancer should be disassembled, spring leaves or packs replaced, and push pins rotated to present a new contact surface to the springs. Or if desired the rebuilder can install the new style gear damper (part number 9323945).

* **Overspeed trip housings** - Modify the overspeed housing to eliminate oil drain seals. This will effectively reduce oil leak maintenance in the future.

* **Cooling fans** - If the horsepower is increased to 2,000, the two original

48" diameter, 6 blade cooling fan must be replaced by two 48" diameter, 8 blade (part number 8310416) fans to provide adequate cooling for the demands of the higher horsepower engine.

* **Engine governor** - A governor stop block should be applied to 8 and 16 cylinder 567C and 16-567D1 blower-type engines to reduce overfueling of the engine. Overfueling is a major factor in piston ring breakage and valve blow. There are several rack and power piston adjustments that must be made based upon the type of injector used, consult M.I. 9547 for the table of various settings available. The high horsepower conversion will call for a .83 full load rack at 900 RPM. This is substantially higher than the original 567 type 835 RPM by a rack setting of 0.90.

* **Electrical modificiations** - In addition to the previously mentioned changes, there are certain electrical improvements that are required if 2,000 horsepower is desired. Due to the fact that these electrical modifications differ between railroads, the specific parts lists and wiring diagrams should be requested from the manufacturer on a case-by-case basis.

I. Start Up and Test

When the upgrade has been completed and the engine is ready to be started, a lube oil prelube must be applied through the engine bearings. Once the appropriate break-in period for the bearings has been achieved, begin the other electrical and mechanical sequence tests required by your railroad procedures. A load box test should then be performed in order to further adjust, and calibrate such other support systems as temperature switches, overspeed, engine speeds, etc.

J. Closing statements

In closing, we feel that this upgrade, which was published some ten years ago, is still as vital to some now as it was to others back then. It has proven to be a new lease on life for 567's even over and above the normal rebuild or overhaul program that would normally be required. This paper has provided a general outline of information without specific part numbers or detailed technical data.

II. CONVERSION OF SD40 LOCOMOTIVES TO SD40-2 ON CSX

Presented by: Jay Holly

The locomotive upgraded to SD40-2's on CSX were refitted with a number of modern features. Some of the features are listed as follows:

1. 645F power assemblies
2. Single shoe trucks
3. D-78 traction motors
4. AP - type journal bearings
5. On-board lubricators
6. Extended range dynamic brake
7. Pulse "Train Sentry III" alerter
8. Microphor toilet
9. EOT device installation
10. Bag-type secondary air filters
11. Air filtration to electric locker
12. Dash-2 cab interior
13. AAR Clean Cab II modifications.

As the locomotives were stripped, certain components were retained for rebuild and application to these or other locomotives. This held overall costs to a minimum.

Items reused were:

1. Engine
2. Main alternator
3. Traction motors
4. Wheels
5. Air compressors
6. Trucks
7. Radiators
8. Auxiliary generators
9. Batteries
10. Connecting rods
11. Radiator cooling fans
12. Dynamic brake grids
13. Dynamic brake blower motor.

When rebuilding these locomotives CSX also decided to do the following routine repairs and upgrades to make the package complete:

1. Zero out all air dates
2. Modify dynamic brake cutout
3. Emergency sand timing
4. Overhaul trucks, new springs
5. New wheels, axles, drive gears
6. New conn rods, injectors, damper
7. Overhaul air compressor
8. Apply mechanically bonded radiators and oil coolers
9. New batteries
10. Electric cab heat
11. Apply Dash-2 cab interior
12. Carbody overhaul and cab repairs.

This work was done at Huntington Shops of CSX. Locomotives selected for the project were those with the highest failure rates or those previously stored needing major repairs. The locomotives were rebuilt in the shop using a spot system for organizing certain work in certain areas of the shop.

Work done at Spot 1 included the following items:

1. Completely strip the locomotive including engine, generator, electric locker, wiring; remove cab, remove fuel tank, traction motor cabling
2. Frame and carbody are completely washed
3. Fuel tank cleaned, reworked and applied.

Work done at Spot 2 included the following items:

1. Applied electric locker
2. Renewed brake piping with cab removed
3. Renewed both draft gears
4. Applied AC cabinet and clean cab control stand
5. Applied new motor cabling
6. Applied rebuilt engine, alternator and air compressor
7. Applied cab and air reservoirs.

Work done at Spot 3:

1. Carbody set on trucks
2. Long hood applied
3. Applied cab floor and ceiling
4. Finished cab heat, refrigerator, speed indicator and recorder
5. Applied toilet and cab lighting
6. Performed static tests

Tests were then performed on Spot 4. These tests included load testing, calibrations and finally track testing.

Spots 5 and 6 were the painting of

the locomotive and trim out, including final inspections of the entire locomotive.

The SD-40's rebuilt and upgraded to SD-40-2 style units were worked at Huntington with safety and quality built into each and every locomotive. The locomotives were turned over to the Transportation department as an inexpensive alternative to buying new locomotives and with the expectation of another 15 to 20 years of service.

III. UPDATE — DIESEL ENGINE EMISSION CONTROLS

Presented by: Tad Volkmann

Emissions controls have become a hot topic among railroads recently, highlighted by pending regulation by the EPA clean air act, the California Air Resources Board, and others. The purpose of this paper is to summarize some actions that can be undertaken by railroads today to reduce their additive component to air pollution, including general measures, and specific improvements and retrofits offered by the OEM's at present.

General actions which can be taken to reduce the railroads' contribution to atmospheric pollution from exhaust emissions include the following:

Shutting diesel engines down when ambient temperatures permit is an effective means of totally eliminating exhaust emissions while locomotives are not needed. Maintenance penalties in the areas of battery and starter maintenance will be incurred by railroads adopting this practice. The Soo Line is currently testing an automatic stop/start feature on one of its locomotives which automatically restarts a shutdown diesel engine when the cooling water temperature drops to a preset point.

Testing of ultra low sulphur fuel, with a maximum .01% sulphur content, on current EMD and GE engines at Southwest Research indicated a decrease in oxides of sulphur (SOx), particulates, and oxides of nitrogen (NOx). EMD has expressed concern regarding fuel injector durability on ultra low sulphur fuel, as sulphur may provide some degree of injector lubrication.

Research to date indicates that retarding fuel injection timing by approximately 4° from spec in locomotive diesel engines will reduce NOx by about 20% throughout the power range.

Some significant negative effects of timing retardation include a fuel economy penalty of approximately 2%, and increased smoke and particulate emissions. Also, increases in exhaust gas temperatures will result in the danger of turbocharger overheat/overspeed failures, particularly at high altitudes. Amtrak is currently testing a F40PH locomotive with retarded injector timing.

The use of high cetane, low sulphur #1 diesel or kerosene spec fuel could offset some of the negative effects of particulate and smoke emissions from retarded injector timing. Fuel injector longevity may be compromised by this lower lubricity fuel. #1 diesel fuel also has a lower heating value than #2 fuel, which could result in a fuel economy penalty of as much as 7%.

Current Developments on GE Diesel Engines

General Electric locomotive model U25B was introduced in 1960. It contained a model 7FDL16 diesel engine rated at 2,500 horsepower for traction.

In the ensuing years the 7FDL family of engines has grown into a 4,000 HP for traction diesel and today powers over 1,300 GE Dash 8 locomotives operating worldwide as well as a fleet of over 4,100 GE Dash 7 locomotives.

Development of the engine over the years has resulted in many improvements in reliability, maintainability, fuel economy and, very important in todays environment, emission controls. Let us review a few of the current emission control improvements, including their development, their benefits, a little about why they work, their application, both current production locomotives and the possibility of retrofit.

We will start with the fuel injection nozzle.

The low-sac injection nozzle was introduced into production during the fall of 1983. The low-sac design has a fuel cavity volume greatly reduced from the previous nozzle. This design has demonstrated improvements in specific fuel consumption and smoke emissions. This has resulted in better fuel atomization and reduction in particulates and hydrocarbons.

This standard production part is readily available for retrofit on all GE engines.

Since the mid-1970's GE has been designing and manufacturing the turbochargers for its diesel engines. The GE model 7S1616 turbocharger resulted.

The demands placed on locomotive engine turbochargers have always been very severe. Power levels have risen so that at standard sea-level conditions a pressure ratio of just over 3:1 is required. At high elevation (8000 ft.) one must be able to produce over 4:1 pressure ratio, or reduce fueling to the engine. GE turbochargers have been developed to withstand this rigourous service through design and material selections, utilizing the resources and experience of the diverse GE organization.

Several years ago GE undertook a program to further improve the Turbocharger used on the 16-cylinder engine. The objective of this program was to provide state of the art efficiency, thereby improving engine fuel efficiency.

This turbocharger, model 7S1716, has been fully field tested on various railroads and has been in production since August 1990. (Fig. 1)

In addition to providing better fuel efficiency, it has improved transient response and engine breathing to low loads, thus reducing smoke. Exhaust temperatures have also been reduced, particularly at high elevations. Improved components include:

* High efficiency compressor wheel with computer designed backswept blades
* New vaned diffuser with improved aerodynamics
* Air inlet and discharge castings with improved performance
* Optimized turbine blade angle and matching to engine.

To obtain optimum performance, the new turbo should only be applied with reduced valve overlap camshafts. Because of the improved turbo efficiency the engine timing was changed to further optimize performance.

In early 1990 GE also introduced the single helix fuel injection pump.

This results in removal of the timing retard helix at low notches and provides a reduction in visible smoke, both steady state and transient. This has a major effect on smoke as injectors wear.

Fig. 2 shows the significant transient smoke reduction during an idle to notch 8 throttle sweep.

Note the four conditions shown are all with worn, 350,000 mile injectors. The top left trace shows the 7S1616 turbo and the double helix pumps. The lower right trace shows the results for 7S1716 turborcharger and the single helix pumps.

Maximum steady state smoke was measured at notch 3. Again all four conditions shown in Fig. 3 are with worn, 350,000 mile injectors.

The total improvement measured here shows a reduction from 40% opacity to almost 10% opacity.

One last improvement that can be retrofitted easily is the dual pipe exhaust manifold that replaces the previous single pipe manifold.

While developed as a reliability improvement, it has also proven to reduce transient smoke because of the improved turbo response. In summary, the GE 7FDL diesel engine configuration which includes:

* low-sac injection nozzels,
* 7S1716 turbo,
* reduced valve overlap camshafts,
* single helix fuel injection pumps, and
* dual pipe manifold

gives the best value to the customer in:

* improved fuel consumption,
* faster transient response,
* longer life components,
* visible smoke reduction,
* greatly reduced port carboning, and
* environmentally a significantly more acceptable locomotive.

Update on EMD Diesel Engine Emission Controls

EMD has been measuring emissions on locomotives for over 20 years. During this time EMD has not only stayed abreast of emission regulation activities and technology advancements, but has understood and considered the effect that the various design changes have had on emissions.

Emission Reduction For Older EMD Engines

The following is a discussion on the current developments for emissions reduction which are available for retrofit to older locomotives.

During 1977 and 1978, the Electro-Motive Division of General Motors conducted some preliminary studies of methods to reduce nitrogen oxide (NOx) emission from 16-645E3 engines. These initial studies indicated that one method to reduce NOx emissions is to retard fuel injection timing. This is generally effective, but is usually accompanied with an undesirable increase in fuel consumption.

EMD is developing a retrofit strategy for EMD 645E3 engines that reduces NOx emissions to the same degree that retarding timing does, but without incurring a reduction in fuel efficiency. The method used is to increase the fuel injection rate while retarding the beginning of injection (BOI). This is accomplished by using an injector (Fig. 4) with a larger (½ inch) diameter plunger, similar to but different in some design details from the fuel injectors used in the EMD 645B engine, and timing the injector so that BOI is retarded. Since the injection rate is higher with these injectors the end of injection (EOI) is not significantly affected, even with retarded BOI.

This strategy is particularly attractive because no new technology needs to be developed and, as noted above, the fuel efficiency of the 645E3 engine can be maintained.

The engines that are candidates for this retrofit were used in pre-1979 series locomotives such as the GP40, SD40 and SD45.

The data obtained for the 645E3 engine during these initial tests indicates:

1. A 17% reduction in NOx (10.8 g/BHP-hr)
2. Fuel consumption at full load remained constant
3. Carbon monoxide emissons were reduced by 12%
4. Hydrocarbon emissions were unchanged.
5. Smoke was slightly higher.

Emission Reductions on Current Engines

EMD introduced the 4067 BHP 710G Series turbocharged two-stroke diesel engine in 1984 and the 4,100 BHP 710GA Series in 1990.

EMD 16-710G Engine

This engine series represents a significant step in EMD's emission and fuel economy improvement program. The Model 710G engine exhibits lower gaseous emissions than its Model 645 engine predecessor and has a high degree of environmental acceptability. Exhaust emissions of the 710G rail engines are well below UIC/ORE limits (Fig. 5).

1. Carbon monoxide - 90 percent of 645FB engine rate.
2. Oxides of nitrogen - 85% of 645FB engine rate.
3. Hydro-carbons - 29% of 645F3B engine rate.
4. Exhaust opacity at rated output is essentially invisible (four to five percent) at sea level with 90 degrees F (32.2 degrees C) air into the engine.

Brake specific fuel consumption of the 710G was also improved. The BSFC at rated load is ten percent lower than the 1980 model 645F engine and four percent lower than the latest FB model introduced in 1982.

The primary performance features are a high efficiency turbocharger, a new GM unit injector, and optimized thermal efficiency.

Turbocharger (Fig. 6)

The large improvement in increased air flow and efficiency on the 710G series turbocharger could not have been attained without extensive design and development of the turbocharger compressor and turbine stages. A significant four percentage point net gain in turbocharger combined efficiency has been attained.

The EMD design concept of a positive, mechanical gear drive through an overrunning clutch was retained in the G series design because of its many advantages such as rapid response from quick air delivery for starting, for suddenly applied load acceptance, and to provide an adequate air supply to the engine cylinders at part load thereby reducing emissions and attaining excellent part load fuel economy.

Injector

The 710G engine uses the GM unit fuel injector which was redesigned to incorporate a larger diameter plunger for a higher fuel injector rate. The plunger diameter is 0.5625 inch and the injector spray tip contains seven orifices drilled at an included angle of 150 degrees. The relatively flat, well atomized spray produced with this configuration is an excellent match to the combustion chamber over the entire operating speed and load range of the engine.

In comparison with the 645FB engine injector, at the same fuel rate, the beginning of injection at full load is retarded approximately 4 degrees and the end of injection is the same for reduction in injection duration of approximately 4 degrees (Fig. 7).

Thermal Efficiency

Optimization of the timing events during the engine cycle is of prime importance and directly affects engine performance. Performance trends of exhaust valve duration and timing, compression ratio, and liner port timing for the 710G engine were established through the evaluation of extensive engine test data and computer modeling. The 710G piston crown takes advantage of a symmetrical combustion chamber made up of a toroidal shape with high outer rim and a narrow piston to head clearance (Fig. 8).

EMD 16-710GA Engine

Further improvements were designed into EMD's newest latest engine, the 710GA model introduced in 1990. The 4,100 BHP 900 RPM

16-710G3A, offers reduced emissions and improved fuel economy compared to the previous model, the 16-710G3.

* NOx emissions were reduced by approximately 12%

* Full load fuel economy improvement of 1.5%.

* Duty cycle fuel economy improvement of 1.8%.

These improvements were made possible by the following improvements:

Four pass aftercooler - Reduction of combustion air temperature.

Cylinder liners - Changed to 18 degrees swirl and 138 degree port timing.

Injector - Reduced air flow injector tips. TDC Injector timing @TDC vs. 1 degree ATDC.

The entire 16-710GA package can be retrofitted to any SD60 or GP60 built.

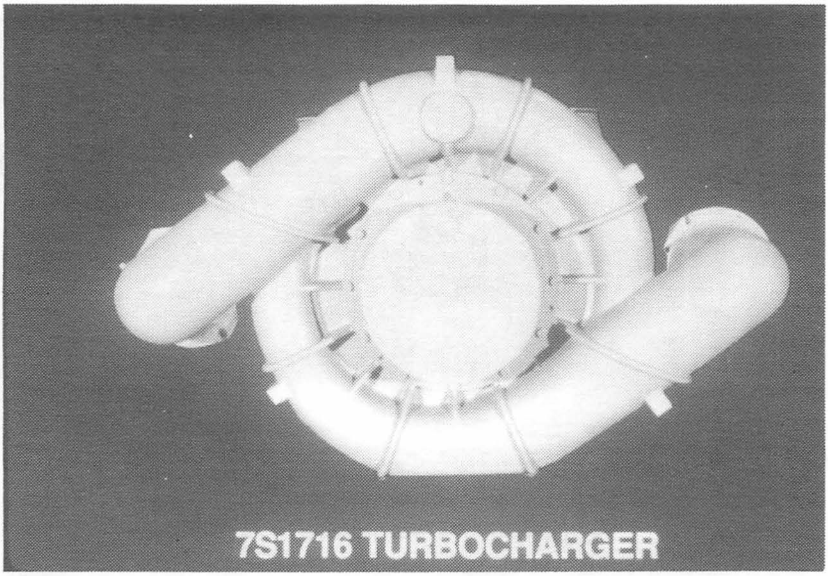

7S1716 TURBOCHARGER

Fig. 1

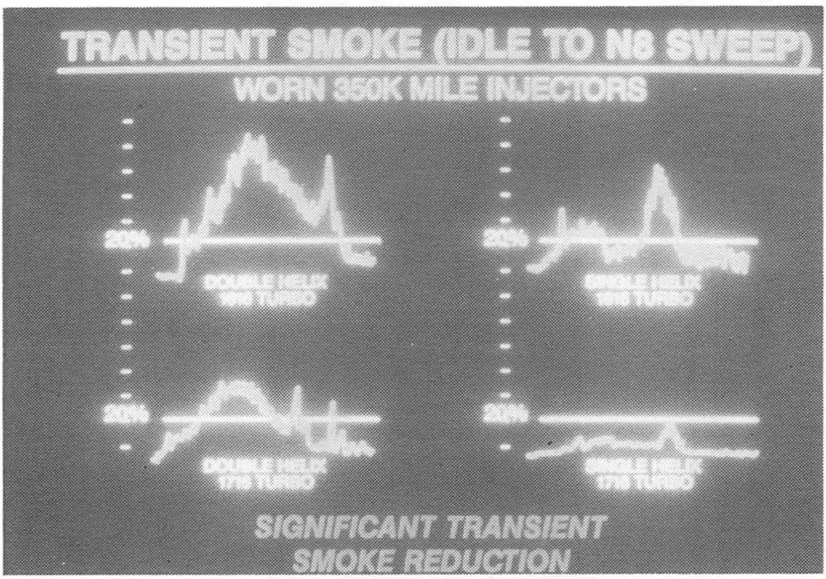

TRANSIENT SMOKE (IDLE TO N8 SWEEP)
WORN 350K MILE INJECTORS
SIGNIFICANT TRANSIENT
SMOKE REDUCTION

Fig. 2

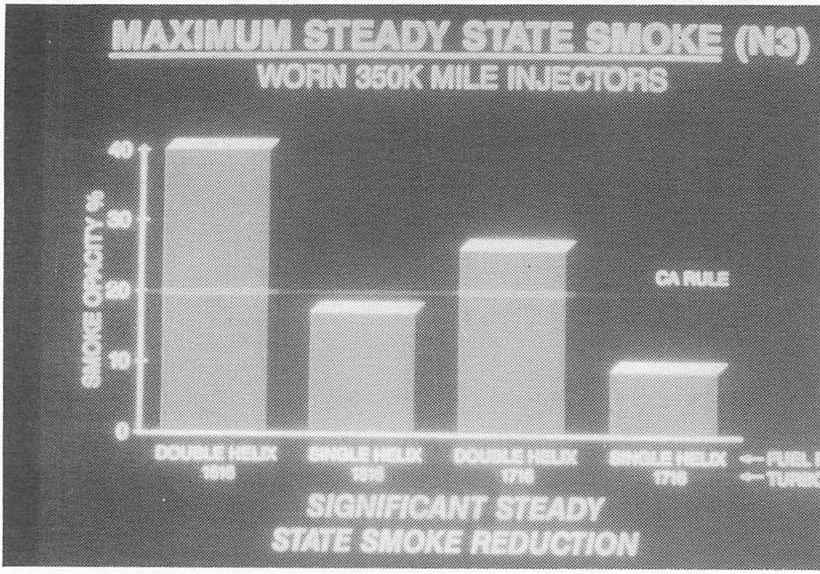

MAXIMUM STEADY STATE SMOKE (N3)
WORN 350K MILE INJECTORS
SMOKE OPACITY %
40
30
20
10
0
CA RULE
DOUBLE HELIX
SINGLE HELIX
DOUBLE HELIX
1710
SINGLE HELIX
1710
SIGNIFICANT STEADY
STATE SMOKE REDUCTION

Fig. 3


E3B
FUEL
INJECTOR
Larger Diameter Plunger-.500 inch
Low Sac Spray Tip
Improves Engine Combustion and Thermal Efficiency

Fig. 4

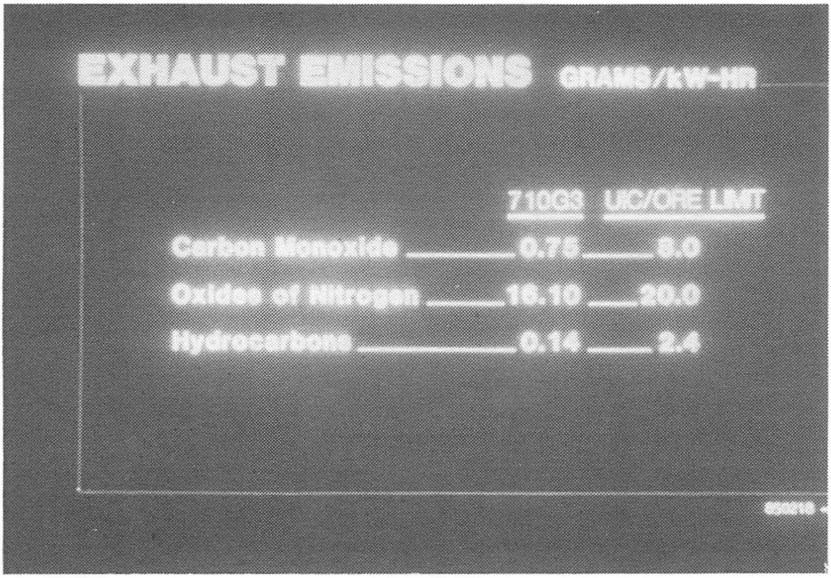

EXHAUST EMISSIONS GRAMS/kW-HR
710G3 UIC/ORE LIMIT
Carbon Monoxide 0.75 8.0
Oxides of Nitrogen 16.10 20.0
Hydrocarbons 0.14 2.4

Fig. 5

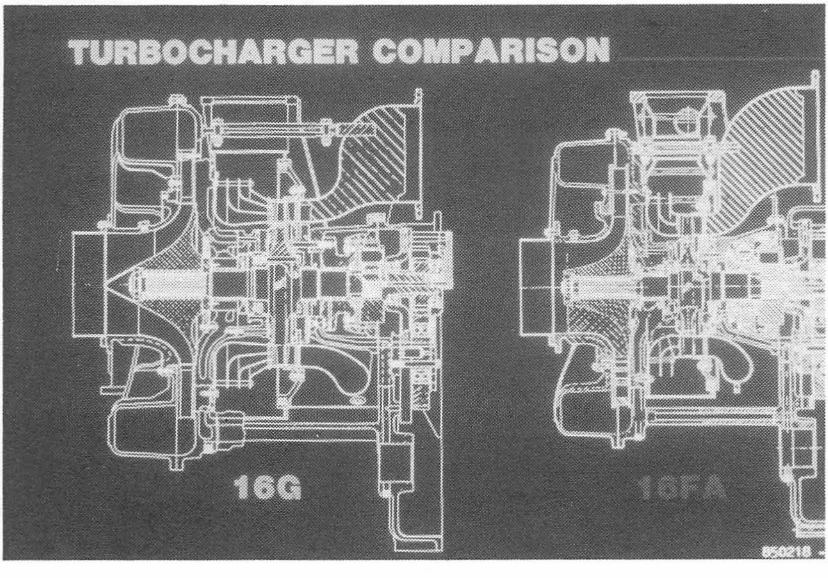

TURBOCHARGER COMPARISON
16G
16FA

Fig. 6

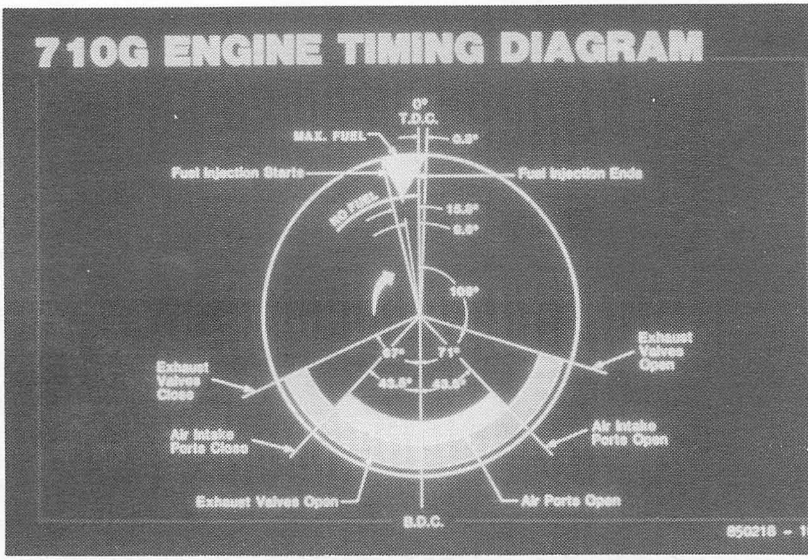

710G ENGINE TIMING DIAGRAM
0°
T.D.C.
MAX. FUEL
Fuel Injection Starts
Fuel Injection Ends
71°
Exhaust Valves Open
Exhaust Valves Close
Air Intake Ports Close
Air Intake Ports Open
Exhaust Valves Open
Air Ports Open
B.D.C.

Fig. 7

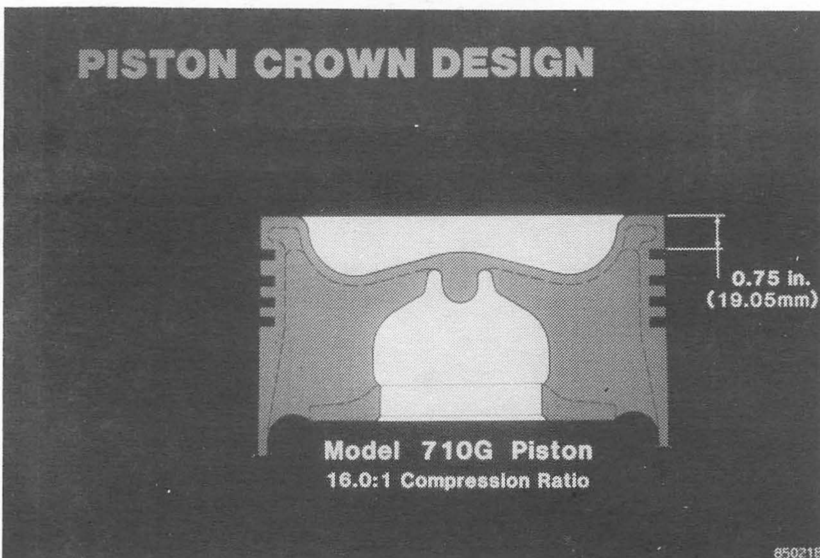

PISTON CROWN DESIGN
0.75 in.
(19.05mm)
Model 710G Piston
16.0:1 Compression Ratio
850218

Fig. 8

IV. STATIONARY AND DYNAMIC TEST PROCEDURE FOR LOCOMOTIVE FUEL EFFICIENCY MEASUREMENT

Presented by: Chuck Kunkel

Railroad's sole use for locomotives is to pull trains. Performance of a locomotive should ideally be measured at the coupler, with fuel efficiency being one of the most important elements of the performance equation.

However, with existing technology, total performance cannot be measured with meaningful accuracy. Adequate accuracy can be achieved by measurements at the output of the locomotive's main alternator while carefully measuring parasitic loads and the amount of fuel consumed by the locomotives' diesel engine.

Fuel efficiency tests are conducted to:

1. Verify locomotive fuel consumption and horsepower, advertised by the engine builders and locomotive manufacturers.
2. Determine fuel consumption of different engine configurations.
3. Calculate consumption to estimate fuel budgets for forecast traffic volumes.
4. Determine fuel consumption changes because of the addition of auxiliary equipment which puts more load on the engine and adds to locomotive engine wear, a factor in determining economic overhaul intervals.

Two types of fuel consumption tests are utilized by U.S. railroads. They are stationary and road tests. In stationary testing, an instrumented locomotive is connected to an external load box so that electricity generated by the diesel engine/generator set is disspated as heat through a set of electrical resistors. In road testing, an instrumented locomotive is connected to an actual train allowing the locomotive to function during normal train operation.

This paper will present this committee's recommended procedures on conducting either type of test.

Locomotive Efficiency

Locomotive efficiency can be defined as the work done per pound of fuel consumed. The problem comes in trying to standardize on how the work will be measured and what type of fuel to base it on.

This measure of fuel efficiency is called "specific fuel consumption". For locomotive operation, the industry has settled on two equally valid rating units:

1. The amount of standard #2 diesel fuel to produce one horsepower hour. The smaller the number the better.
2. The number of kilowatt hours produced by one U.S. gallon of standard #2 diesel fuel. The larger the number the better.

Fuel Specifications

Standard #2 diesel fuel has a specific gravity (SG) of .846 which equates to approximately 7.043 pounds per gallon at 60°F and is able to produce 19,350 BTU's of combustion energy from each pound. Historically, the fractions of crude oil stock used to create #2 diesel fuel was standardized from all refineries so you were assured of a fixed energy density per pound of fuel. Today, fuel energy density can vary and be less than standard though the mass density may be correct.

That is why it is important that samples of the test fuel be sent to a modern chemistry lab with an adiabatic calorimeter to determine the heating value in BTU's/lb. All test data then can be corrected back to standard #2 diesel fuel which is 19,350 BTU's/lb.

Fuel Measurement Methods

Stationary:

You obtain fuel consumption rates while operating in a steady state condition over an extended period of time in each throttle notch while trying to control the ambient and operating conditions as much as possible. Fuel consumption can be measured by using volume flow meters or by weight, while power measurements in kilowatt hours produced are made over the same period of time.

Major errors can occur using volume flow meters.

Fuel increases in volume as it is heated within the engine, decreasing its energy content per gallon. Therefore if the fuel is returned to the locomotive fuel tank, the volume due to temperature rise needs to be taken into account.

Return fuel may also be aerated which could cause an increase in volume, decreasing the energy content per gallon, the degree depending on whether the meter readings are taken before or after the relief valve. Also gas vapors are produced at the injectors which leak into the return fuel. If volume flow meters are used the fuel must pass through a deaerator or the line pressure kept up to level sufficient to prevent the gas from coming out of solution.

Major errors with weighted fuel tank:

If the fuel is returned to a weighted test fuel tank, the tank's temperature will rise, causing the fuel volume to increase and engine horsepower to drop. The return fuel should pass through a heat exchanger of sufficient capacity to cool the fuel at or near the temperature of the fuel in the test tank.

Therefore, it is recommended that the weighted test fuel tank approach be used.

Power Measurement Specifications

There are various definitions for the "useful" power produced by a locomotive. The four common ones are:

1. Gross engine horsepower.
2. Horsepower into the alternator.
3. Kilowatts produced by the alternator.
4. Drawbar pull.

O.E.M.'s usually publish the horsepower into the alternator, (2), but this is virtually impossible to measure in the field. That makes it impossible to figure gross engine horsepower (1) even if you could measure auxiliary power draw. With the drawbar pull method it is very difficult to get meaningful over the road measurements of coupler work because of highly cyclic nature of the coupler forces caused by train dynamics and the reliability of the equipment used to measure these forces.

That leaves method 3, kilowatts produced by the alternator, as the best way to measure power. It is relatively easy to find access to traction motor power cables to install calibrated sensors. Keep in mind that the horsepower that finally gets to the rail is less than the input to the traction motors because of:

1. Traction motor heating losses and resistance;
2. Brush and commutation losses;
3. Gear ratio, tooth design, gear lube viscosity;
4. Wheel profile, suspension equalization etc.

Therefore the definition for power that will be used is:

The equivalent pounds of #2 diesel fuel at 19,350 BTU's per pound, at 60°F, to produce one horsepower for one hour into the traction motors. As an electrical measurement this equals 745.7 watts (amps x volts) for one

hour.

Measuring Power

Ideally, the same system which is used to measure the instantaneous KW power into the traction motors or the load box can be used to integrate it over time to produce the kilowatt hours of work done. In that way the same system of proven accuracy and calibration can be used for stationary or over the road tests. This measurement system must have its linearity calibration accuracy proven under conditions of low, medium and high currents and voltage, checked and rechecked during the test period to make sure it does not drift with time or temperature.

A data logging system is most advantageous for stationary tests and mandatory for over the road tests. It reads volts and amps simultaneously, then multiplies them together to get power, about 60 times per second. The logger calculates a running three-second average in a buffer with last-in last-out handling of the 180 readings. This is required to eliminate both the effects of the AC noise spikes riding on top of a DC signal and the typical out-of-phase nature of cyclic variations of volts and current.

Commerical recording systems are available. These commerical systems can vary by as much as 20% from each other. It is believed these meters are prone to reading AC noise riding on the DC signals, causing false readings as indicated above. Also if generator output voltage is equal to or greater than the maximum the meter is designed to handle, a precision voltage divider must be used so that excessive voltage will not damage the equipment.

Extreme caution is urged in the selection of any power measuring and recording system because the validity of the whole test depends on it.

*** Electrical Cautions ***

Care must be taken during these tests because very high voltage signals are being brought out of the high voltage cabinet and measured. This can destroy equipment or cause loss of life. The voltage drop across a shunt may only be 30 millivolts but it could be at 1,300 volts with respect to neutral potential. Digital voltmeters should be checked that they can withstand that voltage.

Data logging equipment should be spike protected to at least 4,000 volts at an energy level of 300 joules for 50 microseconds. Spikes can occur in a companion locomotive such as a traction motor flash over and travel through the couplers and frame and blow out the sensitive digital components.

Stationary Fuel Testing

Advantages and Disadvantages of Load Box Testing:

Load box testing is the least expensive type of efficiency test with equipment readily available but subject to reading and calibration errors.

Usually digital voltmeters with shunts are used which are not prone to AC signal error riding on top of the DC signals. Test shunts or transductors should be used rather than the nominal factory installed devices which are accurate to within 3% at best and have been found to read high compared to calibrated devices.

While you can test alternator efficiency at the equivalent of low, medium and high speeds through proper load box settings, it is difficult to know how it compares to real train operations as far as the percentage of time a locomotive will spend in each speed range at each throttle notch.

Also, load box tests do not take in-

to account wind resistance, wheel slip and wheel creep control capability, traction motor efficiency and losses versus speed and load.

Procedures:

1. All stationary engine conditions and settings need to be thoroughly checked and recorded, including rack setting, injection timing and all feedback voltages.
2. Install clean air filters.
3. Modify the locomotive fuel system to allow switching from the fuel supply on the locomotive to the source of the test fuel ensuring no leakage of locomotive fuel into the test fuel system. See Fig. 9 for an example of fuel test system schematic.
4. Instrument calibration needs to be checked to ensure there is no calibration drift with temperature during test runs.
5. Engine and alternator should be at operating temperatures with water, fuel, exhaust and air inlet temperatures and pressures correct for each throttle notch.
6. Record barometric pressure at least once per hour.
7. Ensure air compressor is unloaded or non-rotating state.
8. Turn off the lights, cab heaters, air conditionerrs and any other equipment not essential to the test.
9. Record by throttle notch the steady state volts and amps or power draw of the cooling fans, or in the case of an EMD locomotive the amount of time each cooling fan runs, while operating under all combinations along with the appropriate temperatures, pressures, RPM etc. You should continue to record all data till the accuracy of the readings is less than 1/10th of one percent with no noticeable trend up or down.
10. Load box should be equipped with a recently calibrated shunt, matched to the current to be measured and the meter taking the readings. Alternator voltage should be read with a 4½ digit digital voltmeter accurate to 0.2%.
11. Record average along with minimum and maximum for notch speeds, power levels, fuel rate, air temperatures, pressures and ambient conditions.

Static Fuel Efficiency Test (U.P. NLR Testing)

Testing Site considerations.

The Union Pacific Railroad conducted a series of fuel consumption tests to verify the manufacturers' fuel consumption data on the newest configuration of diesel engines. The GE Dash 8 locomotive with 7FDL16 engine with 1716 turbo and two pipe manifold and the EMD SD60M locomotive with 710G3A engine with L11 liner, tangent flow head and 4 pass aftercooler were tested and compared to old Dash 8 and SD60M engines without the latest refinements. Also other models of locomotives were tested to verify the injector change out interval.

Little Rock, Arkansas was chosen for the test site based on:

* convenience for any work that might be required on the locomotive requiring trained personnel;
* noise restrictions because of the high noise level over sustained periods of time;
* ambient conditions to avoid large temperature and humidity swings;
* track location: large enough to accommodate test consist of locomotive and tank car if it is the source for the fuel supply and located away from any structures that would restrict adequate air movement for cooling. Access to water supply to cool the return

fuel from the diesel engine as well as compressed air supply for control air, because the air compressor was blocked in unloaded condition.

Measurement of Horsepower.

A computer controlled Fluke 8842A digital voltmeter with a Julie Laboratories voltage divider was used to measure main alternator output voltage and the voltage drop across a recently calibrated Ram Meter 200 milivolt, 6,000 amp current shunt installed on the main alternator positive load cables leading to the load box. The shunt was obtained from an electrical supplier and was recalibrated per the manufacturers' specifications.

Measuring engine speed:

Engine RPM was observed on the screen of the locomotive's on-board diagnostic display when equipped, and a magnetic pickup was mounted next to the engine flywheel to sense passing gear teeth which were counted and converted to engine RPM with readout in test car.

Measuring fuel consumption:

The fuel consumed during the test was sent to two different chemistry labs to verify the heating value and specific gravity. The fuel consumed during the test was accurately determined by using a test fuel tank mounted on a Weightronix electronic scale.

The tank had adequate capacity to allow at least one test run, at full engine throttle, for the time period designated.

The test fuel tank was enclosed in a shelter to reduce the chance of contaminating the test fuel with dirt or rain water, reduce rapid temperature variations and prevent wind currents from affecting scale readings.

The mechanism used to control the test fuel transfer from the fuel supply to the test tank was a pneumatic pump with a solenoid valve provided positive shutoff so no additional fuel was added to the tank while making a test run. The pump and solenoid valve were controlled from the test car.

The locomotive fuel system was modified to allow the switch from the on-board fuel supply to the test fuel. All the return fuel, not used by the engine, was returned to the test fuel tank.

A heat exchanger, supplied by cold tap water, was placed in the return fuel line to stabilize the fuel temperature before the fuel went back to the test tank.

The fuel suction line, return fuel line and test fuel supply line were positioned so they did not touch the test tank as that would affect the scale readings. Thin walled electrical conduit was used for the suction line to avoid weight errors due to buoyancy.

The return and supply lines should not extend below the surface of the fuel.

Remember not to contaminate the test fuel with the on-board fuel. This can be accomplished by operating on the test fuel for a period of time thus purging locomotive fuel from the system.

Measuring fuel temperature:

The engine inlet fuel temperature was measured to determine engine stability. A T-type thermocouple with analog output signals, accurate within 1°F was installed in the secondary fuel filter housing mounted on the engine.

Measuring air temperature:

Inlet air temperature was measured for normalizing engine horsepower. T-type thermocouples with analog output signals, accurate to 1°F were installed two in each intake air grill for a total of four per locomotive.

Measuring barometric pressure:

The barometric pressure reading is necessary for normalizing engine horsepower. The barometric pressure was taken from a remote Setra electronic digital barometer located in the test car. This instrument read to hundredths of inches of mercury with less than 1 percent error. The barometer produced an electronic signal that was fed into the PC data logger.

Measuring engine coolant temperature:

The coolant temperature was measured to determine if the engine was operating properly. For this test a T-type thermocouple was placed in the coolant line at the inlet to the water pump. Signals from the coolant, fuel and air temperature thermocouple were converted by a Fluke Hydra data aquisition front end interfaced to a computer.

Measuring lube oil temperature:

The lube oil temperature is an important measure of engine stability and proper operation. Lube oil temperature was not documented during this test. A T-type thermocouple could be placed in lube oil line at the inlets to the oil pump. This thermocouple should be accurate to within 1°F.

Measuring auxiliary loads:

During this static fuel consumption test the auxiliary equipment was unloaded, except for the cooling fans necessary to run the engine. The unloaded drag horsepower for the auxiliary equipment was obtained from the locomotive builder. The expected horsepower load from the cooling fans was also obtained from the builder. The data collection was automated, therefore the number of cooling fans running and the speed of fans was obtained from a sensor circuit attached to the power leads to the fans.

Data recording:

Locomotive power, fuel weight, parasitic loads, fuel, air and water temperatures were all recorded using a IBM 386 personal computer. All measurements were taken every two seconds during each test run. The computer then calculated the corrected horsepowers and fuel efficiencies to standard AAR conditions. These standard conditions are:

A. AT = 60°F
B. BP = 28.86 in. Hg
C. SpGr = 0.845
D. FT = 60°F
E. HV = 19350 BTU/lb.

All fuel consumption information published by the locomotive builders are corrected to these standard values. It is the comparison of your test results to the builder's information that tells you how your locomotive is operating.

(See Appendix A for analysis to calculate specific fuel consumption for Dash 8 and SD60M locomotives).

The chart (Fig. 10) shows typical load box test results from a number of stationary tests that were run on two locomotives. The comparison to the over-the-road results will be seen later in this paper.

The specific fuel consumption can be calculated for each of the throttle notches stated on the chart. Generally a duty cycle or percent of time in each throttle notch is applied to calculate the total net traction specific fuel consumption for comparison between locomotives.

The question of real importance to the railroad is what is the overall operating efficiency of a given locomotive on a typical run on a train? How realistic can a prediction made from a stationary fuel consumption test be? The remainder of this paper will attempt to qualify this.

Road Test

Over-the-road performance testing has several potential problems which could lead to erroneous results if they are not controlled. Locomotive efficiency varies considerably by notch so we need to define the conditions that affect efficiency so data can be compared to tests previously run.

The attempt should be made to try to get the same duty cycle percentages on repetitive runs on the same track with the same train and operator, changing throttle notches at the same milepost. This is often not possible. What was found to work was allowing the operator to run normally, specifying target speeds by track segments.

Final results and relative comparisons between locomotives should be grouped by train type, that is:

Heavy drag - 1.0 HP per trailing ton

General freight - 2.0 HP per trailing ton.

If two locomotives are being compared the only fair way to test locomotives over the road is with simultaneous operation on the same train, alternating positions and directions based on time of day, weather conditions, etc., not to give any one locomotive an unintentional advantage over the other. The test train operation should be set up so that as close as possible it emulates the type of duty the locomotive will see on the railroad.

Because of many inherent problems measuring fuel consumption during over-the-road testing, the approach that worked consistently was leveling the locomotive and refilling to a specified full mark after each trip.

During test setup, you need to weigh the risk of how much data would be lost if something were to go wrong with the locomotive or the recording equipment.

Testing Two Locomotives Simultaneously:

If testing two locomotives simultaneously, should one locomotive be taken off line for any reason, the other test locomotive should also be taken off line so they both see identical service. To ensure that all data collected are valid, each locomotive should be equipped with horsepower or KW-hour meters and throttle notch indicators mounted in the cabs; or better yet these signals can be brought to one monitoring location.

The range and power levels by notch expected for each locomotive should be posted near the indicators so that any deviation outside the expected range can be investigated immediately so that only one test run will be lost.

The locomotives should be load tested by train line frequency between test trips to ensure that power levels remain within a preestablished range and that each locomotive sees the same service. The fuel rates can be assumed to remain the same if the power levels are correct.

After each test trip the locomotives should be shut down and filled with fuel, and the data recording system down loaded. If there is considerable idling time or if any load testing is performed between test trips, it should be considered a separate run and the fuel tanks refilled and data logger down loaded prior to leaving on the next test trip. This way trip efficiency variations are not clouded by different amounts of idle or load test fuel consumption.

A Successful Over the Road Test

A test was run on 45 miles of dedicated track belonging to a mine in Minnesota. The test was run to make a comparison between the operating efficiency of two locomotives mentioned at the end of the stationary test section.

Power Measurement:

Kilowatt-hour production by each locomotive was recorded on data loggers provided by Trac-Rail, now offered by ZRT Electronics. This system proved to be very accurate and immune to recording erroneous power levels caused by AC commutation noise. Calibration accuracy was repeated througout the test series. In addition to KW hours and throttle notch times the locomotives' fan and air compressor times by notch; water, air and fuel temperature; engine RPM, engine and locomotive fault recordings were all recorded.

Voltage and ampere sensing calibrations were checked with a bank of three precision 5,000-amp shunts connected in series each with its own digital voltmeter. The overall absolute accuracy of the power measurement system was within 2%. Greater accuracy could have been achieved had 4½ digit 0.1% digital voltmeters been available for the test.

Each test run produced lots of raw data and a computer based system was used to do the tedious calculation and provide the results in meaningful comparisons. Fuel consumption data were in addition to this.

Typical data include:

— raw data for one trip of one locomotive showing KW hours produced by throttle notch.

— Notch time in hour/minute/second format.

— Calculated times in decimal format and notch percentages by trip and by day.

— KW hours by notch, by trip and totals for the day.

— Measured average KW produced in each notch for each trip.

— Cumulative efficiency of both locomotives by trip.

After all instrumentation was equipped and calibrated and engine checks were made, complete stationary load box fuel consumption testing was performed similar to the stationary testing mentioned in the first part of the paper (Fig. 10).

The locomotives were then assigned specific fuel fill sites.

The rail was marked with a paint spot at the same wheel contact point requiring the locomotive face the same direction at each fuel fill.

The locomotive was then jacked to a specific height above a reference point to ensure it was in the same attitude on its springs. A spike was then placed in the ground at one corner of the locomotive beneath the side sill. The distance from the underside of the side sill to the spike was measured and a steel rod ground to a length so that it just passes under the side sill. That rod then became the jacking reference for that locomotive's fill site.

The fuel was then pumped from the fuel tank; then the drain plug removed for complete draining. Test fuel was then pumped into the tank using 10 GPM pumps from weighed, serialized barrels. The pumps had remote control capability and had very precise control in returning the fuel to the full mark.

An electronic scale with resolution to within at least 0.2 pounds was used to weigh the full and emptied barrels. A sufficient quantity of barrels was used so that both locomotives were filled after each test run without having to stop and refill and weigh barrels. Barrels were left outside, so protection was provided so that rain would not leak into the fuel.

After the tank was filled to a specific level, the sight glass was scribed with a line at the bottom of the fuel meniscus. This then became the reference point to which all future fills were made.

Actual Test:

After each test the locomotive was shut down on its own fill site, jacked to the correct height and fuel pumped from the barrels one at a time until fuel level was back to the full mark. The data loggers were down loaded, counters zeroed and train parameters and ambient conditions recorded. The locomotives were then put in the correct order for the next test and connected to the train.

After the fuel tank was full, the fuel remaining in the fill line was pumped back into the last barrel so no fuel was lost. The empty barrels were weighed, including the last partial barrel to determine the net fill.

There was some question as to the accuracy of the fuel fill method, relative to the ability of personnel to fill to the scribed full mark. The results for the 18 test trips were combined to reduce the potential reading errors.

Fig. 11 shows the effectiveness of the fuel weighing method in terms of initial fill versus the weight of final drain. The worst case was one locomotive which had a 0.35% overall error. This is unexplained but is considered to be insignificant because it equates to 60 lbs. in 17,000 lbs. handled.

Comparing Stationary Load Box to Over the Road Testing

Fig. 10 takes the load box data, multiplying it by the actual over-the-road duty cycle to see how close the predictions of power and fuel came to the actual measured results. The projections did vary slightly from the actual trips. On the left is the duty cycle percentage and the actual hours spent in each notch. In the light highlighted areas are the projections by throttle notch. Across the bottom are totals.

Fig. 11 shows the projected consumption in gallons for both locomotives and below that is the equivalent volume of fuel actually added to the tanks. As can be seen this was a close projection of only 14 gallons more than actual. The explanation for this is that part of the time each unit is in current limiting, either while starting the train or climbing a hill at low speed, so full notch horsepower is not being developed. A second reason is that for up to 30 seconds after each throttle notch change, the power is ramping up to the new level so the power produced and fuel consumed are less than produced on the stationary load box test.

Looking at the kilowatt-hours projection again, actual power produced was approximately 1.5% less than projected. The explanation for the projection being higher is the same as stated for the fuel projection.

Therefore the power produced and fuel consumed for a given duty cycle on the load box test will always be higher than the over the road test result. The percentage reduction is fairly repeatable and with experience can be estimated by reviewing the number of heavy pull starts and percentage of time spent in high throttle notch at low speed.

Fig. 12 shows the projected efficiencies versus the actual measured efficiencies for both locomotives. The projected relative efficiency difference and the actual differences were very close, a little above 2.5%.

Fig. 12 was based on the actual test fuel at 7.311 lbs/gal. Another chart, Fig. 13, shows the slightly lower absolute efficiency number corrected for standard #2 diesel fuel. The relative percentage differences remain the same.

Conclusion

As seen by the test result comparisons, the projected stationary load box relative performance was within 0.6% of the time consuming, labor intensive over the road test efficiency just described.

Because of the closeness of the results, this committee recommends that if you determine a fuel consumption test must be run, a stationary test will give you adequate results with a reasonable amount of accuracy.

For those of you who have experience conducting over-the-road testing, your experience will tell you what percentage of stationary testing will reflect the actual over-the-road consumption.

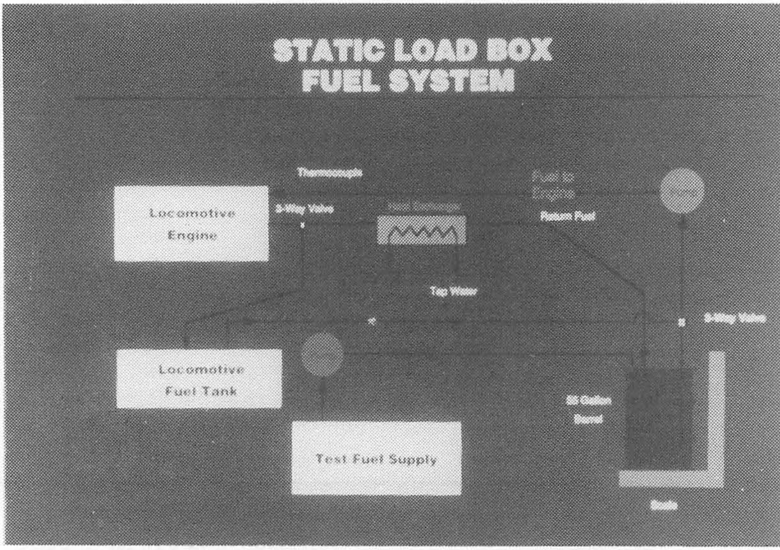
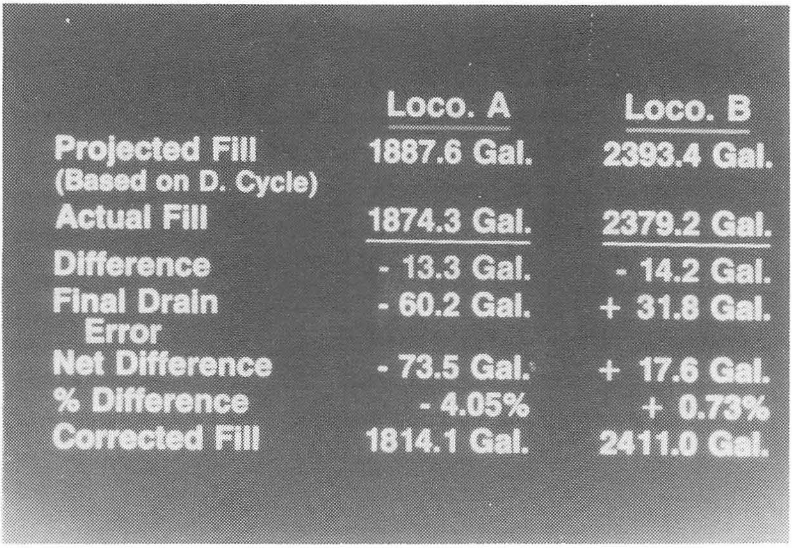


Fig. 9

Duty Cycle Consumption Projection

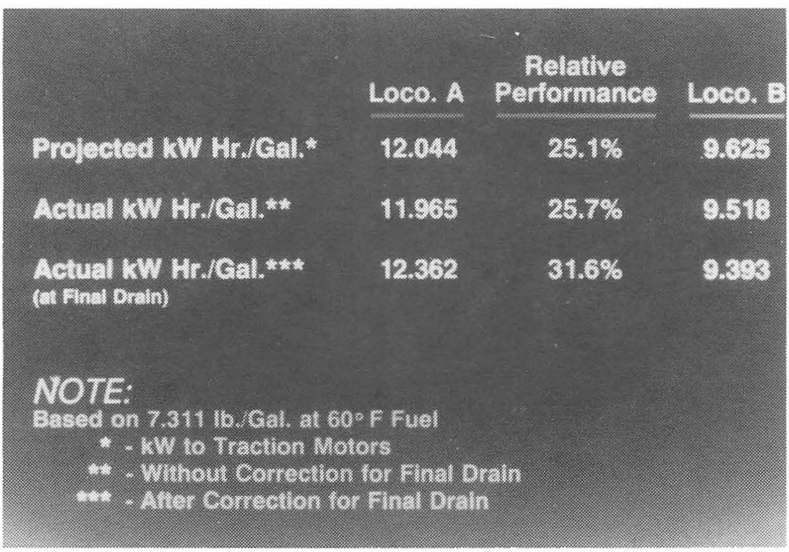
			Loco. A		Loco. B	
Notch	%	Hours	Proj. Gal.	Proj. kW Hr.	Proj. Gal.	Proj. kW Hr.
8	8.68	9.93	1,036.2	14,276.3	1,180.6	13,835.9
7	2.20	2.52	225.1	3,077.8	254.4	3,100.8
6	2.30	2.64	189.3	2,535.0	211.3	2,678.3
5	1.24	1.42	79.4	1,032.4	93.6	1,217.9
4	1.14	1.30	56.5	708.5	65.1	851.9
3	1.40	1.60	44.9	526.6	52.1	658.7
2	2.35	2.68	35.7	417.6	50.1	598.1
1	3.24	3.71	16.6	160.1	21.3	95.0
Idle	70.42	80.51	162.2	–	359.1	–
DB Low	0.94	1.09	2.3	–	5.0	–
DB Hi	6.09	6.95	39.3	–	100.9	–
Total	100.00	114.33	1,887.6	22,734.3	2,393.4	23,036.6

Fig. 10



	Loco. A	Loco. B
Projected Fill (Based on D. Cycle)	1887.6 Gal.	2393.4 Gal.
Actual Fill	1874.3 Gal.	2379.2 Gal.
Difference	- 13.3 Gal.	- 14.2 Gal.
Final Drain Error	- 60.2 Gal.	+ 31.8 Gal.
Net Difference	- 73.5 Gal.	+ 17.6 Gal.
% Difference	- 4.05%	+ 0.73%
Corrected Fill	1814.1 Gal.	2411.0 Gal.

Fig. 11



	Loco. A	Relative Performance	Loco. B
Projected kW Hr./Gal.*	12.044	25.1%	9.625
Actual kW Hr./Gal.**	11.965	25.7%	9.518
Actual kW Hr./Gal.*** (at Final Drain)	12.362	31.6%	9.393

NOTE:
Based on 7.311 lb./Gal. at 60° F Fuel
* - kW to Traction Motors
** - Without Correction for Final Drain
*** - After Correction for Final Drain

Fig. 12

	Loco. A	Relative Performance	Loco. B
Projected kW Hr./Gal.*	11.603	25.1%	9.272
Actual kW Hr./Gal.**	11.526	25.7%	9.169
Actual kW Hr./Gal.*** (at Final Drain)	11.909	31.6%	9.049

NOTE:
Based on 7.043 lb./Gal. at 60° F Fuel
* - kW to Traction Motors
** - Without Correction for Final Drain
*** - After Correction for Final Drain

Fig. 13

APPENDIX A

DASH 8 ANALYSIS

Locomotive performance is affected by environmental conditions such as air temperature (AT), barometric pressure (BP), fuel specific gravity (SpGr), fuel temperature (FT) and fuel higher heating value (HHV). So that the results of different tests may be compared, they are, by convention, corrected to AAR standard conditions, which are

$$\begin{aligned} AT &= 60^{o}F \\ BP &= 28.86 \text{ in. Hg} \\ SpGr &= 0.845 \\ FT &= 60^{o}F \\ HHV &= 19350 \text{ BTU/lb.} \end{aligned}$$

The brake horsepower produced by a Dash 8-40C locomotive is regulated at a prescribed level by its controlling microprocessor. As the demands of accessories such as cooling fans and air compressor change, net horsepower varies. Changes in environmental factors like air pressure and temperature cause the fuel rate to be adjusted so that the diesel engine maintains the prescribed brake horsepower.

The net horsepower produced by the locomotive at test conditions is

$$NPH_t = \frac{V \text{ x } A}{746}$$

where V and A are the main alternator voltage and current. The brake horsepower is

$$BHP = \frac{NHP_t}{Eff} + XHP_t$$

where Eff is the alternator's efficiency, which is a function of throttle position and load point. Data for main alternator efficiency, provided by General Electric, are listed in Table 1.

The aggregate accessory power at test conditions is

$$XHP_t = AuxAltHP + \frac{FanHP + AuxBlwrHP + EqptBlwrHP + ComprHP}{AuxEff}$$

where AuxAltHP is the auxiliary alternator power, FanHP is the radiator fan power, AuxBlwrHP is the auxiliary alternator blower power, EqptBlwrHP is the equipment blower power, ComprHP is the unloaded air compressor power and AuxEff is the efficiency of the auxiliary alternator.

At standard conditions, the net horsepower is

$$NHP_s = Eff \text{ x } (BHP - XHP_s)$$

where XHP_s is the accessory power at standard conditions. During actual service, the compressor does not rotate unless it is pumping air. Since rating conditions for specific fuel consumption assume the compressor is not pumping, unloaded compressor power is not part of XHP_s. Values for the various components of accessory power were supplied by General Electric and are listed in Table 2.

Since environmental factors affect the efficiency with which the diesel engine burns its fuel, the fuel consumption rate must be corrected to standard conditions. For the Dash 8-40C, the correction factors are for air temperatures.

$$A = 1 + 5.386 \text{ x } 10^{4} \text{ x } (60 - AT)$$

for barometric pressure,

$$B = \left[\frac{28.86}{BP}\right]^{b} \qquad b = \begin{cases} 0.093, & \text{T5 - T8} \\ 0.320, & \text{otherwise} \end{cases}$$

and for fuel higher heating value,

$$E = \frac{HHV}{19350}$$

Thus, at standard conditions, the fuel consumption rate is

$$FR_s = FR_t \times \frac{E}{A \times B}$$

where FR_t is the fuel rate at test conditions. Brake specific fuel consumption is

$$BSFC_s = \frac{FR_s}{BHP}$$

and net specific fuel consumption is

$$NSFC_s = \frac{FR_s}{NHP_s}$$

In idle and dynamic brake NHP=0. BHP varies with auxiliary HP and causes fuel rate to vary accordingly. At standard conditions

$$BHP_s = XHP_s \text{ and } FR_s = FR + \frac{F}{AB} + SX\,(XHP_s - XHP_x)$$

when S=0.3 lb/hr per HP as rate of change of fuel rate with brake horsepower.

Table 1: Main Alternator Efficiencies

Throttle	0.54 ohms	0.31 ohms	0.14 ohms
8	94.9%	97.0%	96.9%
7	95.0%	96.6%	-
6	95.3%	96.3%	96.8%
5	96.4%	96.6%	96.6%
4	-	96.3%	-
3	94.7%	95.7%	95.8%
2	-	94.5%	-
1	93.6%	93.7%	93.8%

Table 2: Accessory Loads at Standard Conditions

			Horsepowers			
Throttle	RPM	Auxiliary Alternator Efficiency	Radiator Fan	Equipment Blower	Alternator Blower	Unloaded Compressor
8	1050	0.880	18.4	30.5	60.0	14.5
8	995	0.879	17.1	23.1	51.4	13.8
7	995	0.879	13.8	23.1	51.4	13.8
6	885	0.871	9.9	14.7	37.2	12.5
5	885	0.871	7.7	12.6	37.2	12.5
4	885	0.871	4.8	10.0	37.2	12.5
3	885	0.871	2.8	7.0	37.2	12.5
2	579	0.801	0.8	3.5	12.2	9.8
1	438	0.741	0.0	2.5	6.3	8.8
LI	336	0.683	0.0	4.5	3.5	8.1
I & DB1	438	0.741	0.0	7.9	6.3	8.8
DB2	580	0.801	0.0	28.5	12.2	9.8
DB3	720	0.841	0.0	35.0	20.4	10.9
DB4	885	0.871	0.0	51.0	37.2	12.5

SD60M ANALYSIS

Locomotive performance is affected by environmental conditions such as air temperature (AT), barometric pressure (BP), fuel specific gravity (SpGr), fuel temperature (FT), and fuel higher heating value (HHV). So that the results of different tests may be compared, they are, by convention, corrected to AAR standard conditions, which are

AT = 60°F
BP = 28.86 in. Hg
SpGr = 0.845
FT = 60°F
HHV = 19350 BTU/lb.

Under most conditions the net horsepower produced by an SD60M locomotive is regulated at a prescribed level by its controlling microprocessor. As the demands of accessories such as cooling fans and air compressor change or as environmental factors like air pressure and temperature change, the fuel rate is adjusted so that the diesel engine makes enough power to drive the accessories while still maintaining the prescribed net horsepower. Under unfavorable circumstances, the demand for power may exceed the diesel engine's capacity; then, the net horsepower is reduced.

The net traction horsepower produced by the locomotive is

$$NPH_t = \frac{V \times A}{746}$$

where V and A are the main generator voltage and current.

At test conditions, the observed brake horsepower is

$$BHP_t = \frac{NHP}{Eff} + XHP_t$$

where XHP_t is the aggregate accessory power observed at test conditions. EMD claims the efficiency of its main alternator is a constant, EFF = 700/746. At standard conditions, the brake horsepower is

$$BHP_s = \frac{NHP}{EFF} + XHP_s$$

where XHP_s is the accessory power at standard conditions.

The power required by the various accessories at EMD rating conditions is given in Table 3. Generally speaking, auxiliary alternator power is constant and unloaded compressor power is proportional to engine RPM. Fan and blower power are both proportional to the cube of engine RPM, proportional to barometric pressure and invrsely proportional to absolute temperature. Fan power also depends on the number of fans in operation at low and high speeds. The fan duty cycle expected at standard conditions is given in Table 4.

Since environmental factors affect the efficiency with which the diesel engine burns its fuel, the fuel consumption rate must be corrected to standard conditions. For the SD60M, the correction factors are given by

$A = 1 + 4.8 \times 10^4 \times (60 - AT)$ for air temperature,

$B = 1 + 2.314 \times 10^3 \times (BP - 28.86)$ for barometric pressure and

$E = \frac{HHV}{19350}$ for fuel higher heating value.

The fuel rate also changes according to the difference between the brake horsepower at test conditions and brake horsepower at standard conditions. For small changes in power, the variation in fuel rate is proportional to the change in power with the scale factor, S = 0.3 lb/hr per horsepower.

Thus, at standard conditions, the fuel consumption rate is

$$FR_s = FR_t \times A \times B \times E + S \times (BHP_s - BHP_t)$$

where FR_t is the fuel rate at test conditions. Brake specific fuel consumption is

$$BSFC_s = \frac{FR_s}{BHP_s}$$

and net specific fuel consumption is

$$NSFC_s = \frac{FR_s}{NHP}$$

Table 3: Accessory Power Requirements for EMD SD60M Locomotive

Accessory	Horsepower	Rating Condition
Auxiliary Alternator	4	Constant
Traction Motor Blower	140	900 RPM BP = 29.03 in. Hg AT = 90° F
Inertial Separator Blower	12	900 RPM BP = 29.03 in. Hg AT = 90° F
Radiator Fan at Low/High Speed	6.3/40.3	900 RPM BP = 29.03 in. Hg AT = 90° F
Unloaded Air Compressor	15.4	900 RPM

Table 4: Radiator Fan Duty Cycle at Standard Conditions for EMD SD60M Locomotive

Throttle Position	Low	High
8	2	1
7	2	1
6	3	0
5	3	0
4	2	0
3	2	0
2	1	0
1	1	0

V. PERSONAL TRAINING ON NEW TECHNOLOGY

Presented by: Doug Corbin

Personal training for railroad employees has been, and continues to be a very important facet in not only operating, but most importantly, maintaining rolling equipment.

This report will endeavor to specifically deal with locomotive training in particular, locomotive maintenance training.

Traditional methods of training Mechanical department employees consisted of on-the-job training, classroom instruction, and in many instances a long-range program utilizing both of these methods in what was generally referred to as an "apprenticeship". They were usually programed over a two to four year period. Because of time constraints and variety of other reasons, the apprenticeship program has been dropped.

The predominant method of training currently consists of on-the-job training. However, there are major differences concerning time constraints and depth of knowledge required. The current method limits the training period and stresses the actual "mechanics" of the task being taught, rather than the principle of the operation. Further, several methods are now used to enhance the on-the-job training by providing the employee with technical data. Generally speaking, this is accomplished in a classroom environment, and on-site classrooms are usually the most common method (Fig. 14). Other sources of technical data for employees are OEM manuals and data sheets.

Training Center

One member road uses the Railway Educational Bureau to provide correspondence courses for laborers seeking promotion to a crafsman's position or for craftsmen wanting some cross-training in other crafts for possible promotion to a supervisory position.

Another method of training Mechanical department employees is to put them through a training curriculum separate from their work place. One member road has an extensive training center constructed for training of Mechanical department, Maintenance of Way department, and Transportation department employees (Fig. 15). This facility includes a short railroad of its own along with a locomotive (Fig. 16) and car shop (Fig. 17) area for hands-on training. Also included is an audiovisual production studio which produces instructional films and materials for training of personnel system-wide at their points of assignment. These films are an extremely good way to get the training out into the field and keep it there for refresher sessions or for new employees as hired.

Technical instructional films are now available from the locomotive manufacturers to assist where local expertise on new locomotive technology is not available.

"Dash Star"

A fairly new method involves a training van that is equipped as a simulator, allowing the OEM instructor to feign problems and develop troubleshooting techniques, which is extremely beneficial. At present, General Electric has the only training van, which is generally referred to as "Dash Star" (Fig. 18). The training van provides the OEM instructor with a mobile classroom, having a capacity of allowing three to four employees at a time into the van for instruction. The van is equipped with the three main computers, such as are found in the new GE Dash 8 locomotives. It also has a DID (display) panel and associated swit ches, such as would be found on a GE-8 locomotive (Fig. 19). The van also is equipped with a computer, similar to those used for down loading the computer on the locomotive. The Dash Star van equipped as previously mentioned, provides the employee with an excellent opportunity for hands-on training.

On-site Library for Facilities

Another member railroad utilizes an on-site library. This library includes modifications, schematics, SMP's - MI's, equipment manuals and parts listings. This will be a specific place to obtain emergency information as well as to train employees in a classroom environment. The library includes a VCR with monitor and tapes to explain the different systems of equipment, what they do, how they work, maintenance required, and troubleshooting techniques.

Computer Training

One of the more recent methods of providing specific training is by means of a computer (IBM PC 250 or comparable model). [One of the companies providing the necessary components is the Industrial Training Corporation "ACTIV SYSTEMS", located at 13515 Dulles Techincal Drive, Herndon, VA, 22071-3416, (phone: 800/638-3757 or 703/471-1414).] The computer concept allows the individual to pace himself/herself, and can also be used for small groups. The basic components of the system are a delivery system, floppy disc, color video disc and handbooks for the appropriate lesson plan, (Fig. 20). The employee is instructed on proper use of the computer and the appropriate disc is inserted. After the program is properly inserted into the computer, the employee is then signed on to the course by utilizing his employee number. This will allow the training instructor access to monitor the employee's progress throughout the course. The employee communicates with the computer by simply touching the screen. All courses have a pre-test before the actual lesson plan begins. The pre-test section not only allows the employee an opportunity to become familiar with the computer, but also tests his knowledge of the subject matter. The lesson plan can and does in many instances show diagrams and schematics.

The program is designed so that the employee can stop during the course to comply with time constraints. A good rule is generally one to two hours at any one time.

There are some definite advantages to this type of training. An employee can go at his/her own pace; once instructed on proper use of the computer, the employee does not need an instructor.

In summary, this interactive video training even in its infancy, shows great promise. It can be user-specific and provides the technical training imperative in advanced locomotive control technology. As advanced technology is continually being implemented in the design and operation of rolling equipment, so too, must employee training keep up to ensure proper maintenance of this equipment.

Elements of Interactive Video Training System

1. Delivery System
2. Color Video Disc
3. Floppy Disc
4. User's Handbook (General Information)
5. User's Reference (Presents the lesson objective & reviews key points)
6. Instructor's Handbook (How to monitor and evaluate students)

7. Instructor's Reference (Ideas on how to make the lesson effective)

Within the Color Video Disc are video and audio portions of the lesson. It uses several methods to teach skills and concepts of the lesson, including:

1. Close-up views of procedures
2. Graphic illustrations
3. Animation
4. Demonstrations

The floppy disc contains computer programs and data that control the system

All courses have a pre-test, a series of video presentations, simulations and exercises and a final evaluation.

The following is a partial list of what is currently available:

AC/DC Theory - OHMS Law
DC Circuit Theory
AC/DC - Characteristics of AC Circuits
AC/DC Theory - 3-Phase AC System
Multimeters
DC Motors Theory and Maintenance
Welding and Cutting
Plasma - Arc and Air Carbon Arc
Heating and Air Conditioning

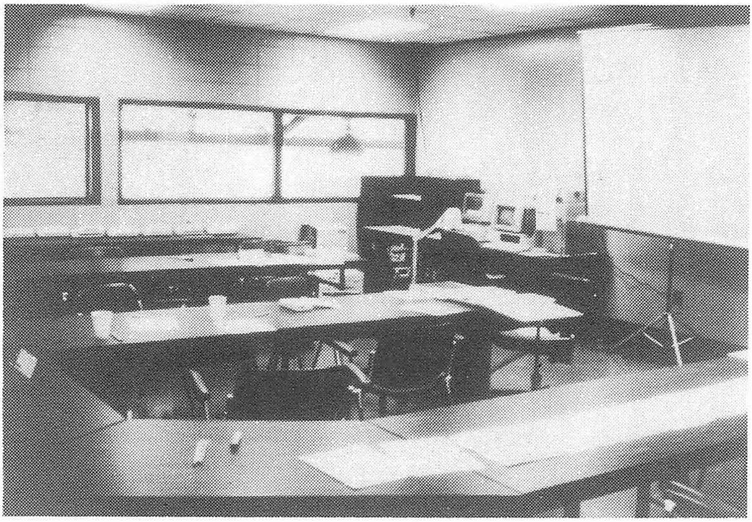


Fig. 14

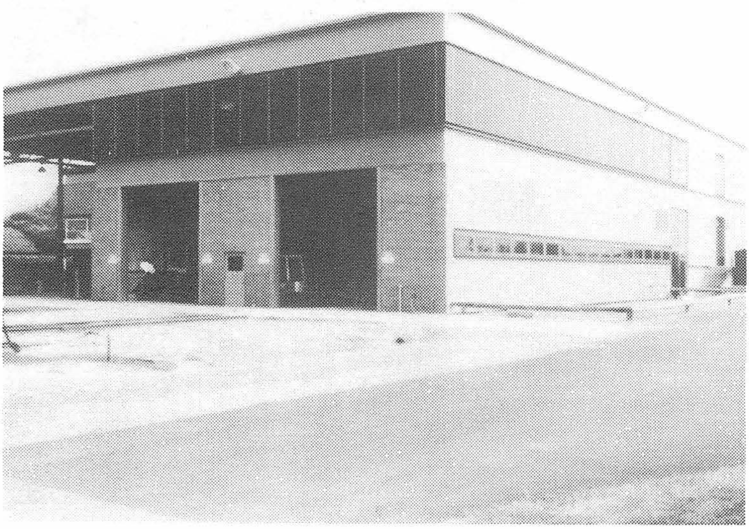


Fig. 15

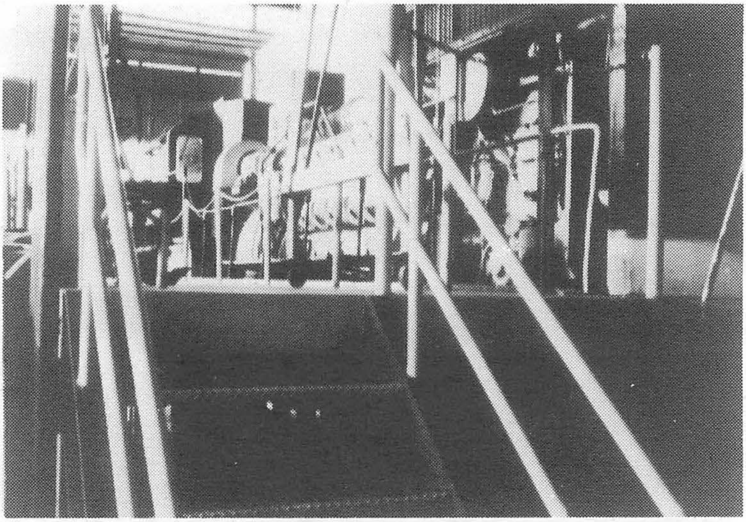


Fig. 16

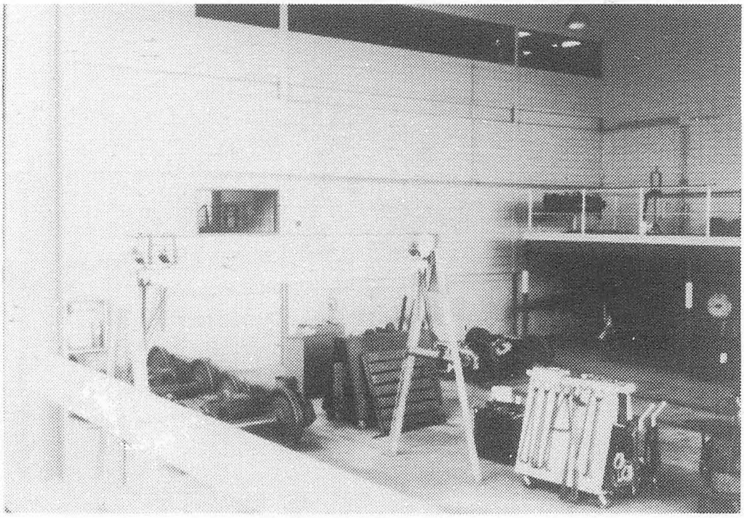


Fig. 17

Fig. 18

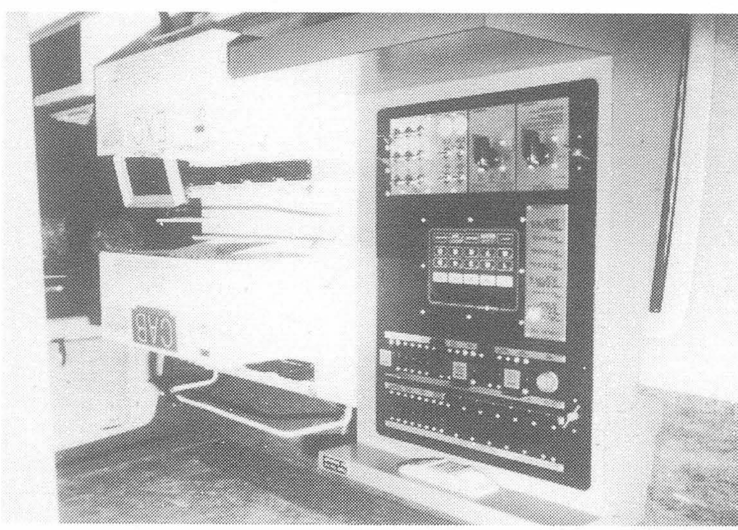


Fig. 19

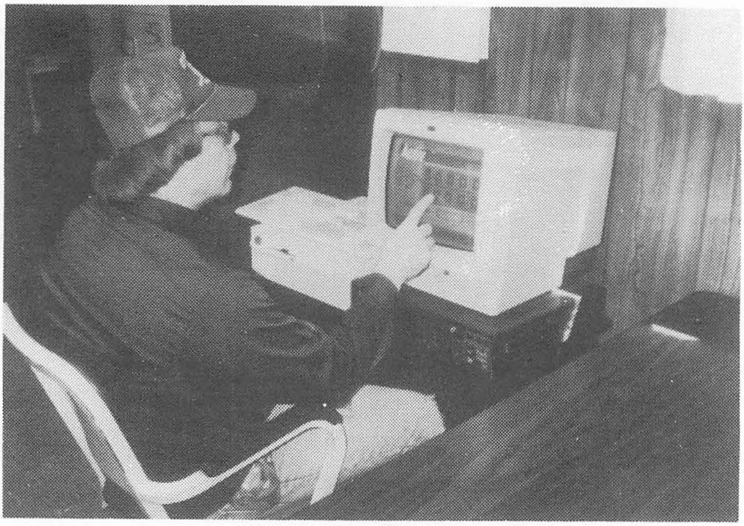


Fig. 20

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

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

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

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

REPORT OF THE COMMITTEE ON DIESEL MATERIAL CONTROL

Tuesday, September 17, 1991
9:00 A.M.

Pre-Convention Presentation Norfolk Southern

May 15, 1991 Marriott Roanoke Airport Roanoke, VA

LOU CALA, Chairman
Mgr. - Material and Production Control
Conrail, Altoona, PA

Vice Chairman
R. CORDER
Director-Material
VMV
Paducah, NY

COMMITTEE MEMBERS

W.O. Albritton	Mech.-Supt.	P&L	Paducah, NY
P.S. (Skip) Carstensen	Material Dist. Mgr.	C&NW	Clinton, IA
R.F. Early	Purchasing Agent	ATSF	Topeka, KS
J. Griffin	Material Analyst	EMD	LaGrange, IL
M. Kardos	Supv.-Material	CR	Pittsburgh, PA
J.A. McCubbin	Dist. Mgr.-Inv. Control	CSX	Louisville, KY
J. Minnie	Mgr.-Material	BN	West Burlington, IA
H.E. Nash	Dir. of Purchasing	MRL	Missoula, MT
K. Shaffer	Mgr.-Mktg.	GE	Erie, PA
D.L. Veron	Mgr.-Material-Diesel	NS	Roanoke, VA

PERSONAL HISTORY

Lou Cala

Lou Cala began his railroad career in 1974 as a laborer with the Penn Central Railroad in Cleveland. Later he held positions in the Stores Department and worked as chief clerk in 1977 at the Distribution Center. Several promotions followed: Supvr. of Materials (1977); Material & Purchasing System Auditor (1979); Gen. Supvr. Material (1980); Material Spec. Program-Car Material (1981); Mgr. Material Control for the Mechanical Dept. (1983).

Lou and his wife Joan have three children: Angelo, 27, Vicki 25, Lou, Jr. 5 and one granddaughter. They currently live in Altoona where Lou is Mgr. Material and Production Control for Conrail.

I.
THE WORLD OF RECYCLING

Presented by: Rita Meyer, BNRR

Our dilemma is that we hate change and love it at the same time. What we really want is for things to remain the same, but get better! This presentation is about changing your habits, because if you're not recycling, you're throwing it all away! We can save the environment and still run our business successfully. Approximately 70 to 80 percent of an office person's wastebasket is recyclable paper. Each year Americans throw away enough office and writing paper to build a wall 12 feet high, stretching from Los Angeles to New York City. It is time to bring our activities together at work and at home for our environment. Merely ignoring a problem will not make it go away nor will merely recognizing it.

Burlington Northern people realized they had waste problems and started an office recycling program in November, 1989 at the St. Paul general office building. It began as a special project to determine if they could recycle office paper, corrugated cardboard and aluminum cans without adding significant cost and still run their business. There are 1,450 employees in the building. The American Paper Institute estimates that a pound of paper, per day, per person is generated in an office environment. Financial institutions generate about two pounds of paper each day. If everyone in this office recycled, at most about 2,000 pounds of paper a day would be generated. They are now collecting 1½ to 1¾ tons of paper each day that's 50,000 pounds of paper a month being recycled from just one building.

When they brought the program to the maintenance shops and distribution locations, they found that these facilities were a lot like supermarkets. Many of their products came in boxes that they would unload and dispose of as refuse at some cost to the company. To reduce or eliminate these costs, BN purchased 19 balers to bale the cardboard and, in most locations, sell it. One location baled 2,000 pound a week; still another location baled 3,200 one week and one western location baled 3,700 pounds in one week. With this volume, the return on investment was 100 percent.

Trash going into the landfills was reduced by 50 percent, and disposal costs were reduced accordingly. National statistics provided by the Environmental Protection Agency state only that 10 percent of the American trash is recycled each year, or 16 million tons. New York's largest export is wastepaper.

Do you remember that infamous barge that floated out of the New York harbor a few years ago -- the one out of Islip that had a sign that said: Next time, "try recycling!" That barge floated for months looking for a new home. It came back to roost in the New York harbor, loaded with the original garbage it left with, sending a strong signal to New Yorkers and all Americans take care of your garbage, America, because you cannot sell it to a third world county or dump it on anyone else.

Americans represent 5 percent of the world's population, yet we generate more than 38 percent of the world's garbage. We are a one-time, throw-away, out-of-sight, out-of-mind society. Appliances are just some of the problems raising havoc by seeping chlorofluorocarbons into our ozone layer. The ozone layer protects us from the sun's ultraviolet light. A new report on the depletion of the ozone states that 12 million Americans will be developing skin cancer of which 200,000 will die. This is 24 times greater than originally forecast a few years ago. And this is what we emitted in the atmosphere 15 years ago. The impact of the 80s and 90s chlorofluorocarbon emissions will not be known for 40 to 50 years. The saddest news of all is that people will say "Why didn't someone tell me"? The earth and atmosphere are shouting at us right now "Do something"! But is anyone listening — are you?

By the end of 1993, 80 percent of America's landfills will be closed, leaving about 4,000 operating landfills. The Environmental Protection Agency clearly indicated that all landfills have the potential to leak toxics into our groundwater. If we continue generating garbage in the same volumes we do today, we will need 500 new landfills a year.

Garbage is an international problem. Last spring, mountain climbers from the United States, Russia and China scaled Mount Everest and came back down, leading a string of yaks, carrying 4,000 pounds of garbage left by generations of earlier climbers, most likely including garbage left behind by the first person to conquer Mount Everest, Sir Edmund Hilary. Even our highest peaks are laden with garbage. We must all remember that we are billions of people, living on one, very volatile Earth. Together as the nation's railroad professionals, let's have the next generation something to remember us by -- besides our mountains of garbage!

Some say the answer to our garbage dilemma is the "waste to energy" facilities. Resource recovery plants, incinerators — any glitzy name we give them, it is still plain old burning of garbage. There are 144 incinerators in the United States, with 250 more on the drawing board. The incinerators are being built by the same people who used to build our nuclear power plants. Does that make you feel better? Isn't it great that we're storing our nuclear waste for someone else to take care of? Thirty-eight states have intragarbage contracts so your state may be taking another state's garbage and ash. Hopefully, the landfills meet or exceed government specifications and the ash is properly neutralized. An incinerator's smoke emission is supposed to be clean, but the Environmental Action group says that incinerators are the largest new source of air pollution. No one wants to breathe that pungent or toxic air. Is there anyone going through the garbage? No! It is compacted, lead acid, mercury or nickel iron batteries included and it is burned.

Last year, consumers in the State of Minnesota alone purchased 55 million batteries. About 40 percent of the dry cell battery sales were made before Christmas. Whatever happened to the wind-up toys, or for that matter, the wind-up watch? Not all batteries are landfilled or burned. We have agreements with the original manufacturers of the lead acid, nickel cad and nickel iron batteries to return the spent batteries and recycle all the elements. Ultimately, they furnish us with certificates of reclamation that relieve us of any further responsibility. Our spent batteries are shipped in these high impact, plastic reusable containers so the electrolyte does not leak out and it can then be safely recycled.

We all want and need landfills and incinerators — but with a catch, the not in my backyard (NIMBY) syndrome. Give me a landfill or incinerator, as long as it's not in my backyard. Put the garbage out and let it disappear.

One answer to our landfill crisis is office recycling. I'm going to share with you just how easy it is to set up an office program.

Consider recycling at the office like

garbage reincarnation because the only thing you have to give up is your recyclable paper.

- Assign a program coordinator and a small committee who can sell recycling to the employees.
- Work with the building management or owners to get their support in setting up the program.
- Find the right recycling contractor with high quality service first and price second. Paper prices fluctuate with the market prices. Most waste paper dealers are listed in the Yellow Pages, or contact your state recycling office or the Environmental Protection Agency.
- Have a question sheet ready for the vendor you are meeting with. Ask about training your employees, recycling supplies, pick up hours, pricing, records storage and references.
- Is the storage place for the paper fire safe? Can the recycling contractors get to the storage area to pick up the paper?
- Most recycling contractors require at least 2,000 pounds of paper to be collected before they will pick it up. Do you have storage for these containers inside or must it be stored in an outside, enclosed container that will be furnished by the contractor?

Once you've accomplished these things you are ready to educate your employees. For years, recycling was considered dirty, costly, time-consuming and unimportant. The success of your program will depend on how you present it! Give them the correct message right away. Send out a kick off memo inviting them to a meeting and educate them about recycling:

- Train them to be responsible for the paper they generate and to use their desktop container.
- When their desktop is full, they empty it into marked secondary containers that are located near copy machines, printers and high-volume paper areas.

Now that we've taken care of the office paper, let's see what else can be changed, and remember: don't find fault, find a remedy! For example, what about a remedy for the office styrofoam cup?

Americans produce enough styrofoam cups every year to circle the earth 436 times! Styrofoam is a trademark for a chemical company. It is made up of benzene, converted to styrene and then injected with gases that make it a "foam" product. It is not biodegradable, and if does break down fish or animals that eat it die because it creates a false sense of food in their stomach but is not digestible. Encourage employees to use a washable cup, make them responsible for what they generate. When attending in-house meetings, ask them to bring their washable cup and offer paper cups for guests.

Recent reports state the styrofoam/polystyrene cups and packaging have not been given a fair shake by the environmentalists. Paper cups are made from renewable wood pulp while polystyrene cups are made from nonrenewable oil and gas. Pilot polystyrene recycling programs are going on, and we encourage these efforts but, from all indications, it will be a few years before we know if they are successful.

Let's go home and see what we can do there. Because you are changing personal habits, when you start recycling at work, you'll want to start source separating your garbage at home.

I have a question for you: the last time you went on a picnic, were you even able to get rid of your garbage at the end of the day? Probably not, everyone is using disposable products. When grandma went on a picnic, the dishes were packed from the kitchen, used at the picnic and then brought back home. Has the pendulum swung that far that we can't use a product twice? We all have that treasured, stained melmec, buried in our basement along with grandma's silverware -- stop saving it! Dig it out and use it at your next picnic!

We don't expect you to go this far in reducing, reusing and recycling your products, but for every aluminum can you recycle you have a half a pop can of gasoline — that's how much energy it takes to make one aluminum can out of raw bauxite ore. With gas at $1.20 a gallon, if you threw away an aluminum can yesterday, you tossed 60 cents out the window. You can recycle 20 aluminum cans for the same amount of energy it takes to make one can out of raw material. If you recycle that can, it will be back on the store shelves in six weeks. Each year, America recycles about 65 percent of its aluminum. Globally, if we continue using our bauxite ore as we do today, it will eventually be depleted from our Earth's resources.

An average American family of four generates five pounds of garbage each day, at home, work and at school. Let's not forget about our children in school. They're the ones who cannot write on both sides of the paper, and heaven forbid that they would use a pencil once the eraser is gone. What habits are we instilling in our children? If you're a family who source separates and recycles newspapers, aluminum and glass, your five pounds, recycling cuts your garbage in half.

Have you been feeling a little sluggish lately because you slipped a little in your recycling habits? Well, there's a new green earth virus going around called recyclosis -- (pronounced ree si klo sis). Recyclosis that you are suffering from. It is guilt that overcomes you when you throw away cans, bottles, and papers that you know they should be recycled. Don't worry, as soon as you get back on the recycling track, the recyclosis guilt will disappear!

Have you checked under your kitchen sink lately? Do you realize that there are more chemicals in the average American home today than there were in a chemical laboratory 100 years ago? Labeling a product "nontoxic" can be misleading. It is not recognized by the Food and Drug Administration—to the FDA it is a generic term. Manufacturers may place the word nontoxic on their labels simply by meeting federal requirements. If less than 50 percent of the lab animals die within two weeks when being exposed to the product through ingestion or inhalation, the product can be called "nontoxic" and placed on the market. So the question is, who are the real guinea pigs of the world? The caged animals tested for two weeks or the consumers purchasing the product for the rest of their lives?

Let's move to the laundry room. When product labels have more warning information than laundering instructions — beware! Warnings may include precautionary statement hazards to humans and domestic animals; environmental and chemical hazards; and a statement of first aid. Do you still want to use this product on yourself or your clothes? How many warnings do we need? I have rule of thumb, if I cannot pronounce the name on an ingredient panel, or spell it, why would I want to drink, smell, wear or use it?

Only five percent of our toxic substances are taken care of properly. Does the name perchloroethylene ring a bell? Can you spell it? There are concerns that dry cleaning our clothes is a dirty business for our environment. "Perc" (perchloroethylene) is the solvent dry cleaners use to clean our clothes. You know that dry cleaning odor? That's perc! To be safe, a Philadelphia pollution-prevention specialist suggest that clothes that have been cleaned be aired outside for 24 hours before wearing. One state pollution control agency recommends removing clothing from the plastic bag immediately. The dry cleaning solvents are so toxic that they are tracked from manufacturing to recycling. In one case solvents were disposed of in a drain floor and backyard pit, making the water from 24 residential wells unfit to drink. The National Dry Cleaner's Association assures us that perc is possibly only a mouse carcinogen and very possibly not a human carcinogen.

What are you doing with your newspapers? We encourage you to change this throw-a-way habit and start recycling your newspapers because it takes an entire forest, over 500,000 trees, to supply Americans with their Sunday newspapers every week. Check with your community to get a program started.

Are you tired of being a car-rt-sort, select area resident, occupant therein or my personal favorite, our friends at? You can have your name removed by writing to this New York Direct Marketing Company or note on the envelope return to sender and have, him pay the postage back. By the way, you spend eight months of your adult life opening junk mail!

If you throw your motor oil away, you are among the 70 percent of Americans who do. Europe recycles 85 percent of its oil. Just one part oil to one million parts water will make drinking water smell and taste funny. We do-it-yourselfers throw away 120 million gallons of used motor oil every year. Remember the Valdez spill in Prince William Sound, Alaska? We create a super tanker accident like that every few weeks. Look around the room, multiply each person by two vehicles times five changes a year. Now, you are all on your way to creating your own personal oil spill—in your own backyard—that will contaminate your drinking water forever. Kick that throw-a-way habit--start saving this valuable, imported resource by recycling it at your gas station.

The railroads have been the predominant oil recyclers for years. As a matter of fact, we do it like champions. After the oil is cleaned and reconstituted, with the proper additive package, the railroads repurchase the oil for use in our locomotives and track equipment. The 50-year old oil recycling program has been extremely successful while returning a substantial savings.

The most important thing to do in solving a problem is to begin.

Let's start with our unending flow of water! We are toying with one percent of our world's groundwater by dumping everything in it. Here are a few suggestions to save our valuable life sustaining water resource:

- Install low-flow faucet aerators in your kitchen, bathroom faucets, and shower head appliances. The top slide is an aerated flow, the bottom is a non-aerated flow. You can cut the water flow by 50 percent as air is mixed into the water as it leaves the tap. You'll drive blocks out of your way to save four cents a gallon at a cut-rate gas station but did you know--you are wasting four cents a minute by not aerating your faucets?
- When brushing your teeth, wet and rinse and use ½ gallon of water. You will save 10 gallons each time you brush your teeth.
- When shaving, fill the basin and use one gallon of water. You will save 14 gallons of water each time you shave.

Next time, let's make it a royal flush. Each time you flush, it uses five to seven gallons of water.

- Put a plastic dishwashing soap bottle, that is weighted with rocks, in your toilet tank. You will save one to two gallons per flush. Don't use a brick, it can damage your plumbing system.

Do you have the golf course syndrome with your lawn? Most lawns are overwatered by 40 percent each time you sprinkle. Don't just fill'er up: there is a simple test you can do. Place three 10-½ ounce soup cans in your yard, different distances from the sprinkler. Check every five minutes to see how long it takes for an inch of water to accumulate in each can. Add the three can times together and divide by three. That is an average on how long to water your lawn and always water in the morning.

How about your drinking water at home? You don't worry because you purchase your water from a bottling company and the container is marked mountain fed sparkling water—and you don't live in the mountains? Just because it's bottled, doesn't mean it's safer! An EPA pilot survey of 25 bottling water establishments across the United States discovered that none of them ever reported having a complete chemical analysis of their bottled water. Laboratory control data revealed a total lack of chemical analysis of the finished water. The bottled water you are purchasing may not be as good as the water from your faucets at work or at home—check the labels. If everyone in the world used water as Americans do, we would be out of groundwater today. Start conserving water like you do when you are camping!

Now let's move into the purchasing arena. At Burlington Northern, the Purchasing and Material Management Department has become more environmentally aware and has taken a leadership position. It has made significant changes since starting to reduce, reuse and recycle products two years ago. When purchasing products, its buyers remember they are responsible for the life cycle of the materials from the cradle to the grave.

They are purchasing interoffice paper that is made from 50 percent virgin and 50 percent recycled paper, encouraging vendors to produce recycled products. They are also exploring the purchasing and use of recycled fax paper; they are recycling and repurchasing laser printer cartridges and ribbons and purchasing recyclable chemicals and compounds. They recapture 100 percent of the freon from mechanical refrigeration units used in refrigerated freight cars.

Our buyers are already part of the solution through subtle, effective purchasing changes they've made. They no longer stock yellow note pads - only white - because colored paper is difficult to recycle; pink telephone note pads are now white with colored ink; a real wood pencil, containing no plastic fillers or colored lacquered finish is being purchased and used by employees. The pencils will have a recycling slogan--reduce, reuse and recycle. They attempt to spread the word about recycling in every way possible.

Some employees suggested the use of reusable envelopes. Burlington Northern had reusable envelopes about ten years ago, and quit using them when passenger services were taken over by Amtrak and it could no longer use the passenger trains to handle company mail. Some of the best environmental ideas were created years ago because the environment hasn't changed—we have. Let me reintroduce the old reusable envelope idea in new paper and color as the "revolutionized" recyclope. The envelope has been well received with 90,000 being used systemwide.

People don't just recycle products—they are also moving into parts of the human anatomy. They have a spitters and chewers association in many parts of America and are asking them to recycle their chew outside.

In some of our locations, we had trouble with the chew going into our recyclable paper bin, contaminating the paper. We hope some "catch your eye, we know who you are" signs will eliminate this unique contamination problem.

As Minnesota's 12-year old Kirsten Milton said: The grownups keep saying to us "I always have to pick up after you." Well, when we get older, we're going to have to clean up their giant mess... and we might not be able to do it unless we start now!

Once you start recycling, you understand reduction of materials and become savvy as to what is and what is not recyclable. When this newsletter was first sent out to BN employees, it was published on glossy, nonrecyclable paper. Employee pressure to the Communications Department has had this monthly newsletter changed. It is now printed on paper that can be recycled. We are working on having it run on recycled paper that can be recycled again. Each of us can definitely be part of the solution.

One area of waste reduction we conquered was in packaging. An employee said that materials were packed two different ways. One was the right way; the other was wrong because it created more waste. Styrofoam was foamed in the box, plastic was laid inside and then the fragile part was laid on the plastic. The styrofoam adhered to the cardboard box, so neither the box or styrofoam could be reused. BN asked the companies to change their packaging by laying the plastic in the box, foaming in the styrofoam and then placing the part inside. Both companies agreed it was a great idea and changed their packaging. They were able to reuse the boxes and parts of the styrofoam for repacking and shipping. At two locations, container pick ups were cut in half -- with an annual saving of $17,000 on garbage hauling fees. Positive proof that no one knows the workplace environment better than the employee who works there everyday.

One report, run everyday, 365 days a year, on one side was changed to two-sided copying. With this change the annual savings are 1,182 reams of paper, $3,500 in purchases and landfill costs and 4 tons of paper—and this is just the start with one report.

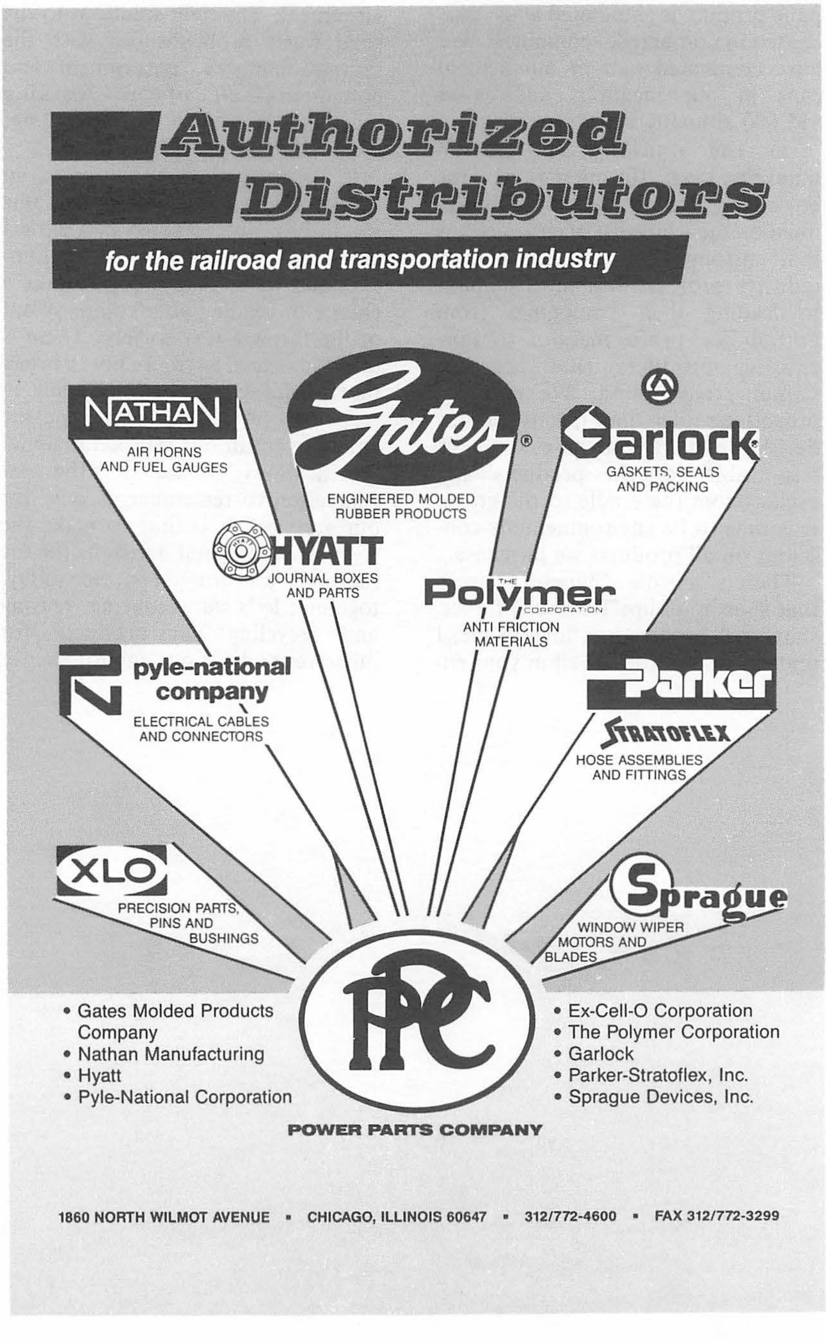
We encourage you to work with the vendors who service your company, asking if it is possible to reduce, reuse or recycle their product. BN is requesting its suppliers to look at the way they package their products, and if possible, change their packaging so that containers and packaging material can be used, like the heavy-duty, plastic, multi-use container to ship parts in, rather than one-time wood pallets or boxes.

Another area of waste reduction is the small containers we use everyday. BN purchased about 25,000 aerosol cans of oil product in 1990. We changed from the small, one-time use, throw-away can to a refillable plastic spray bottle. The oil product now comes in gallon plastic bottles and is refilled by the user. When we changed to the larger, refillable containers, a safety hazard was also eliminated. Because chloroflorocarbons can no longer be used, the aerosol propellant was changed to a propane. This propane in the aerosol cans is a potential safety hazard if used near sparks or flames. The pro pane product is eliminated when purchased in non-aerosol containers. We have eliminated half of our aerosol cans in our locations and saved $15,000 annually with this change.

As the pollution prevention magazine says, "In other words, the environment is now another requirement on the whole list of satisfactions that customers want." All railroad industry professionals must commit to leading their companies from bottom-line profit margins to purchasing products that are environmentally sound. We must be proactive rather than reactive in our decision-making purchases and be responsible for the products' life cycles--from the cradle to the grave. It is time to be environmentally conscious on all products we purchase.

There's an ole Chinese proverb that sums it all up: Tell me, I forget, show me, I remember, involve me, I understand. Get involved in your environment. The right solutions to the solid waste problems rest with the railroad industry, government and consumers—all of us—working together. If you're not recycling, you're throwing it all away!

If Columbus had turned back, no one would have blamed him; no one would have remembered him either! Columbus took a chance on his hunches and we're asking you to take a chance on leading your company out of the throw-a-way society. There is no good reason anymore not to break the landfill habit. Let's commit to reducing our waste and include the environment in our railroad material specifications. Do we want the next generation to remember us only for our garbage? It is time to make the right environmental decisions for the railroads and suppliers. So today, together, let's start reducing, reusing and recycling our products—for ourselves and for our environment!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II. PROBLEMS WITH SOLUTIONS

Presented by: Mike Pennell

One needs only to open the evening paper to discover an article on illegal dumping of waste, landfill problems or some environmental issue that is closer to home than ever before. And closer to home than any of us want! Because of a new awareness regarding environmental issues and also because of new regulations, it is imperative that all of us analyze how waste materials are handled at home and in the work place.

For years, the railroad community has monitored and regulated hazardous waste, but we have failed to seriously look at the reoccurring normal waste generated by our railroad. Why? Because we have all been effectively, and legally, disposing of our waste in approved landfills; never thinking that someday there wouldn't be any more room for more waste, or that new laws would be enacted prohibiting the disposal of certain types of waste. With these items in mind, let's take a look at waste that is common to all of us and see what is currently being done to dispose of it. We have identified some problem areas and have found viable solutions. One small solution is a step in the right direction.

What kinds of products pose a problem?

a. Any item which can be reused, recycled or reduced.
b. Those items which are costly to transport to an approved disposal facility.
c. Those items (chemicals) which are costly to handle, due to their caustic, explosive or corrosive characteristics.
d. Items which are not biogradeable.
e. Those items whose disposal is hindered by the distance to an approved disposal site.

Office Waste

Immediately when we think of office waste, we think of paper. You would assume that with our increased used of computers and workstations we would generate less paper. Not true. Just the opposite has happened. Since 1970, paper waste in landfills has increased 15 percent. In 1970, paper made up 35 percent of the total landfill space; today that percentage has increased to 50. Instead of going directly to the trash and then to landfill, check with local recyclers and get on a recycling program. You may even generate revenue from your efforts.

Those items which the recycler won't accept should be compacted. This use of compactors, instead of open hoppers, not only save space in the landfill but will reduce the number of trips to the landfill from approximately four to one. The resulting cost savings have been demonstrated to be about half the original cost of disposal.

A not so frequently thought of office waste is printer cartridges. Check with your supplier of printer cartridges to see if it will recycle the old ones.

Product Waste

We have all experienced the dilemma of whether to use rags or shop towels, cloth overalls or paper overalls or green lab jackets, and paper towels or cloth rolls. The economics of disposables versus laundered goods is now an issue across all industries. An economic review of in-house laundry and a reevaluation of outside services now have merit. In more than one instance, it has been found there are suppliers in the market who not only launder dirty items and exchange them for clean, but who have a minimal, if any, service charge for losses. They virtually elminate our concern for these products becoming hazardous waste or a problem to clean.

Batteries

Enormous quantities of used batteries are generated each year and it has become more and more difficult to find acceptable sites to handle them. It is a wonder that OEM's do no accept them back with a trade-in allowance similar to automotive batteries. We must challenge them and all of our suppliers to assume responsibility for the products from 'cradle to grave'.

Locomotive and signal batteries contain all of the ingredients that no one wants once they have been expended: plastic, acid and lead. Plastic doesn't break down environmentally and acid and lead end up being hazardous waste. The proper method of disposal is to send the used batteries to an approved disposal site. There are smelters who will not only utilize or recycle batteries but will also pay for the lead.

Oil Filters

Every railroad changes out oil filters on a regular scheduled basis, consequently generating waste filters loaded with waste oil. Often times these filters were thrown in with everyday refuse and shipped to the local landfill. Recent changes in regulations now prohibit this type of material going to landfill, due to the oil in the used filters. There are two possible alternatives for this problem:

1. Use an **oil filter crusher** which would crush the filter and squeeze the majority of the oil out, or;
2. Use a **centrifuge** whereby the oil is centrifugally spun out of the filter.

In both cases, the oil could then be recycled and the filter could be disposed of at the local landfill. Let us all be aware these are today's solutions. But due to forthcoming regulations, even these solutions may be tomorrow's pollution.

Wicks

There is currently a program whereby locomotive wick assemblies are recycled on a unit exchange basis. The used wick felt pad is removed from the metal retainer and then replaced with a new wick felt pad. The used pad, which is considered hazardous waste due to the lead content, is burned in a cement kiln. Under intense heat (2700 degrees Fahrenheit), raw materials (such as limestone, clay and sand) are fed into the kiln along with fossil fuels (coal, oil or natural gas) and liquid-waste derived fuel. New compounds called 'clinkers' are formed as organic compounds are destroyed and inorganic compounds bond with the raw materials. The clinkers are cooled, mixed with gypsum and ground into a fine powder which can be used by concrete makers. Once this process is utilized industry-wide, we will have fulfilled our 'cradle to grave' responsibility.

Pedestal Liners

Another item that is frequently changed and which results in waste that is difficult to dispose of is pedestal liners. Yes, they can be sent to landfill and no, they are not currently regulated; but this is a component that will never break down if it is landfilled. Since not all kinds of pedestal liners can be recycled, it is important to check with your supplier to see if the type of pedestal liner you are purchasing can. If it is a thermoplastic product, it can be blended with other materials to become a new product. If it is not, the recycling process could have a degenerative effect on the pedestal liner's physical properties. The resulting product would be inferior and probably dangerous to use. Another concern is the ability of the recycler to take a used pedestal liner—dirt, grime, grease and all, clean it and recycle it, thereby eliminating the need for the railroads to do a preliminary wash.

Packaging

The disposal of protective packaging and, in particular cardboard, is the last aspect of railroading that we will examine. Obviously, no one is going to tell the supplier not to box or crate a valuable piece of material—it has to be protected from the environment, both natural and man-made. Once the part has reached its final destination and the packaging is no longer required, what do we do with it?

One alternative would be to reuse the box or crate to store parts. For example, when replacing like injectors, the old injectors could be placed in the box of the new injector. Then that box could be placed in a bulk box of like injectors, thus eliminating future sorts and reidentification. Another alternative would be to use the crates and boxes for shipments of parts to other locations. And yet another alternative would be to recycle the corrugated cardboard through avenues similar to those used in recycling paper. The volume and size alone may warrant the need for compactors and balers, but the return on investment comes from the sale of the bales to a recycling company.

Along with bulk packaging, there is a filler. Items to considered in place of blown foam and styrofoam peanuts are shredded magazines (this paper is not easily recycled and can be donated by the work force) and biodegradeable peanuts made from cornstarch.

Is there overkill in the way we package or build our containers and shouldn't we be thinking 'light weighting'? Can the plastic wrapping be of lighter weight and still be strong enough? Can crates be made of thinner material? Materials that cannot be recycled as of yet can be made to take up less landfill space by looking at what is really needed when we package.

Conclusion

The railroad industry, both the railroads themselves and their suppliers, must work hand-in-hand to eliminate the unnecessary waste that we generate today and look ahead for new products and new packaging that will help reduce the waste we may create tomorrow. What are some of the other items which need to be looked at now or in the near future? Composition brake shoes, rubber hoses, gaskets, MU cables, engine air filters and rubber and plastic products which are unique to locomotives are examples.

It will take all of us working together to find ways which both economically and feasibly slow down and eventually stop the tide of this ever-increasing problem. We must look closely and challenge ourselves not to create a new waste or environmental issue in the efforts to solve an existing one.

III. PROBLEMS WITH OPPORTUNITIES

Presented by: Lou Cala

The items for discussion here are presently being disposed of in landfills. The challenge to our industry, both railroads and suppliers, is to find a way to encourage ourselves to use these items either a second time or recycle them into new products.

Composition Brake Shoes

We have investigated both large and small operations and determined that we use three major types of composition brake shoes. Combining car and locomotive shoes, our study reveals that a large railroad consumes more than 571,000 composition brake shoes while a 300-mile regional line uses 17,500 per year. This problem is universal to our industry. The total weight associated with this product works out to four million pounds. These shoes laid end to end would extend 10,000 miles almost halfway around the world. The construction of this product further adds to the recycling problem, as two different materials are used. The shoe is constructed of a rubber/phenolic friction material bonded to a metal backing designed to last the life of the shoe making it nearly impossible to separate. Whenever two materials are used in a product, current recycling practice requires they be separated as each material normally goes to a different destination. The current shoe design precludes present recycling processes.

The cost of disposing of one cubic yard of industrial waste presently averages $22. We estimate that the 4 million pounds of brake shoes used by the larger road equates to 1,900 cubic yards of landfill. This 1,900 cubic yards of trash will fill a football field over 10 feet deep. We would fill this room with the usage from a regional line alone, while a major road would fill this building every year and pay close to $42,000 for the privilege.

Researching the MSDS shows no known hazards, and other than volume; there is no present environmental danger. While the metal backing will rust away with time, the composition material will last forever. Is there an answer? Can the brake shoes be recapped? Is there a second use (i.e., boat anchors, door stops)? Can we get this volume out of landfills?

Rubber Products

Our investigation of rubber products focused on locomotive and freight car air brake hose usage.

A regional line will use 2,400 trainline air hoses a year while its larger counterpart can use over 84,000. As these hoses average 30 inches each, we are disposing of 40 miles or 209,000 feet per year per road. Hose weighs 110 lbs. per feet, accounting for 230,000 lbs. or 278 cubic yards of rubber being buried in landfills. A portion of these hoses are used on track sweepers producing a second use and reducing the waste being buried. However, this is not a significant volume compared to the whole. The vast majority of air hoses will be disposed of in landfills, never decompose and always be with us. Is there another use or a new product that can be manufactured from these hoses?

Drums

Normal disposal of drums is through commercial drum recyclers. As environmental issues come to the forefront, the recycling of drums becomes less active due to the problems of cleaning of the drum, disposal of the product and the liability associated with the former product, as well as the condition of

the drums themselves. Can the drums be reduced by melting and the metal reused, or is there a process that can use the metal from the drums as is? Remember, you as suppliers are someday going to be made responsible for these containers. Starting today is not too soon to look for solutions.

Pallets and Wooden Reels

The reuse of wooden pallets is a long-standing practice. In 1990, purchases of new pallets ranged from 1,500 on a regional line to 15,000 on a Class I road. This is few compared to the number of pallets in service. In large industrial areas, there are pallet recyclers. However, they are becoming very selective about the pallets they will accept for renewal. They may pick up the old pallets at your location, but normally they will not deal in less than truckloads lots. Everyone has had programs for the repair of pallets, thereby extending the useful life. Most of these programs have been terminated as the cost associated with repairing pallets could not be justified. As with railroad ties, can pallets be chipped and the chips be used for another purpose such as fuel, or can the remaining wood be used to produce a new product keeping this item out of landfills.

Air Filters

Sixty locomotives will generate 20 tons of air filters per year or 700 lbs. per locomotive. According to the AAR, there are 19,683 locomotives operating in the United States. Imagine the tons of used air filters being generated by our industry each year going into landfills. We can no longer accept this tremendous waste. We understand that a Western road is working with a manufacturer on the reuse of air filters. This manufacturer has replaced the traditional oil coating with a new process allowing the filters to be recycled. This is one step. Are there others? Is there a better way? There must be other solutions.

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

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

Our Shop Equipment Committee's presentation was well received in what we trust was a mutually beneficial experience.

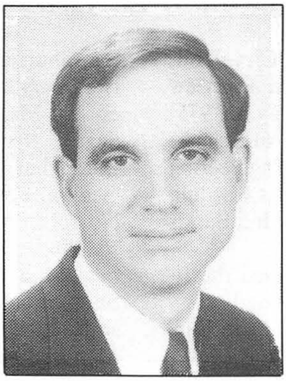
Our thanks again to Mr. J. R. Nussrallah and others responsible for and participating in this activity.

REPORT OF THE COMMITTEE ON SHOP EQUIPMENT

TUESDAY, SEPTEMBER 17, 1991
10:30 A.M.

Pre-Convention Presentation Conrail

May 1, 1991
Ramada Hotel
Altoona, PA



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PERSONAL HISTORY

Donald D. Graab

Don Graab was born in Cleveland, Ohio and graduated from Fairview High School in 1971. In May of 1975, Don received a Bachelors of Science degree in Mechanical Engineering from Purdue University. At Purdue, Don was active in the Purdue Bands and Triangle Fraternity.

In 1975, Don Graab joined the Illinois Central Gulf Railroad as a management trainee. Starting in Carbondale, Illinois, he was later transferred to Chicago and joined the Research and Planning Group of the Mechanical Department. In 1978, he was a car foreman at ICG's Markham Yard when he resigned to join the Norfolk and Western Railway.

Hired as a Training Instructor -Locomotive, Don was transferred to the Shaffers Crossing Roundhouse two years later. In 1982, Don received a Masters of Administration degree from Lynchburg College. Later that year, he was promoted to General Foreman - Machine Shop at Norfolk Southern's Roanoke Shops. In 1986, he was transferred to the new Shaffers Crossing Locomotive Shop as General Foreman of the first shift. In 1991, Don was promoted to Manager Assembly Shop. In his current position he oversees the overhaul of EMD locomotives and component rebuild.

Don has served on the LMOA Shop Equipment Committee since 1985. Don now lives in Chattanooga, Tennessee with his wife Peggy and two daughters.

I. ECONOMIC SEPARATION OF EMULSIFIED OIL FROM WASTEWATER USING ULTRAFILTRATION MEMBRANES

Alan Fleischer
FAST Systems, Inc.

ABSTRACT. Railroad facilities typically produce wastewater containing emulsified oil. Discharge of untreated or inadequately treated wastewater into the sewers or into the environment is prohibited and is subject to severe legal penalties.

Typically, a large amount of water is contaminated with a small amount of oil, and equipment is available for on-site concentration. This equipment produces oil-free water and concentrates the remaining emulsion for separate disposal of a much smaller volume.

The incentive for purchasing and using such equipment is cost savings. The payback associated with purchase of this equipment is extremely rapid.

In most applications below 50,000 GPD (gallons per day), the most economical equipment uses ultrafiltration (UF) membranes to break the emulsions. At higher flows, chemical treatments such as DAF (dissolved air flotation) are more cost effective.

Many railroad facilities already have some form of oil removal equipment installed. This equipment can remove gross oil and solids, but will not remove the emulsified oil.

The UF equipment can be added as a polishing state, and the existing equipment can be used for pretreatment of the emulsions.

Legal Limitations On Discharge. The federal limit for discharge of oil into the environment is 15 PPM, and individual state limits can be more stringent. Limits for discharge into municipal sewer districts (MSD's) vary, but are typically 50 to 100 PPM. Waste emulsions contain water, oil and solids. Proper disposal usually comprises:

—cleanup of the water for discharge into the environment or into an MSD,
—recovery or incineration of the oil, and
—land fill disposal of solids.

Sources of Emulsions. Emulsions are typically produced by washing operations to remove oil and grease from rolling equipment, shop equipment and facilities. Detergents and other cleaning agents are used. As a result, the oil content of the wastewater typically exceeds the legal limitations for discharge into municipal sewers or into the environment. For railroad facilities, typical sources are:

-washing locomotive engines,
-scrubbing locomotive carbodies,
-cleaning engine components,
-washing locomotive trucks,
-cleaning traction motor frames and gearcases,
-washing freight car interiors,
-scrubbing concrete floors and
-cleaning inspection pits.

Emulsions. Oil and water are immiscible fluids. That is, when they are mixed they remain oil and water and do not become a new chemical compound.

Agitating the mixture breaks the oil into small droplets and produces a "mechanical emulsion". If no chemical agents are present, even relatively small droplets can usually be separated by gravity.

Adding detergents breaks the oil into even smaller droplets and produces a "chemical emulsion" which won't separate by gravity., and additional treatment is required.

Hauling Costs. One alternative is to have the wastewater removed from

the premises and treated by an authorized waste hauler. Although this is not common practice in the railroad industry, the cost of removal and proper treatment provides a baseline against which the cost of on-site equipment can be measured.

The rates charged by authorized waste haulers include:

-operating cost of the tanker from disposal site to your facility and return,

-turnaround times at your facility and at the disposal site, and

-the cost of processing your wastewater.

For any given location, tanker operating and turnaround times are relatively fixed. As shown in Fig. 1, the cost per gallon for very small volumes is high.

As the volume per haul increases, cost per gallon decreases. But, when the volume per haul exceeds that which a single tanker can carry, then little further savings can be expected.

When multiplied by gallons per day (GPD) and days per year, these unit costs per gallon add up to serious money (Fig. 2). Using representative figures, hauling away a flow of 6,000 GPD 5 days per week will total over $250,000 per year.

Since this emulsion is mostly water, concentrating it on-site to remove the water will save a lot of money, and the amount of money to be saved is not likely to decrease. Hauling costs have been rising rapidly nationwide and will continue to rise as liquid waste disposal becomes more difficult.

Also, the hauling costs discussed here are for petroleum based oil:

1. A market exists for used oil. The oil can be re-refined and sold.

2. Since the water must be eventually removed, the value of the waste emulsion depends upon its water content.

3. Since UF does not add chemicals to the oil, use of UF does not detract from the ability to re-refine the concentrated emulsion.

4. These considerations do not apply to chemical sludges produced by synthetic coolants and by chemical processes such as dissolved air flotation (DAF). Their disposal is a separate subject.

Potential Volume Reduction. As shown in Fig. 3, initial concentration is very important. If the wastewater is very dilute, then it contains a high percentage of water and a substantial reduction in volume is possible.

As the initial oil content increases, the percentage of water and the potential for volume reduction decreases.

Investment In On-Site UF Equipment. In our experience, most railroad facilities generate wastewater which is over 95% water. With equipment which can concentrate this to 60%, the volume to be hauled can be reduced significantly.

For example:

daily volume = 6,000 gallons

initial concentration = 1%

oil = 6,000x0.01 = 60 gallons

final concentration = 60%

volume remaining =
60 / 0.60 = 100 gallons

volume reduced by
6,000 — 100 = 5,900 gallons

percent reduction = 98%

estimated annual hauling cost
= $264,000

potential savings
0.98x$264,000 = $259,000

Also, the initial and operating costs of equipment to obtain the savings illustrated above are relatively small. As show in Fig. 4, the payback is terrific.

Comparison of UF and DAF Equipment. At higher flows, hauling is really out of the question. The real comparison is between alternate on-site processes.

For this paper, we have shown DAF as the alternate to UF. The cost characteristics of DAF are typical of other similar processes and are suitable for this comparison with UF.

In the flow range of concern, the initial cost of UF is higher than that of DAF and its operating cost is lower. Based upon assumed but realistic costs of labor, sludge disposal, electric power, chemicals, etc.:

at flows below 50,000 GPD, UF has the advantage over DAF, and

at flows above 50,000 GPD, DAF has the edge.

Complimentary Processes. UF and DAF do not necessarily compete for the same applications. Each has a range of flows and applications at which it is best.

In practice, the two processes can complement one another. If a smaller flow is disrupting a large DAF or chemical treatment installation, then consider UF for the problem flow alone. This will ease the operating problems of the large system.

Similarly, if an existing biological system is being overloaded, the removal of emulsified oil from a specific discharge stream by UF can greatly reduce the loading on the existing plant, and this can be much less costly then upgrading the existing plant.

What Is Ultrafiltration? UF is pressure-driven, cross-flow filtration with pore sizes between 0.001 and 0.01 microns:

1. Pressures are relatively low, in the vicinity of 50 to 100 psi.

2. Cross-flow means that the liquid is pumped across the face of the membrane at high velocity to minimize fouling.

3. The pores are so tiny that they will reject oil droplets, even those in chemical emulsions.

Perhaps the single most important advantage of UF is that the rejection of oil is mechanical and does not depend upon the skill of the operator.

How Does UF Concentrate Emulsions? Since the membrane passes water and rejects oil, the water extracted from the emulsion is essentially oil-free and can be legally discharged.

As the water is extracted, the remaining emulsion becomes more concentrated. If the water and oil are of the same density, then concentrations of 25% to 30% can be achieved.

However, if the oil and water can separate by gravity, then the emulsion will become unstable at higher concentrations and separate even further. A properly designed regenerative system should routinely obtain concentrations of 60% or more.

Membrane Flow Characteristics. Typically, membranes will produce an average flux of between 10 and 30 GFD (gallons per square foot of membrane surface per 24 hour day) at 100° F. However, the flow can vary considerably:

Temperature. The membrane pores are so small that the viscosity of the water and therefore the temperature of the water has a significant effect upon flow.

As shown in Fig. 6, heating water from 50° to 100° F. can literally double the attainable flow through a given membrane element.

Fouling. The membranes will be fouled by oil over a period of time. Periodic, in-place washing of the membranes with detergent will be required to maintain throughput.

Immediately after washing, flow will be high. It will decrease gradually until the next washing is required. The net daily volume which the unit will process will depend upon frequency of washing and downtime for washing.

Typical flow versus fouling is shown in Fig. 7 for a single 8 inch spiral element.

Fig. 8 shows the effects of fouling, down time for wash and the time to process the washwater on daily net throughput for the same membrane element. The data shown are significant:

1. The very same membrane element can be conservatively rated at 2,500 GPD or claimed to produce "up to 4,500 GPD." The difference is in frequency of wash required to sustain flow.

More conservative equipment selection will result in less maintenance, and the lowest initial cost will result in the highest maintenance.

2. As the time between washes increases, the down time required for wash becomes less significant. The same conclusion would apply to all types of maintenance.

Wastewater Characteristics. The flow to be expected in service will depend upon the oil content, solids content, etc. - the actual characteristics of the wastewater.

For the example above, a flow of 6,000 GPD at a water temperature of 68° F. (20° C.) will require between 300 and 900 ft2 of membrane area depending upon actual conditions and the type of membranes selected.

Types of UF Elements. For this application, three types of elements have been used; tubular, hollow fiber and spiral. The terms refer to the construction of a complete filter element which employs the UF membrane.

The method of construction does not affect oil rejection. For the same membrane material and pore size, the element type has no effect upon its ability to reject oil.

The tubular and spiral elements employ laminated thin film membranes. That is, a thin film of membrane is laminated onto a porous substrate to obtain the desired characteristics.

Hollow fiber membranes are normally extruded. Since the method of manufacture is different, the rejection and flow characteristics may be somewhat different than for tubular and spiral elements.

Tubular. Standard tubes are 1 in.^{2} diameter by 10 ft. long. Each tube has an effective area of 2.2 ft.^{2} For the example flow of 6,000 GPD, and using the flux range from above, between 120 and 350 tubes will be required.

Dirty water is pumped through the inside diameter of the tube and the clean water passes through the outside of the tube. The tubes are installed in individual pressure vessels.

The tubes are cleaned by pumping detergent solution and sponge balls through them.

Hollow Fiber. Individual hollow fibers are extruded from the membrane material. Large numbers of these fibers are bundled in modules with cast blocks at each end to seal the dirty feed from the clean permeate.

Dirty water is pumped through the inside diameter of the fibers and the clean water passes through the outside of the fibers. Each complete element comprises a pressure vessel.

Individual elements have an effective area of about 53 ft.^{2}, so that the example above would require between 6 and 17 elements.

One major advantage of hollow fibers is that the membranes can

be backwashed to extend the period between detergent washes.

Spirals. Several flat sheets of membrane are glued to each other on 3 sides and to a perforated central tube on the fourth side. They are then rolled up around the central tube like a newspaper.

Dirty water is pumped down the length of the spiral. The clean water passes through the membrane and then spirals down to the central tube where it is collected and discharged.

The membrane spacers and narrow openings provide high surface velocity and turbulence to minimize fouling and enhance detergent washing.

Individual elements have an effective area of about 250 ft^2, so that the example above would require between 2 and 4 elements. Also, several spiral elements can be installed in a single pressure vessel.

Spiral Elements. Each type of element has its own advantages and disadvantages, and there is no reason why properly designed equipment will not do the job, regardless of the membrane configuration to be employed.

But, we prefer the spirals and use them exclusively in our equipment. There are several reasons, including:

Initial Cost. The initial cost for spirals are lower. Not only is the membrane element itself cheaper, there are fewer pressure vessels to be installed. This greatly reduces the cost of the pressure vessels and the interconnecting piping.

Also, the spirals are more energy efficient. In general, pumps, feed piping, electric motors and starters are smaller.

Operating Cost. Savings due to energy efficiency are obvious. Not so obvious are savings due to lower element replacement cost.

Despite improvements in membrane life due to improvements in materials technology and equipment design, membranes fail and require replacement. For a given membrane area, the elements themselves cost less.

Also, fewer larger elements require fewer seals and less labor for replacement.

Space. The spirals can be installed in much less floor space than any other configuration, and the advantages are obvious. In addition, larger systems can be factory-built rather than field erected, resulting in lower total installed cost.

UF Equipment Arrangements. Practical UF installations feature certain common elements:

Pressure Vessels. These house the elements themselves and include the seals to isolate the clean permeate from the dirty feed. As a minimum, each pressure vessel has 3 pipe connections; feed, concentrate and permeate.

Circulating Pump. To minimize fouling, the pump may deliver a cross-flow of 60 GPM across the face of the membrane to obtain 1 GPM permeate flow. Therefore, the pump, electric motor and piping are larger than one would expect for the net flow of clean water obtained.

Reservior. To wash the membranes in place requires a minimum volume of water. This volume can be a permanent part of the pump loop or it can be valved in during wash only.

Bleed Piping. Both oil and water are fed to the membrane, and only water is extracted. A small flow is continuously bled off to control oil concentration applied to the membranes.

Fine Solids Removal. Both spiral and hollow fiber elements require removal of fine solids to prevent plugging the small flow openings.

This fine solids removal is normally the final step in a broader pretreatment scheme which is necessary to successful operation of UF equipment.

These components are illustrated in Figures 9, 10 and 11. Note the similarities of and differences between the equipments shown:

Fig. 9 shows a skid mounted UF unit equipped with a single 8" spiral element.

In Fig. 10, a gravity coalescer and automatic oil ejection feature are added. The membrane system is identical to that in Fig. 9.

Fig. 11 shows a unit with nine times the capacity of that in Fig. 10. But, it is essentially identical in principal of operation and layout.

The equipment scales linearly. That is, nine 8" spiral elements will produce approximately 9 times the throughput of one 8" spiral element in the same service.

Pretreatment for UF. In this context pretreatment is essential for efficient operation of UF equipment. Both the initial and operating costs of suitable pretreatment equipment have been included in all cost calculations and charts.

Four basic types of pretreatment are required:

Flow Equalization. Equipment cabable of breaking emulsions is expensive and tanks are cheap. It is more economical to select equipment to process the average flow rather than the peak flow.

As a general rule, the surge tankage should comprise a volume of not less than 24 hours at rated capacity of the UF system installed.

Gross Oil Removal. UF does a good job of processing dilute emulsions. But, free oil rapidly blinds membranes.

A good gravity separator with an efficient means of oil removal is not only desirable as a pretreatment, it is necessary.

Solids Removal. Removal of gross solids is necessary ahead of UF. It is also necessary ahead of the gravity separator to prevent plugging and ensure good oil removal efficiency.

Although a separator can be designed to pass large solids, the same sized unit will do a much better job of oil removal with smaller clear openings.

Removal of fine solids also enhances UF. The fouling rate of the UF membranes is reduced, producing a higher average throughput with less maintenance.

Disinfection. In many cases (not all), microbial slimes in the wastewater can cause rapid fouling of UF membranes. When this does occur, low rate chlorination can be employed to prevent slime formation.

Note that similar pretreatment is required for virtually all methods of breaking chemical emulsions.

Pretreatment Paradox. Efficient removal of oil requires prior removal of solids, and efficient removal of solids requires prior removal of oil.

Stokes' Law. Stokes' Law is the underlying basis for selecting gravity separation equipment. It also describes the settling characteristics of tanks used for flow equalization and other purposes.

Stokes' Law applies to gravity separation of solids as well as of immiscible liquids, and a very useful form of the equation is:

$$\frac{GPM}{FT^2} = 8.023 \times 10^{-6} (B - A) \frac{D^2}{u}$$

where:

GPM/FT^2 = the rise rate of the oil

droplet (overflow rate)
B = density of water in g/cc
A = density of oil in g/cc
D ⁵ diameter of oil droplet in microns
u ⁵ viscosity of water in poises.

This is illustrated for oil/water separation in Fig. 12.

As indicated by Stokes' Law, heating the mixture has several effects upon the separation:

1. The viscosity of the oil is significantly reduced, making it easier to settle water and solids out of the oil.
2. The viscosity of the water is also reduced, making it easier for the oil droplets to rise.
3. Also, and to a lesser extent, heating enhances the difference in specific gravity between water and oil.

The effects of heating are illustrated in Fig. 13.

Gravity Separators. Gravity separators are Stokes' Law devices. They will separate a droplet or particle of a given diameter based upon overflow rate, temperature, viscosity and differential specific gravity.

Note that the gravity separator discriminates oil droplets on the basis of diameter and not on the basis of PPM.

Practical gravity separators incorporate tilted plates or coalescing media to enhance separation by increasing the projected area available within a tank of a given size. Usually, the projected area for each model of separator is published by the manufacturer.

It is therefore useful to write the Stokes' Law velocity in GPM per square foot:

EXAMPLE: You wish to separate 20 micron droplets of oil with specific gravity of 0.85 at a temperature of 20° C. (68° F.) at a flow of 50 GPM.

According to Stokes' Law, the terminal velocity of these oil droplets is 0.1 GPM/SFT. At 50 GPM, a projected are of

$$\frac{50 \text{ GPM}}{0.1 \text{ GPM/SFT}} = 500 \text{ SFT}$$

is required, and you can select the separator from a catalog.

There are several major considerations in selecting a separator for this application:

1. The angle of repose of the plates or coalescing media (as applicable) should be 60° to prevent plugging.
2. Plate spacing or clear opening of the media should be not less than twice the diameter of the largest spherical solid which can reach the separator. Conversely, the separator can be protected with a strainer with openings one-half the clear opening of the separator media.
3. The separator should be equipped with an efficient means of automatically removing separated oil.
4. If the separator is also to be used to remove fine solids, then:
   (a) The separator should be equipped with a conical or hopper bottom with a 60° angle of repose, and
   (b) An efficient means should be provided to automatically remove separated solids.

Plugging by solids is a major consideration with coalescing plates and media in service. Pretreatment to remove solids will permit closer plate spacing and more efficient separation for a unit of given size and cost. This is illustrated in Fig. 14.

Flow Equalization - Secondary Effects. Surge tanks have area, overflow rates and separation capability of their own. There performance as separators can be calculated using Stokes' Law.

At low daily flows and with

relatively light solids loading, the surge tanks can be used to remove gross oil and the bulk of the solids from the wastewater.

A typical tank sized for 24 hour detention will have an overflow rate of approximately 0.06 GPM/SFT (Fig. 15). As shown in Fig. 16, such a tank will separate 20 micron oil droplets and dirt particles down to below 10 microns - really pretty good.

For the tank to remain an effective separator, regular removal of both oil and solids is required, Otherwise, the tank will fill with solids and cease to act as a separator. As illustrated in Fig. 17, the accumulation rate of solids in a surge tank can be surprisingly rapid.

At high flows and solids loadings, solids and oil separators will be installed ahead of the surge tankage:

1. It is desirable that the overflow rate of the primary separator be less than that of the downstream surge tank. This will prevent accumulation of oil and solids in the tank.
2. The surge tank and separator may be subject to different flows. For example, the separator may be connected to the discharge of a sump pump, while the surge tank will effectively be subject to the average flow.

Existing Equipment. It is almost always wise to retain existing treatment equipment as pretreatment for UF. Many railroad installations are equipped with open pit separators, and these can be equipped with baffles and an oil skimmer to enhance performance.

In most railroad shop applications to date, an existing separator supplemented by bag filters on the UF unit have proved to be both practical and adequate.

Disposal of Concentrate. The cost data shown on the charts assume that a contractor will be paid to haul away the concentrate and oil-coated solids. At higher flows and associated higher volumes of oil, alternatives are available:

Incineration. At 60%, the concentrate should be able to support combustion so that no additional fuel should be required for disposal. Incineration is a viable alternative to hauling.

Centrifuging. Despite the presence of detergents, 60% emulsions are unstable and can be centrifuged to produce salable waste oil.

Requirements differ from area to area. But, a typical situation is that 80% oil will be hauled away at no charge, and a premium will be paid for the waste oil proportional to its oil content above that concentration.

Post-Treatment. For typical railroad applications, the UF permeate can be discharged directly without further treatment.

Solvents and other light fraction hydrocarbons will pass through UF membranes. However, in most railroad applications, they do not materially affect the acceptability of the permeate. If they do, then activated carbon is the usual method of polishing the permeate before final discharge.

The need for post-treatment has been further reduced by recent membrane developments. New membranes are available with improved hydrocarbon rejection combined with higher flows.

Hints and Suggestions for Application of UF Equipment. Some hints based upon experience in railroad and other applications:

Sizing and Selection.

1. Make sure the UF equipment has sufficient capacity to meet your needs. Net daily processing capacity depends upon frequency of washing. This frequency must tie into your maintenance schedule.

2. Wastewater production grows over time as facilities expand.
3. Irreversible fouling may reduce membrane capacity over time. Adequate membrane area can prevent premature replacement of membranes.

Installation and Operation.

1. Suction lifts, underground tanks and buried pipes are problems waiting to happen. Use lift pumps, install new surge tanks and piping above grade and operate UF equipment in the flooded suction mode.
2. For low temperature operation, heat the emulsion:
   the membranes will produce more flow,
   the concentrate will contain less water,
   fouling will be reduced, and
   maintenance will be reduced.
3. Don't purchase the UF equipment and then skimp on tankage and pretreatment:
   the result will be poor performance and high maintenance, while
   the installation would show a terrific payback when properly equipped.
4. Don't skimp on the maintenance budget:
   equipment which will break emulsions requires maintenance, the installation would show a terrific payback when properly maintained, and
   it won't show any payback at all if it's down.

Maintenance. The most significant item of maintenance is washing the membranes to maintain flow:

1. Use the gentlest wash procedure which is effective. Although the membranes have excellent chemical resistance, continued use of harsh cleaning agents can shorten the life of the membrane.
2. Make sure the membranes are thoroughly cleaned. The membranes should wash back to the same flow each time. If the flow is degrading after each wash, use more aggressive procedures as needed.
3. Use a concentrated low-sudsing or non-sudsing detergent. Each commercial detergent formulation incorporates different wetting agents and builders. Some are much more effective than others in specific applications.
4. A source of warm soft water for washing is critical. In extreme cases, on-site water treatment may be required.
5. Caustic is useful to remove paraffin and grease. Inexpensive lye enhances the cleaning abilities of relatively expensive detergents.

   However, lye is hazardous, requiring safe procedures. Also, continued use of strong caustic wash solutions can shorten membrane life.
6. Good pretreatment minimizes but does not eliminate the need for washing.
7. The washing process can be automated.

Conclusions.

1. For most railroad facility applications, on-site concentration makes good economic sense. It will significantly reduce operating costs and provide the payback necessary to justify purchase of equipment.
2. UF is the method of choice below 50,000 GPD and DAF above 50,000 GPD. There is an area of overlap, and each process has its own advantages and pro-

blems.

3. Both UF and DAF require good flow equalization, pretreatment and maintenance. Both will provide a good payback when properly selected, installed and maintained.

4. The main item of maintenance for UF is washing the membranes to maintain flow, and this can be automated.

References. Ultrafiltration of oily wastewater is a relatively new and rapidly changing technology. Most of the real knowhow is closely held by equipment manufacturers, and very little information of practical value in application is available in the literature.

Author. *Alan Fleischer is President and chief engineer of FAST Systems, Inc. He has been designing industrial wastewater treatment systems for 18 years. Mr. Fleischer holds a B.S. Aeronautical Engineering and an M.B.A. from St. Louis University.*

FIGURE 1. TYPICAL HAULING COST PER GALLON

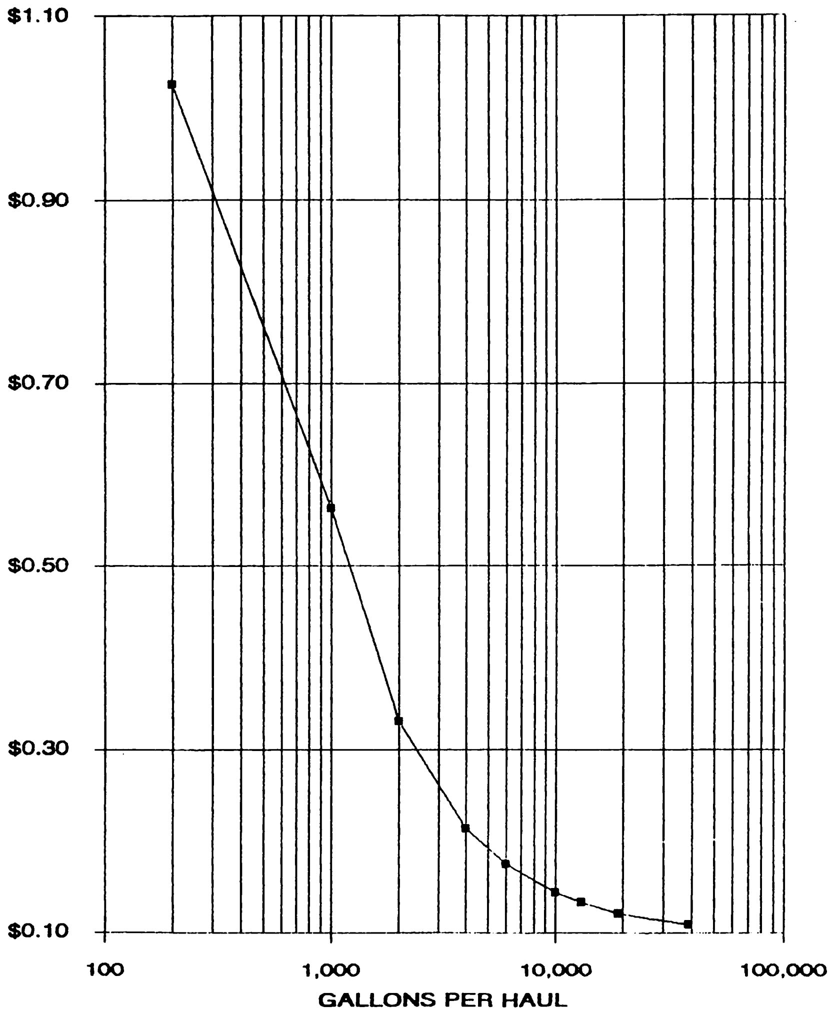


FIGURE 2. ESTIMATED ANNUAL HAULING COST

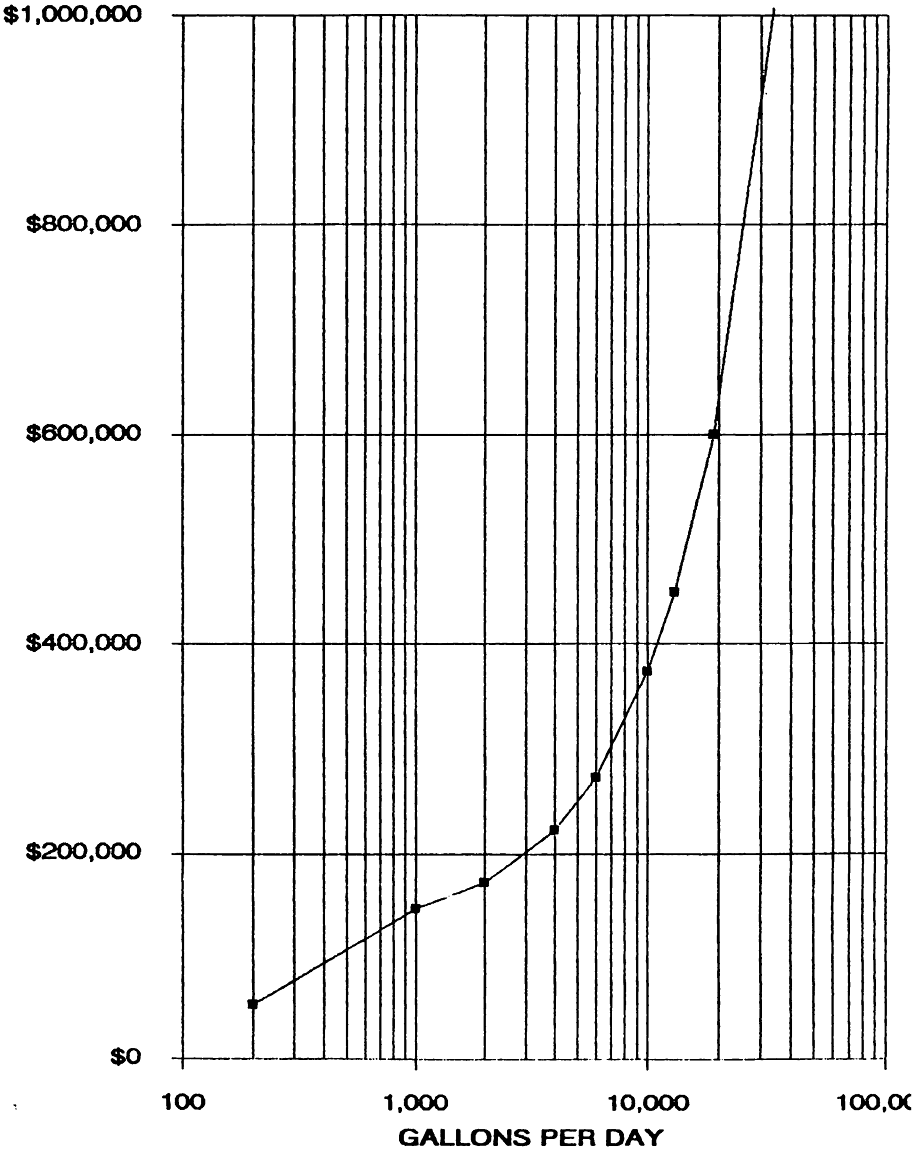


FIGURE 3. POTENTIAL VOLUME REDUCTION VERSUS INITIAL CONCENTRATION

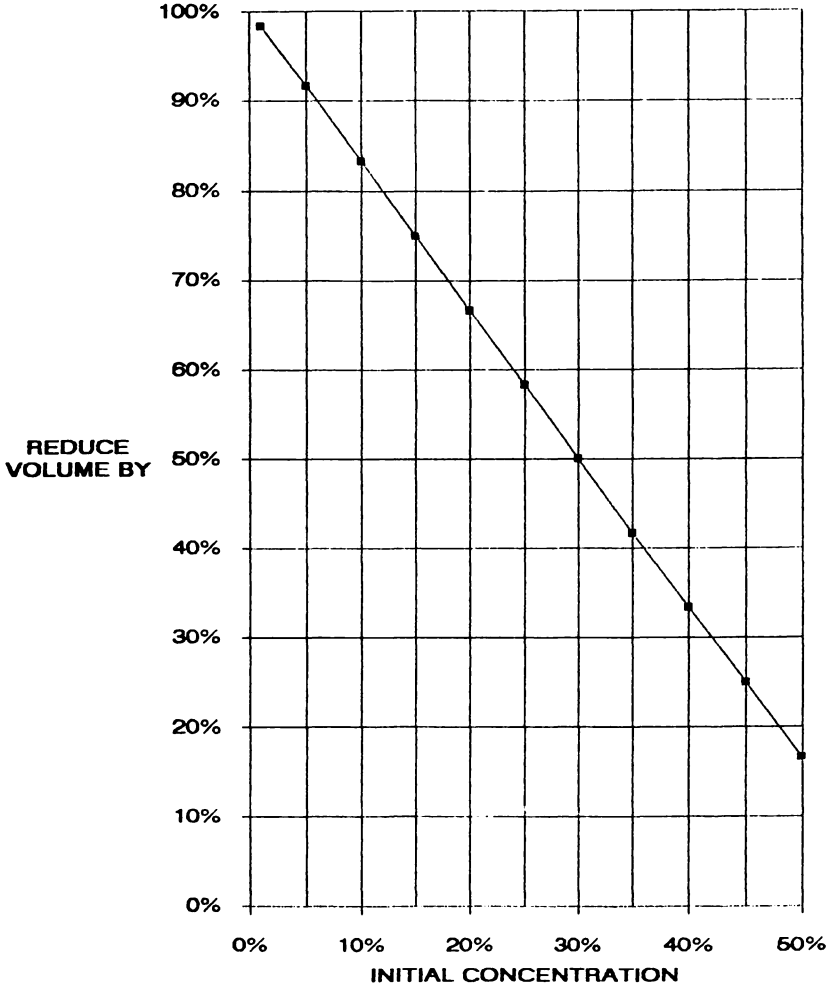


FIGURE 4. SAVINGS IN HAULING COSTS VERSUS INVESTMENT IN ON-SITE UF EQUIPMENT

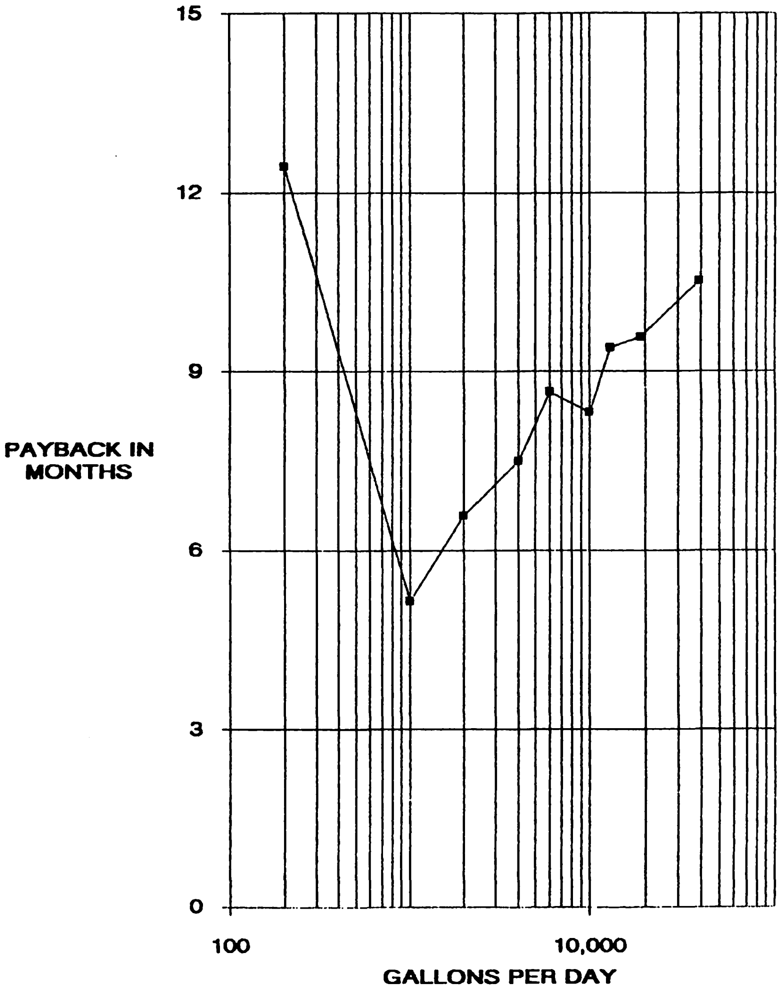


FIGURE 5. SAVINGS IN OPERATING COST VERSUS EXCESS INITIAL COST OF UF OVER DAF

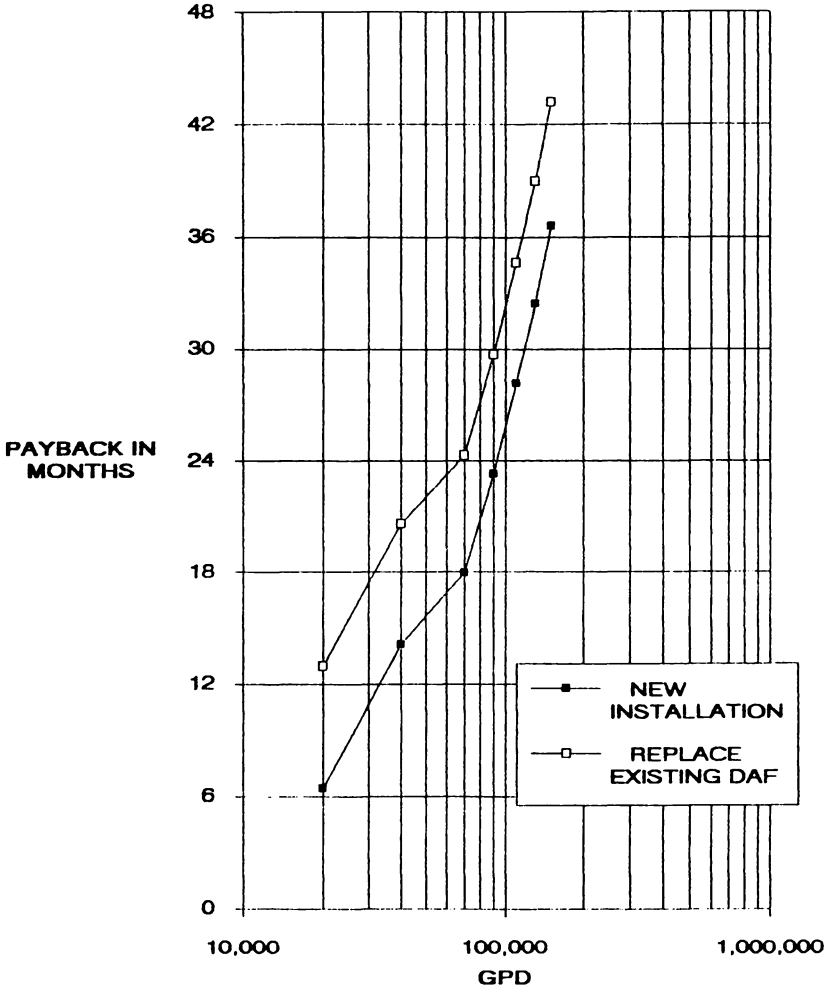


FIGURE 6. MEMBRANE THROUGHPUT VERSUS WATER TEMPERATURE (100% = 100 DEG. F.)

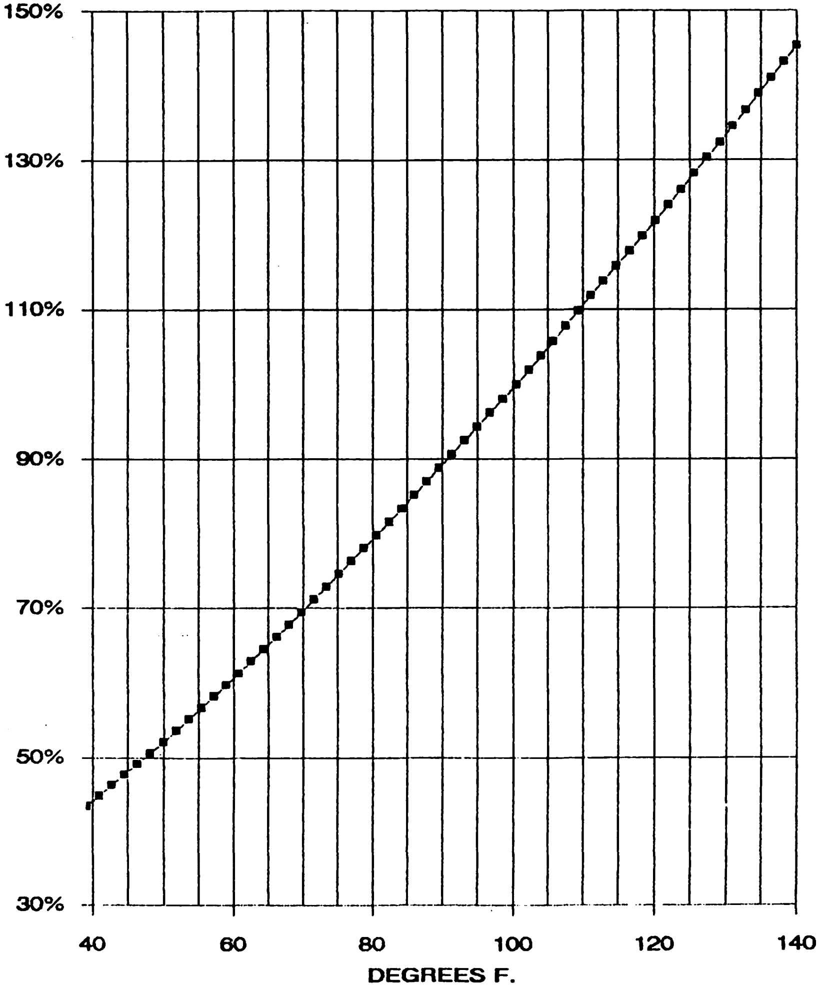


FIGURE 7. TYPICAL FOULING OF UF ELEMENTS

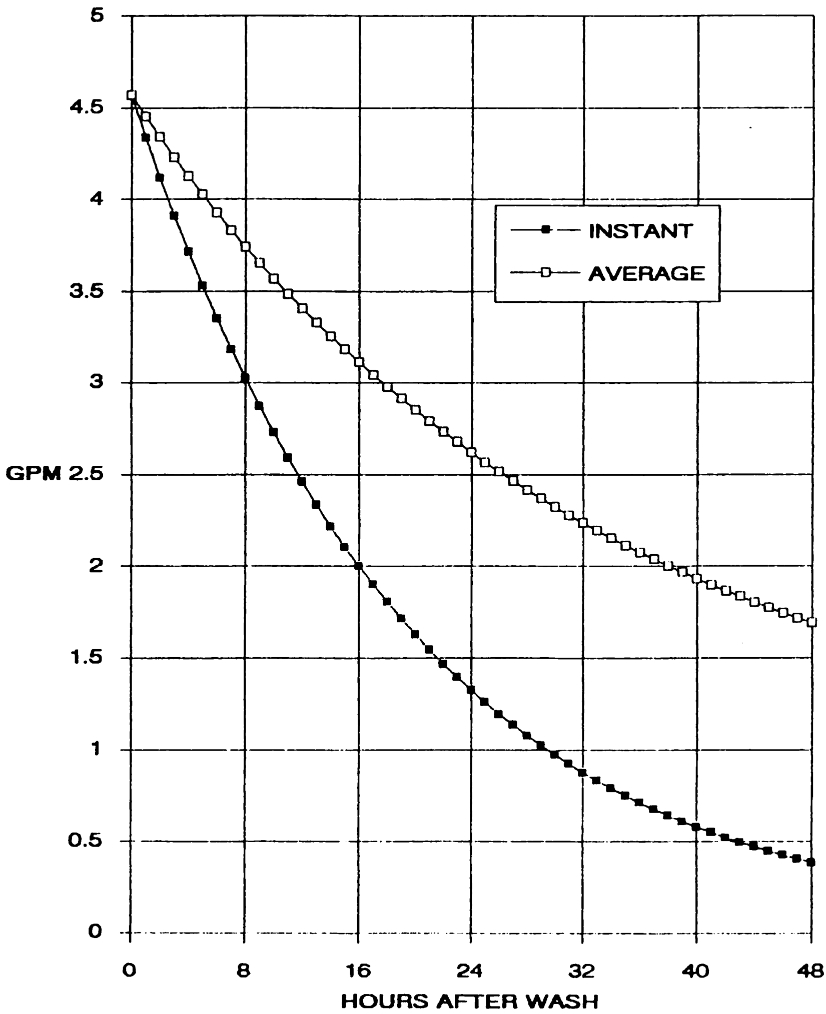
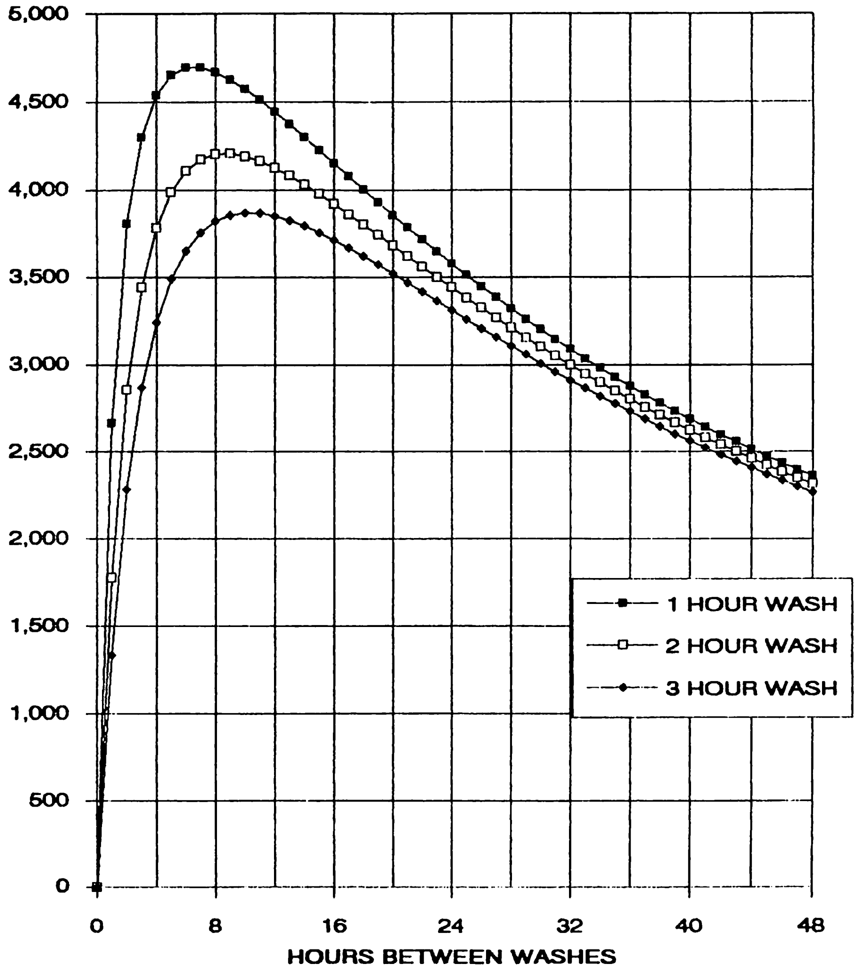


FIGURE 8. TYPICAL UF ELEMENT GPD NET OF DOWN TIME FOR WASHING AND NET OF WASHWATER TO CLEAN MEMBRANE



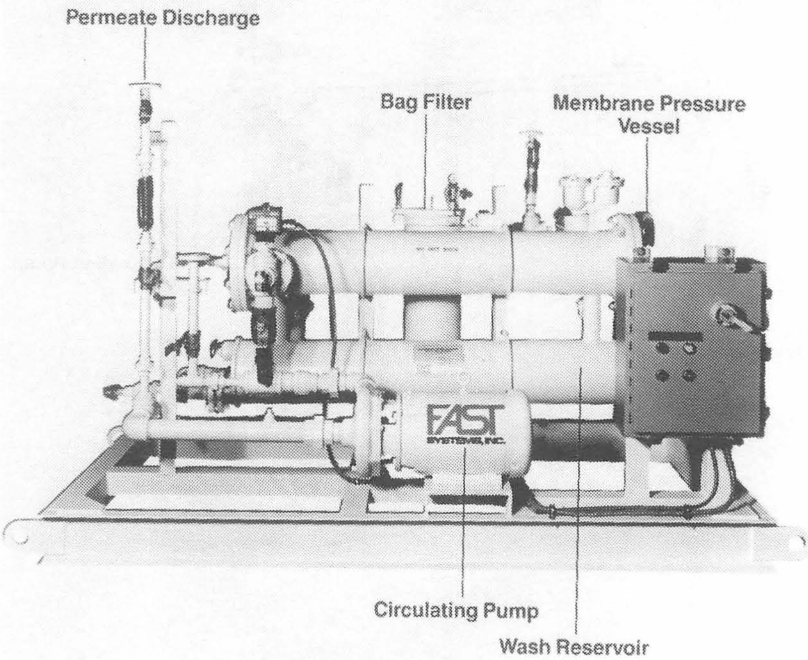


FIGURE 9
UF oil/water separator equipped with one 8″ spiral element, nominal capactiy 2,400 GPD.

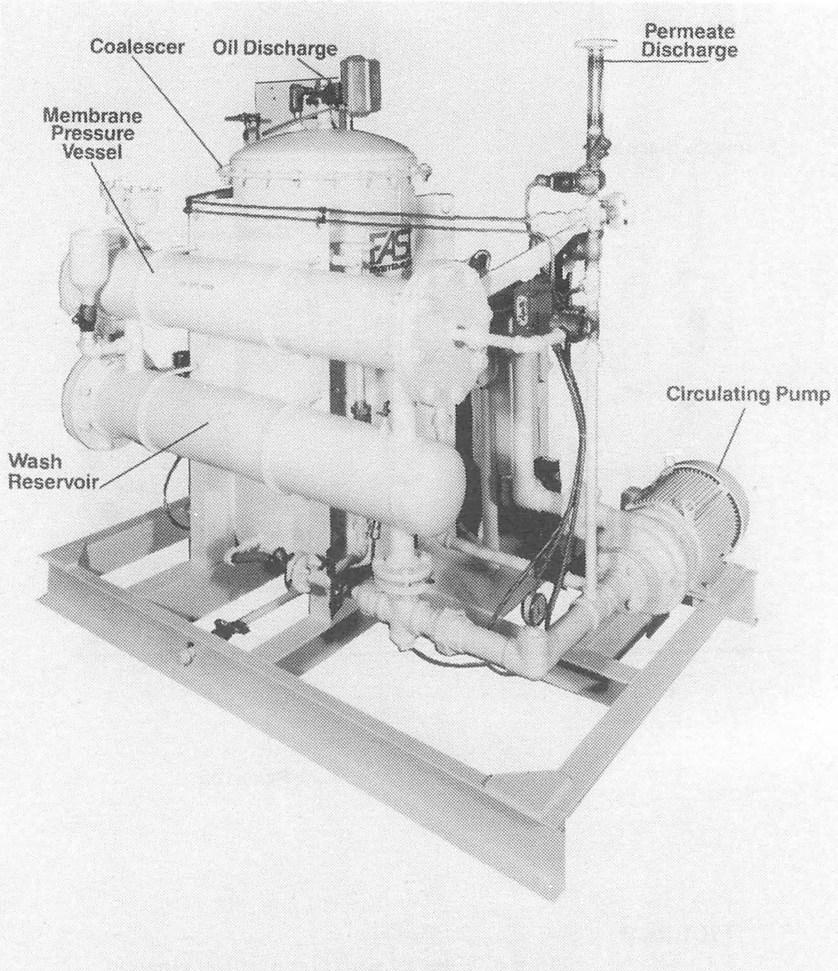


FIGURE 10
UF oil/water separator equipped with one 8″ spiral element, coalescer, automatic oil ejection, nominal capacity 2,400 GPD.

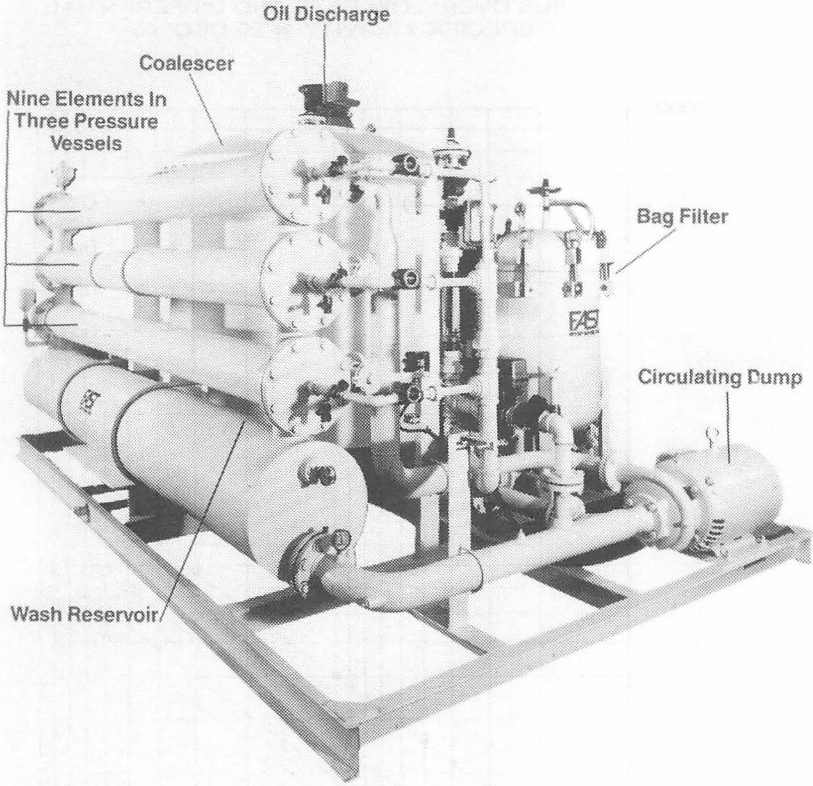


FIGURE 11
UF oil/water separator equipped with nine 8″ spiral elements, coalescer, automatic ejection, nominal capacity 21,600 GPD.

FIGURE 12. STOKES' LAW, DROPLET DIAMETER VERSUS OVERFLOW RATE AND DIFFERENTIAL SPECIFIC GRAVITY @ 20 DEG. C.

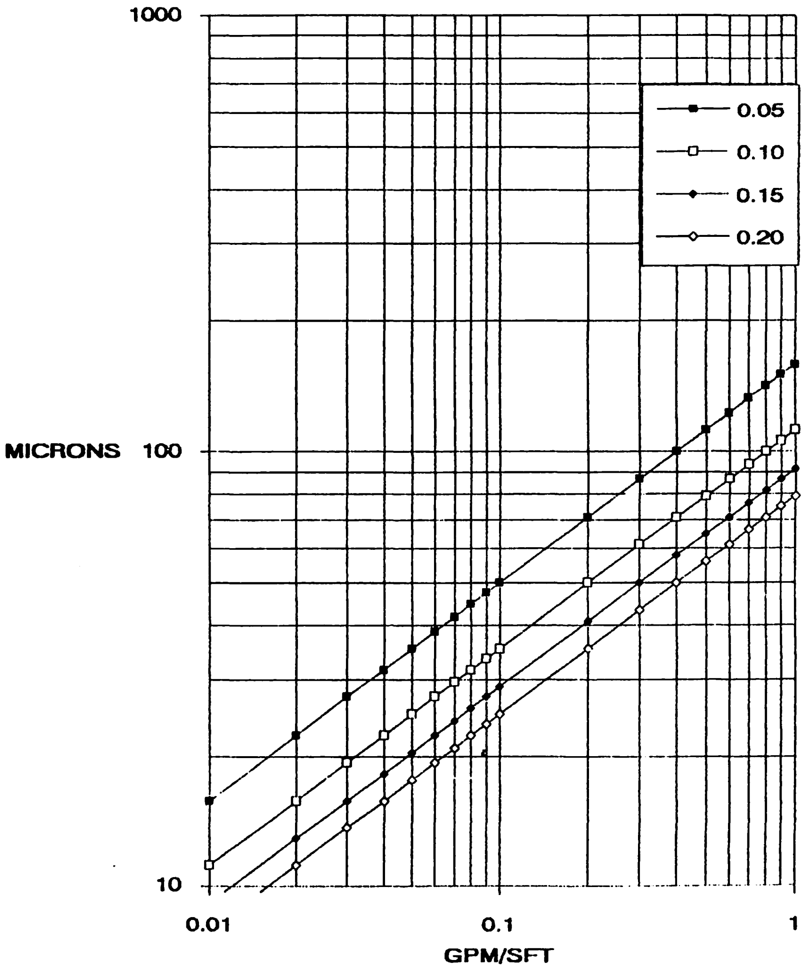


FIGURE 13. STOKES' LAW, DROPLET DIAMETER VERSUS WATER TEMPERATURE AND DIFFERENTIAL SPECIFIC GRAVITY AT 0.1 GPM/SFT

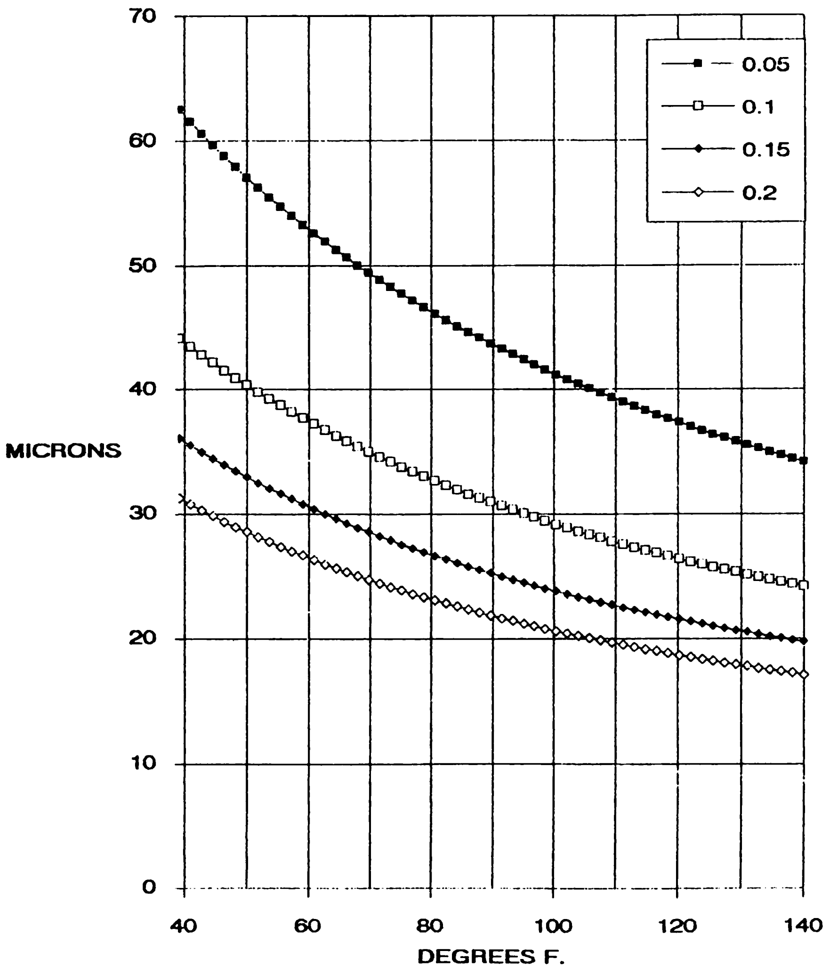


FIGURE 14. TYPICAL COALESCING MEDIA, EFFECT OF CLEARANCE ON SEPARATION PERFORMANCE

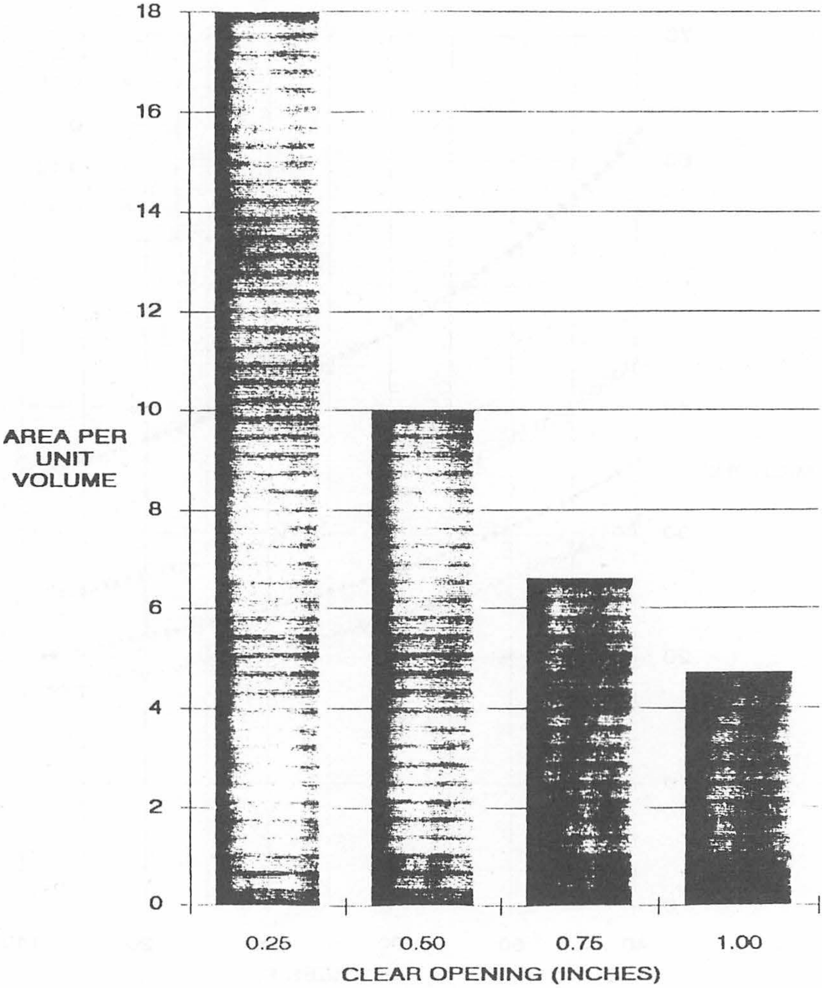


FIGURE 15. AVERAGE OVERFLOW RATE OF HOLDING TANKS WITH HEIGHT = DIAMETER

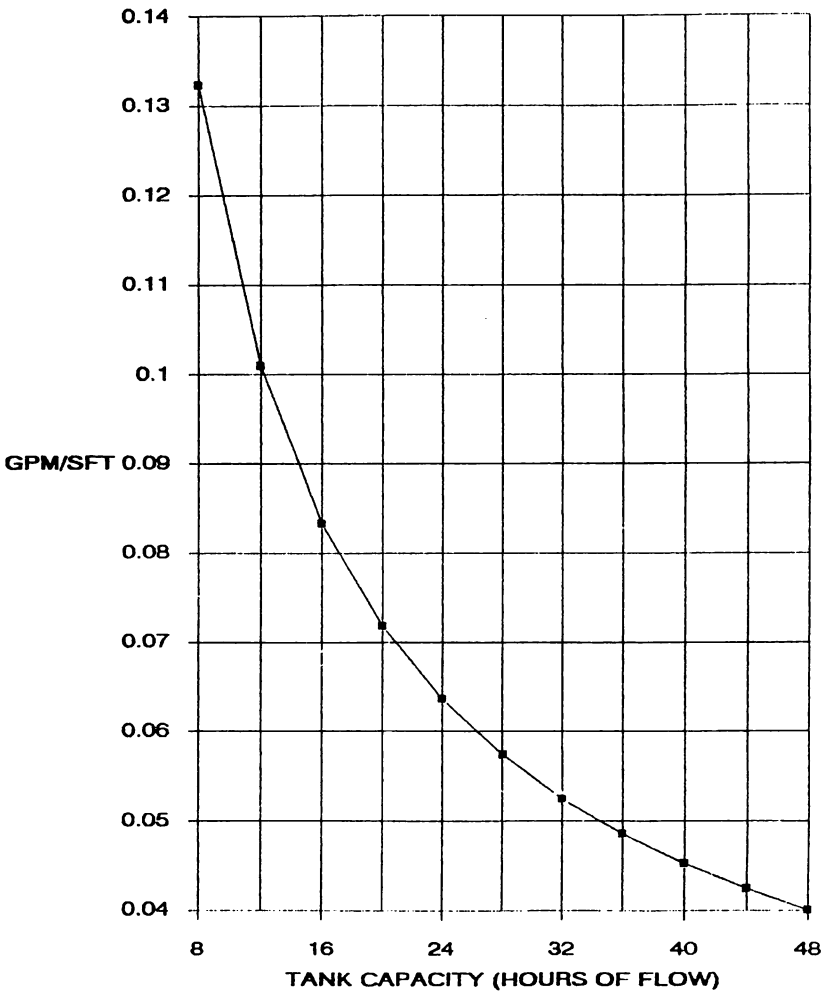


FIGURE 16. STOKES' LAW, SEPARATION PERFORMANCE OF SURGE TANKS WITH HEIGHT = DIAMETER

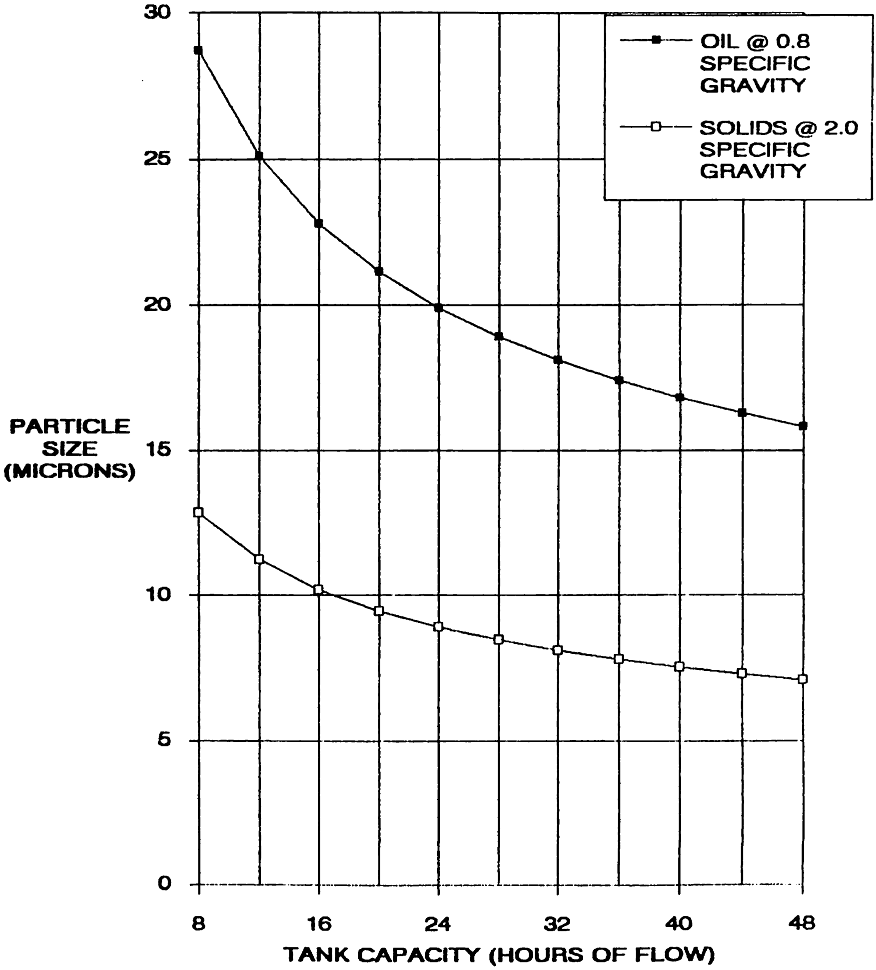
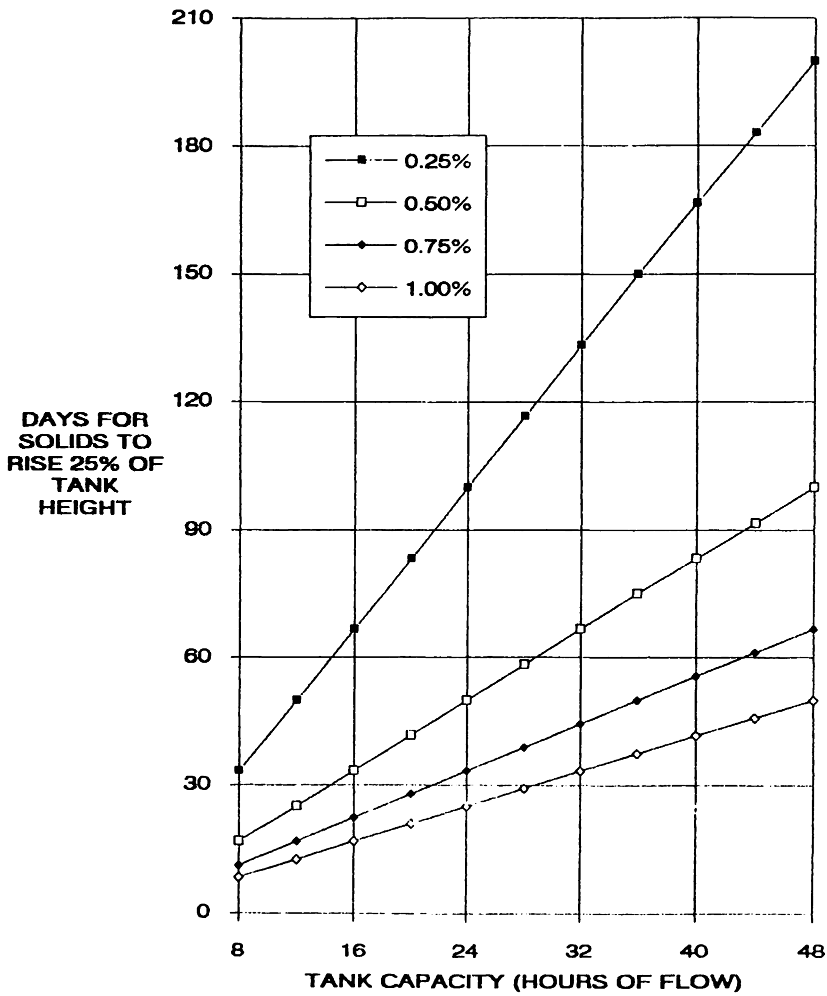


FIGURE 17. RATE OF SOLIDS ACCUMULATION VERSUS SOLIDS CONTENT BY VOLUME



II. EMD CYLINDER HEAD VALVE SEAT MACHINING

Presented by: John Clontz

The grinding of valve seats on EMD cylinder heads has traditionally been a very time consuming and difficult job. Depending upon the severity of wear, it typically takes as long as 15 minutes to grind a new profile onto each of the four valve seats. Simple mathematics indicate that it takes 16 hours of labor to complete the valve seat grinding process on a standard 16 cylinder EMD engine.

During a typical cylinder head rebuilding process, the head is first cleaned, then physically inspected for cracks and the fire face is resurfaced to the correct phonographic finish. Provided the head has not been determined unserviceable by this time, new valve guides are then installed and the head is now ready for valve seat grinding. The grinding process typically requires three individual grindng motors, each one equipped with a grinding stone of the particular configuration required to resurface the various angles and surfaces of the valve seat area.

Along with being a time consuming process, grinding of valve seats has several other quality and safety disadvantages. The grinding stones wear as they are used, having a tendency to acquire the profile of the worn valve seat areas. This tendency decreases the accuracy of the finish that is applied to the valve seat. Special grinding wheel dressing tools must be used periodically to ensure that correct profiles are obtained. The mandatory use of the dressing tools increases the cycle times required for valve grinding. In addition, the grinding stones and the refinishing tools generate clouds of abrasive dust and metal particulates that cause safety concerns for the grinding tool operators. Finally, the grinding process requires fairly intensive operator training and a certain "touch" to ensure a quality finished product.

Several railroads and cylinder rebuild shops have now abandoned the valve seat grinding process in favor of a newer, safer, faster, higher quality valve seat machining center. Machining, as opposed to grinding, offers numerous advantages. First, and possibly most importantly, cycle times for machining a complete EMD head are typically four to five minutes, including loading and unloading the head onto the machining center. Using the machining process, the time required to finish all four valves on all the heads of a sixteen cylinder engine is one hour and twenty minutes, resulting in a total labor saving of greater than 14 hours per engine. The process is also highly accurate, generating a much higher quality valve seat with accordingly improved power assembly reliability. In addition, operator training is minimal and the generation of dust and metal particulates is nonexistent.

The typical machining process for an EMD cylinder head will be described in the following paragraphs. A machine being used by a western based railroad was specifically designed to be readily interjected into an existing EMD cylinder head rebuilding line. All of the controls for the machining, clamping and centering functions of the machine are conveniently placed for the operator to access.

Upon completion of the cylinder head cleaning process, the head is placed on a special fixture that enables it to be easily transported on standard roller conveyors while in the inverted position. These fixtures were already being used on this rebuild line and did not have to be specially manufactured for this machine.

After the head has successfully completed the inspection and rebuilding processes, it is advanced in the fixture to the valve seat machining center. The operator places the head into the machine where it is locked into place by pneumatic operator actuated clamps. To simplify handling and movement of the head, the machine is equipped with ball transfers on the work table as well as the inbound and outbound loading areas. After clamping, the operator actuates the air bearing for the machine head assembly, allowing the head and cutting spindle to "float" over the power assembly head for positioning with minimal effort. He places the cylindrical pilot portion of the cutting tool into the valve guide of the head, and actuates a second air bearing that allows the work head of the machine to float. This floating aspect allows the cutting head to find the true center axis of the valve guide. The accuracy of this floating system has proven to be within .002 in.

After the machine has been allowed to float to find the exact center, the operator now shuts off the air bearings, automatically applying two tons of clamping pressure to the bed and head to ensure that the machine remains rigid and accurate during the machining process.

The operator now starts the machining spindle and lowers it onto the valve seat. A carbide cutting tool is contained in a holder on the end of the spindle. This tool is specifically manufactured to duplicate the exact contours required to reprofile the valve seat. Contact is made with the seat and slight pressure applied to allow the cutting tool to remove the small amount of metal necessary to obtain the correct valve seat profile. The machining process provides a very high quality seating surface, eliminating any need for additional grinding or valve seating.

Experience at this railroad has indicated that the carbide cutting tool will machine at least 300 to 400 heads before requiring replacement. Its experience has also shown that the floating head system and the consistent profile provided by the carbide cutting tool have considerably improved the seating quality between the valve and the head. After the first valve seat has been completed, the operator removes the machining spindle from the valve guide and places it into the second valve seat, again repeating the centering and machining processes previously described. In order to complete the third and fourth seats, it is necessary to unclamp the head, turn it 90 degrees and then reclamp. After the machining process for the entire head has been completed, compressed air is applied to remove any remaining metal shavings that might cause power assembly contamination.

The head is now moved to the next rebuilding position for application of the rebuilt or new valves. Upon completion of head rebuilding, it continues down the line for application to the lower portion of the power assembly. The completed power assemblies are then placed into containers for transport to various repair locations.

The valve seat machining center has been in use at this facility for over a year. The results to date have been more than satisfactory and labor savings over the grinding process have been significant. In summary, the use of the valve seat machining center offers the following advantages:

1. **Decreased cylinder head valve seat refinishing cycle times.**
2. **Improvements in the quality of the finished valve seat.**
3. **Reduced dust and metal particulates normally accompanying the grinding process.**
4. **Comparatively simplistic operator training.**

III. AUTOMATED BARRING OVER MACHINE FOR ELECTRO-MOTIVE DIESEL ENGINES

Presented by: Don Graab

Shop personnel of an Eastern railroad have developed an automated barring over machine for EMD engines.

A manually operated version of the conventional Model 42 Tame barring over machine is widely used at railroad facilities across North America. This new automated machine makes several advances over earlier machines. The microprocessor unit replaces conventional relays, increasing reliability of the equipment. More importantly, the microprocessor stores data on crankshaft position for eight models of EMD engines and automatically positions the crankshaft for each step of the operation. In effect, the mircroprocessor commits to memory the tables in the EMD engine manual showing when to inspect each cylinder for water leaks, adjust valve lash, and set injector timing.

The automated barring system is designed around a conventional Tame machine. Controls consist of a model 7152 microprocessor from Encoder Products Company, a model 725 enhanced high speed encoder, and a Nematron IWS-100 man/machine interface station. A regulated power supply feeds the system. Crankshaft position is sensed by rotation of the right camshaft. The encoder attaches to the overspeed housing at the same place you would hold a tachometer. This generates a signal representing crankshaft position.

All the control components used in the system can be readily purchased from suppliers of electrical components. In fact, a local supply house was instrumental in selecting the encoder and a microprocessor to handle measurement data. No proprietary hardware is involved.

When the automated barring over machine is first turned on, the operator sees a main menu on the Nematron keyboard. At this time the operator has four choices as shown:

1 - MOVE MAN
2 - TEST ENG
3 - INPUT DATA (PW)
0 - EXIT.

"MOVE MAN" refers to a choice that allows the operator to move the crankshaft under manual control comparable to the conventional Tame machine.

Let's look more closely and see where the controls lead us after we select "1" to move the crankshaft manually. The next screen prompts the operator to make a visual inspection of the area around the engine. The purpose of this inspection is to assure that all drives, tools, and auxiliary devices are free to permit the engine to turn over safely.

Having started the machine's hydraulic pump when the number 1 was selected on the keypad, we are given a choice between fast and slow speed operation. At anytime, we can press the enter pad on the keyboard to stop rotation of the crankshaft. While the crankshaft is turning, a motion alarm is turned on to alert personnel.

Returning to the main menu, choosing "2", TEST ENG, refers to the automatic mode of this machine. Selecting test engine brings up the first page of a two page menu listing eight engine types. The first page offers the choice of a sixteen cylinder turbo engine, a sixteen cylinder blower engine or a twelve cylinder turbo engine. These choices all refer to the 645 model engines. Selecting 10 on the keypad brings up a second list of later models 710G3 and 710G3A engines.

After choosing the apapropriate engine model, the operator must tell the computer the initial position of the crankshaft. At this point the operator looks at the crankshaft pointer and enters the degree position between 0 and 359 at the keypad. The controls respond by stating the data has been accepted, and the machine is ready to move the crankshaft to the forty-five degree mark. The operator selects one to begin positioning. The controls then indicate the machine is moving the crankshaft to the desired position. Once the crankshaft reaches the initial position, a task screen appears. The task screen prompts the operator to the particular jobs that can be performed at a given crankshaft position. Due to the limited size of the display, an abbreviated format is used. For example, at this position, "P GAG LEAD H20 2" means check the pee pipe gauge for proper alignment, remove the lead from a lead reading and check for water leaks at the No. 2 power assembly. When this work is complete, pressing enter brings up the following screen: TURNING TO NEXT POSITION 157.5 DEGREES. As the crankshaft progresses to new position, other abbreviated prompts appear. "ADJ VAL BRG INJ 10" means adjust the valve bridge lash and injector timing at cylinder No. 10. Once again, having completed this task, the operator presses enter to step to the next position of rotation. A third prompt which appears is "REMOVE P GAGE 8". This tells the operator it is now time to remove the pee pipe gauge at power assembly No. 8.

Returning to the main menu, you may recall there was a third choice, "3" INPUT DATA (P.W.). This refers to a selection that allows editing of the engine data stored in memory. This might be necessary to set up the data for an additional model of the EMD engine. Access to this area requires a password, hence the abbreviation P.W. Within the input data section, other changes can be made, such as changing the point at which the machine automatically shifts from fast to slow speed. Adjustments here are necessary to compensate for some coasting of the crankshaft so as to achieve the desired stop position.

In conclusion, this new development in shop equipment promises increased productivity for shopcraft employees working on EMD engines. The automated barring over machine is ideal for an overhaul program or a thorough engine inspection. At least one supplier of specialty tools has recognized the value of this development at Norfolk Southern and plans to market its own version of the automated barring over machine this year.

IV. NEW EQUIPMENT FOR TESTING EMD ENGINE PROTECTORS

Presented by: Jeff Gamble

The combination low water and crankcase pressure detector is well known as the "engine protector" on EMD locomotives. Since the later 1970's, EMD locomotives have been equipped with the "Delta P" or differential protector.

This paper is about new equipment for testing both types of EMD engine protectors. Maintenance Instructions 259 and 260 have long included a test procedure for operational checks of used or rebuilt engine protectors. A different test panel is required for the original engine protector and the later Delta P model. Both procedures introduce compressed air into the crankcase, water, air box, and oil cavities to check for leakage. Soapy water or liquid leak detector is then used to check for external leaks. A flowrator checks for leakage at the oil return port. Ten cubic feet per hour is condemning. Further tests check operation of the low water detector by introducing compressed air on the air box side of the low water diaphragm. To qualify as a new detector, the low water button must trip when air pressure equal to 20 inches of water is introduced on the air box side. To qualify as a used detector, the low water button must trip by the time air pressure on the air box side of the diaphragm reaches 30 inches of water.

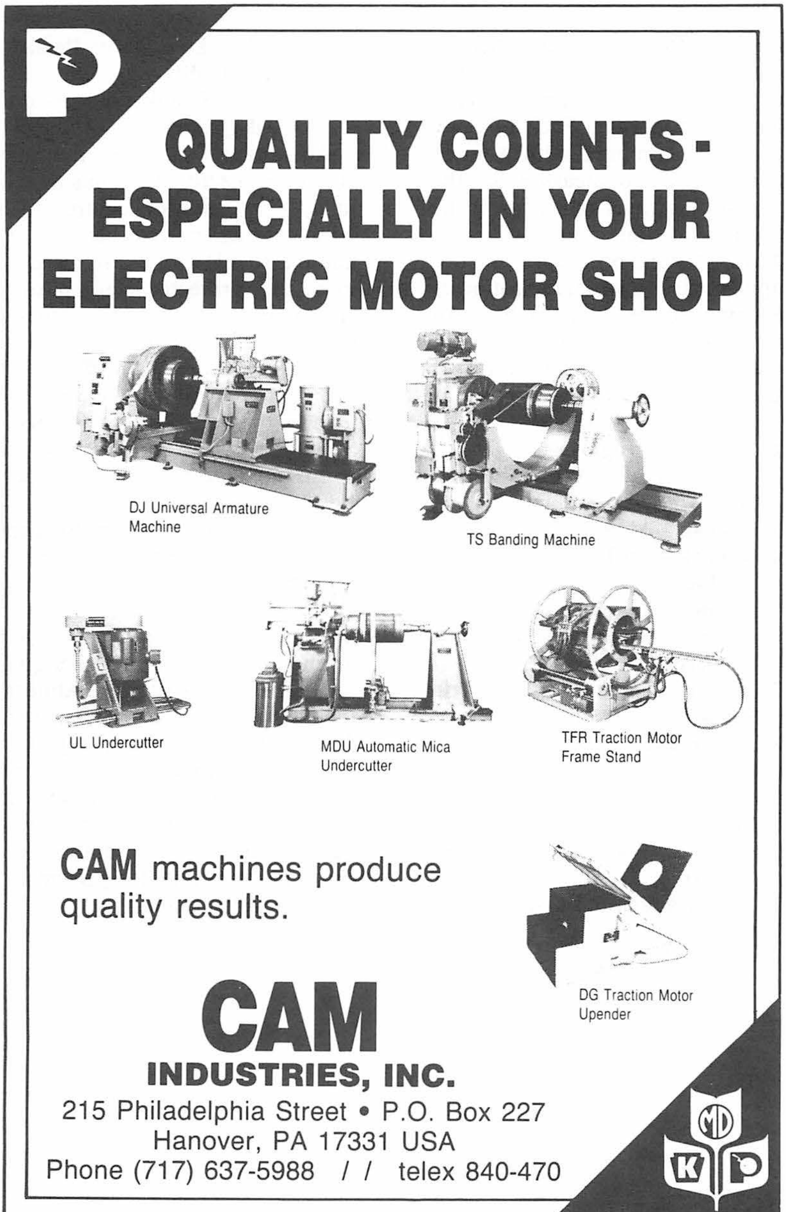
Separately, the crankcase protector is tested to ensure that it trips when a positive pressure of 3.0 inches of water is introduced on the crankcase side of this larger diaphragm. If the device will trip with as little as 0.8 to 1.8 inches of water, the crankcase protector meets new standards.

In 1988 Norfolk Southern designed and built a new test machine for EMD engine protectors. Pneumatic and electrical devices are combined under the control of a programmable logic controller to automate the test procedure. This machine accommodates both the older engine protector and the later Delta P protector with two separate mounting bases. The mounting base on the right is equipped with the additional piping connections characteristic of the differential protector.

The test criteria came from the respective maintenance instructions for the original engine protector and the later Delta P protector. Again, to meet new standards, the water protector must trip when the equivalent of 20 inches of water pressure is introduced on the air box side of the diaphragm and the crankcase protector must trip when air pressure equal to 0.8 - 1.8 inches of water is introduced on the crankcase side. If the protector meets less stringent requirements, either device of the combination protector can pass the test but qualify only as a used device.

To review the test procedure for a turbocharged delta protector, the automated machine introduces 90 psi air to the water cavities connected to the pump's water discharge, 20 psi of air to the air box section, 35 psi of air to the pump inlet section and 80 psi of air to the governor oil port just as an operator would do with the manual test panel. However, with the automated machine, these cavities are pressurized one at a time while checks are made for internal as well as external leaks. Pressure drops are checked across each cavity using Ashcroft gauges with electrical contacts as the input signal for the programmable controller.

For each button of the combination protector, a pneumatic ram is mounted above the protector. These rams operate the low water and crankcase buttons during the test


QUALITY COUNTS-
ESPECIALLY IN YOUR
ELECTRIC MOTOR SHOP
DJ Universal Armature Machine
TS Banding Machine
UL Undercutter
MDU Automatic Mica Undercutter
TFR Traction Motor Frame Stand
CAM machines produce quality results.
DG Traction Motor Upender
CAM
INDUSTRIES, INC.
215 Philadelphia Street • P.O. Box 227
Hanover, PA 17331 USA
Phone (717) 637-5988 / / telex 840-470

procedure. Protectors are checked repeatedly to ensure properly latching as the test equipment cycles through its program. Each of these rams is also equipped with a linear position sensor to measure for the .015 inch overtravel called for in the EMD specification.

During the test procedure, the test equipment gives a visual indication of which one of the 75 steps the programmable controller is executing. Eleven lights provide indication of failure modes. Lights 1 thru 11 are as follows:

1 = Test in Progress
2 = Leak - Water Pump Discharge Diaphragm
3 = Leak - Air Box Diaphragm
4 = Leak - Oil Diaphragm
5 = Leak - Water Pump Inlet Diaphragm
6 = Low Water Did Not Latch Properly
7 = Low Water Did Not Trip Properly
8 = Crankcase Did Not Latch Properly
9 = Crankcase Did Not Trip Properly
10 = Low Water Passed - New Quality
11 = Crankcase Passed - New Quality
10 + 7 = Low Water Passed - Used Quality
11 + 9 = Crankcase Passed - Used Quality

Advantages of the automated engine protector test machine are many. First, the test equipment is a labor saving device because it is automated. The operator need only load the protector and push the clamp and start button. Then the operator devotes his attention to assembling other protectors on the companion carousel work bench or loading the dedicated wash machine. Second, the new equipment is more consistent then the EMD test panel. Results from the conventional test panel are somewhat operator dependent. Third, the protectors are subject to more stringent standards as this new equipment tests for internal leaks. Finally, the new methods for testing have resulted in higher quality for the rebuilt protectors. Almost all rebuilt protectors now meet new standards. The scheduled changeout of engine protectors at two year intervals on EMD locmotives have been dropped without adverse consequences. In summary, doing the job right the first time has proved to be the low cost solution.

V. COMPRESSED AIR FOR RAILROAD FACILITIES ISSUES AND SOLUTIONS TO ACHIEVE CLEAN, DRY, OIL FREE AIR

I. Introduction to Compressed Air

Over the past five decades, compressed air has evolved into a leading energy source for production purposes. It is so widely used that virtually every phase of modern manufacturing is dependent upon it. The one single draw back has been and remains that compression, coupled with atmospheric conditions and compressor lubrication has generated compressed air that is severely contaminated. A critical need has developed to properly condition air by removing such inherent contaminants as **Corrosive Moisture, Oil Varnish and Particle Abrasives.**

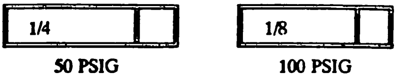
In **Railroad Yards and Shops** the most common results of allowing these contaminants to go unchecked are:

- **Reduced Efficiencies and Failure** of Impact Wrenches and Pneumatic Grinders
- **Airline Leaks** Caused by Corrosion
- **Freezing** of Outdoor Air Lines
- **Sticking Valves**
- **Lubricant Washout** in Cylinders, Motors, Air Tools and Valves
- **Poor Paint Jobs**
- **Freeze-ups** at Retarder Locations
- **Wasted Down Time** on CNC Machinery due to Air Cylinder and Air Valve Maintenance

II. Contaminants in Compressed Air

Compression

This energy source called compressed air is produced by a mechanical device commonly referred to as a compressor. Its purpose is to trap atmospheric air and then mechanically force this air into a volume which is smaller than it normally occupies. When this volume is reduced to ¼, pressure increases to almose **50 PSIG** And at **1/8,** the increase approaches **100 PSIG.** The greater the reduction in volume, the higher the pressure.



Moisture

The problem now arises with the atmospheric air that is drawn in by the compressor. In fact, **100% of the moisture in a compressed air system is directly attributed to this atmospheric air.** A unique aspect about earth and its atmosphere is its life supporting ability to hold and move moisture. In fact, all atmospheric air contains some moisture in a gaseous state known as water vapor. The amount of water vapor is typically expressed as air at a given **temperature** with a certain percentage of **relative humidity.** How temperature corresponds to the amount of water vapor in the air is that as the air's **temperature increases, its ability to hold vapor increases** dramatically. As the table below highlights, for every **20°F increase** in the air temperature, the ability of air to hold water vapor almost doubles.

Air Temperature°F	Total Ability Per Actual Cubic Foot in Grains of Water Vapor
+40°F	2.849
+60°F	5.749
+80°F	11.04
+100°F	19.95
+120°F	34.53

The relative humidity denotes the amount of water vapor actually in the air which is identified as a **percentage of its total holding capacity.** Air at 80°F, with a 50% RH contains 5.52 grains of water vapor per actual cubic foot, or 50% of its total holding capacity (11.04 grains at 80°F). The table below outlines the total water vapor holding capacities of an actual cubic foot of air at various temperatures.

°F	Grains Per CU FT at 100% RH	°F	Grains Per CU. FT. at 100% RH	°F	Grains Per CU FT at 100% RH
-40	.05240	+25	1.554	+90	14.94
-35	.07065	+30	1.935	+95	17.12
-30	.09449	+35	2.366	+100	19.95
-25	.12611	+40	2.849	+105	22.75
-20	.166	+45	3.414	+110	26.34
-15	.218	+50	4.076	+115	30.14
-10	.285	+55	4.849	+120	34.45
-5	.370	+60	5.745	+125	39.22
+0	.481	+65	6.782	+130	44.53
+5	.640	+70	7.98	+135	50.27
+10	.776	+75	9.356	+140	56.94
+15	.986	+80	11.04	+145	63.25
+20	1.235	+85	12.73	+150	72.00

When you compress this air and elevate its pressure to **100PSIG** you are actually crowding **7.8 actual** cubic feet of atmostpheric air into a **single cubic foot of volume.** You have also crowded **7.8 times** the amount of **water vapor** into it as well. When air is compressed a sigificant amount of energy for compression is converted to heat, known as the **"Heat of Compression".** Also, varying amounts of heat are added to the air through friction. This is evident by the high discharge temperatures from a compressor. A typical **reciprocating** style will generate air temperature in the **325°F range** and with a conventional **screw style,** common discharge temperatures are 150°F. By increasing the air temperature you also increase its capacity to hold water vapor. A screw compressor discharges air at 150°F, 100 PSIG has elevated the holding capacity of that air to 72 grains per ACF. The crowded 7.8 actual cubic of atmospheric air at 80°F, 50% RH which is now a single volume of compressed air at 100 PSIG contains over 43 grains of water vapor. **Since the capacity of this single volume can be as high as 72 grains at 150°F, the 43 grains remains in a vapor state.** This increase in **heat** only **affects** the **capacity** of the air to hold water vapor. **Heat will not increase the amount of water vapor** in the compressed air even though its capacity may exceed the water vapor content of the air. **The amounts of water vapor** distributed into a compressed air system depend on compressor size, duty cycle and operating condition. As a point of reference, the chart below highlights **how much water vapor is distributed** by a compressor operating under the following:

- An 80°F 50% RH Ambient
- A 150°F Discharge Temperature
- At 100 PSIG
- At full duty cycle

COMPRESSOR SIZE IN HORSEPOWER	TYPICAL WATER VAPOR AMOUNT IN GALLONS OVER 40 HOURS
50	52
100	104
200	208
300	312

Water vapor itself has minimal corrosive properties. However, when this water vapor changes to a liquid it causes corrosion, washes away lubricants, acts as a carrier for the rust and scale it causes, and will actually turn to ice when freezing conditions are present. The transformation from virtually harmless water vapor to highly corrosive liquid water in a compressed air system occurs as the temperature of the air drops. By dropping the temperature of the air you also reduce its ability to hold vapor. Once the amount of water vapor in the air exceeds its total ability, in other words, the relative humidity exceeds 100%, the excess vapor turns into liquid.

When the air is at 100% RH at a given temperature it can be categorized as fully saturated air and, also, that the air is at dew point.

The air exiting our previous example is at 100 PSIG, 150°F, 62% RH and contains 43 grains of water vapor per ACF. Its dew point; however, is 129°F. This means that if the air were to drop in temperature from 150°F, to 129°F then its relative humidity would increase from 62% at 150°F to 100% at 129°F and become fully saturated.

Any additional cooling would further lower the airs ability to hold vapor, resulting in over saturation, liquid condensation and a lower dew point.

As compressed air exits a compressor it immediately begins the **cooling process.** As it travels through the air piping system, the obvious **external factors** such as **lower ambient temperatures, air conditioning flow, cold water pipes** and **even open doors** and **windows** will lower compressed air temperatures. The not so obvious are the **internal cooling** affects of **rapid air expansion** which occurs as this compressed air is used to do work. Even a typical **pneumatic grinder** and an inlet air temperature of 60°F will experience and **additional 30°F drop** in air temperature due to the cooling effects of rapid air expansion.

In order to identify how much **liquid water** is in a compressed air system as a **result of cooling** we would appreciate your reviewing the following:

Conditions

- 100 HP Compressor
- Operating Pressure 100 PSIG
- Discharge Air Temperature 150°F
- Discgarge Air Pressure Dew Point 129°F

GALLONS OF WATER VAPOR CONDENSED BY COOLING BELOW 129°F

Compressed Air Temperature

100°F	60	58%
80°F	79	76%
60°F	91	88%
40°F	97	94%
20°F	102	97%
0°F	103	99%
-20°F	103.6	99.6%
-40°F	103.9	99.9%

Percentag Total Wate Condense

The practical solution to eliminate the adverse effects of **moisture** is to **lower the dew point** of the air prior to use. By determining the degree of cooling you will also have at hand the level to which the true air's dew point must be lower than.

III. How Dry Is Dry?

By following the four step approach listed below you can determine what dew point you need to safeguard against moisture condensation in all yard locations and within pneumatically operated devices.

1) The first step is to identify the obvious cooling effects of ambient conditions. Assuming the compressed air will at least be cooled enough to match ambient condition, speculate on what the lowest ambient may be and record it. Always consider nighttime, week end and winter operation.

2) The not so obvious reasons for cooling can be identified simply by following the compressed air piping throughout the yard. If this piping is adjacent to cold water pipes, exposed to direct air conditioning flow or run by open windows or doors, especially during winter months, additional cooling occurs. Again, speculate worst case and record.

3) If your air is used for normal air tools and cylinders, you can anticipate an additional 20°F of cooling. If for high volume equipment such as pneumatic grinders and sandblaster, you should anticipate an additional 30°F of cooling.

4) To determine dew point needs, take the low ambient less any additional cooling and the effects of rapid air expansion.

EXAMPLE:

Low Ambient	**+50°F(1)**
Additional Cooling	**-10°F (2)**
Rapid Air Expansion	**-30°F(3)**
Minimum Required Pressure Dew Point	**+10°F(4)**

Oil Varnish

The majority of compressors utilized by a rail yard operation dictate the use of a compressor oil for lubrication. During compression this oil is exposed to elevated temperatures from the heat of compression as well as the shearing action of the compressor.

The result is a burnt or **oxidized oil** carries over into the compressed air system. Contrary to many beliefs this compressor oil is actually transformed into a varnish type substance with **no lubrication qualities,** in fact, many people refer to it as **oil tar.** If left **unchecked** the most common results are:

- Air Brake Valves That Stick Possible Cause of Undesired Emergencies
- Scored Cylinder and Valves Ineffective Blasting Equipment
- Wasted Downtime on CNC Machinery
- Poor Paint Jobs
- Inoperative Retarders
- Premature Failure of Air Tools and Improper Torque Valves

This **oil varnish** as it **carries over** from the compressor does so in an extremely **fine aerosol form** comparable to tobacco smoke. Even a 100 HP compresssor with a low carry over concentration of 25 P.P.M. (parts per million) delivers over 32 ounces of this varnish in 40 hours of operation.

By definition an **aerosol** is a **liquid particle** which is lighter than air and will stay **suspended in the air.** With compressor oils the aerosols particle size range is from .01 (1/100) micron to as high as 40 microns in size. As a point of reference the largest single particle which is visible to the naked eye would measure 40 microns. There are two types of aerosols present in a compressed air system; the first is, a **Dispersion Aerosols** which ranges in size from 1.0 micron to 40 microns. They are created as the compressor oil mixes with the compressed air and both exit the compression chamber at high velocities. This velocity actually atomizes the oil. The second type; which is the most troublesome due to its submicron size, are called **Condensation Aerosols.** They range in size from .01 (1/100) of a micron to just below 1.0 micron. They are created from the cooling of oil vapors that have been taken in from the atmosphere and the vaporized lubricating oil generated by the compressor. By count, **99% + of the total** oil aerosols in an air system are of the **condensation variety.**

Since these aerosols are of a varnish or tar like substance, their tendency is to adhere to surfaces by direct impact. Every bend of a pipe, fitting, orifice, rotor, cylinder or gear is subject to the accumulation of this contaminate and the ill effects they cause.

Particle Abrasives

The air we breathe contains **millions** of **dust particles** and other airborne contaminants per cubic foot. In a compressed air system, at 100 PSIG, the **concentration** of particles-in-suspension may be **eight times** the concentration in the atmosphere. In addition, abrasives such as **pipe scale, pipe compounds,** and **particles from compressor wear** are extremely harmful to pneumatically-operated equipment. If unchecked, the results are **reduced or plugged orifices** and **premature wearing of seals.** When placed in a high speed air stream, the particles or fine dirt **act much like a sandblast** and will erode components, in a manner of a **lapping abrasive.**

IV. Removing Contaminants From Compressed Air

Eliminating the Corrosive Effects of Moisture

Step 1

The **first step** is relatively inexpensive and requires the **installation** of an **after cooler/separator** assemble after the compressor. Its purpose is to economically reduce the air temperature as much as possible and remove the condensed liquids it has created. This normally represents in excess of 58% of all the water vapor distributed by the compressor.

There are two types of after coolers, air cooled and water cooled, both of which are rated with an approach temperature from 10°F to 30°F.

To determine the temperature of the compressed air exiting the after cooler, simply add the approach temperature to the high ambient temperature on air cooled models or to the water temperature for a water cooled models.

Step 2

Determine what actual dew point at pressure is needed to safe guard against liquid condensation every where compressed air is used. Reference: How Dry Is Dry?

Step 3

Select the drying equipment which conforms to your specific dew point needs. Equipment that produces a higher dew point, allows condensation, conversely, equipment which produces a lower dew point than needed, represents higher initial costs and greater operating costs. (Similar to Goldie Locks, where the porridge was too hot, too cold then just right).

Although drying equipment appears to be available in many shapes and forms, there are essentially five types:

DELIQUESCENT
REFRIGERATED
TWIN TOWER
REGENERATIVE
GRAHAM-WHITE AIR SYSTEMS

Deliquescent Air Dryer Design and Performance

The Deliquescent Air Dryer is basically a welded pressure vessel which is filled with an absorbing chemical. The most common **chemicals** used are **salt of sodium, potassium, calcium** and **urea based chemicals.** In the process of absorbing water vapor, these chemicals **change** physically from a crystalline **solid to a liquid.** The affluent **solution** is then **drained** from the bottom of the vessel

The **benefits of a Deliquescent Dryer** are **lower initial costs, zero energy** consumption, **design simplicity** and for use in both indoor and outdoor installations. From a performance standpoint, they are designed to afford a dew point depression of 20°F at an inlet temperature not to exceed 90°F at 100 PSIG.

Precautions

The **suspect** aspect is that a 20°F depression translates into delivered pressure **dew point of +70°F** which affords its user minimal dew point protection. **Operating costs** are considered the **highest** in the industry since these chemicals change to liquid they must be continually replenished.

A major aspect to servicing is to eliminate **oil coating** that will **block** the changing of these chemicals to liquid and negate the absorption of water vapors. **A Coalescing Filter** should be installed accordingly. Without a filter, once oil coating occurs, the chemicals must be changed. Under **excessive heat** there is a very real possiblity of **liquid desiccant carry over.** This can be extremely damaging if there is no after filter, particularly with those dryers using salt. They are also sensitive to excessive air flows. Sustained or temporary pulsating air flows may cause **channeling** (Gopher-holing) in the desiccant bed. Should this happen, the wet air will then follow these channels of least resistance and drying aspects may be negated.

Service

If the precautions outlined are followed, then the service aspect is minimal, requiring only the replenishing of chemicals and changing of Coalescing Filter and After Filter elements on a pre-determined frequency basis. If channelling occurs, the only remedy is to shut down the unit and fill the Gophers or replace the entire desiccant bed.

Refrigerated Dryers
Design & Performance

Utilize the heat of absorption qualities of refrigerant to **physically cool this air and lower its pressure dew point.** The resulting moisture condensation is then removed by a separator and drain. Typical **ratings** are at **100 PSIG, 100°F Inlet Air, 100°F Ambient** with maximum flow capacities relative to either a **+40°F or +50°F pressure dew point.** Common components are (1) **air to air heat exchanger,** (2) **refrigerant to air heat exchanger,** (3) **internal separator,** (4) **automatic drain,** (5) **refrigerant compressor,** (6) **condensing unit,** (7) **refrigeration components** such as expansion valve, hot gas bypass, solution line accumulation, cut-out switches, crankcase heater, etc (8) **frame and cabinets.** Factors such as heat exchangers, preconditioning, environment, location, service and last but not least, your required pressure dew poit should all be reviewed prior to selection.

Heat Exchanger

Since all manufacturers utilize the same basic principal of cooling by refrigeration, the **efficiency of the heat exchanger** is one of the **dividing lines** for comparison. Delivered pressure **dew points** are tied directly into the **chill level** of the refrigerant and the **approach temperature** of the refrigerant to air **heat exchanger.** With a heat exchanger that has an initial approach temperature of +20°F in order to achieve a +40°F pressure dew point at full rated capacities, then the refrigeration chill level must be set at +20°F. The common **problem** with this configuration is that when operating at less than full rated capacities, the temperature of the compressed air may be lowered to below freezing temperatures resulting in a **frozen, ice blocked heat exchanger.** This same heat exchanger is prone to **losses in efficiency from varnish contaminants** and requires that the air be pre-conditioned accordingly.

Internal Separator

The **efficiency** of the **internal separator** is a key ingredient to delivering **dew points.** Once the air has been physically cooled to +40°F it is now left up to this **separator to remove 100%** of all the **liquid water** that has been created. With **less than 100% efficiency,** once the air is **pre-heated** by the **air-to-air heat exchanger** (typically to 70°F) or by higher ambient temperatures, then a portion of the condensed moisture will **return to a vapor form** and be **re-captured by these higher compressed air** temperatures. To better understand this phenomena, simply refer to our every day use of electric hair dryers. By generating heated air you also increase the airs ability to hold moisture in a vapor state. For every 20°F increase this ability actually doubles. This heat affords the air a desire to capture moisture, resulting in the case of a hair dryer - dry hair and in the case of a **Refrigerated Dryer with** an **inefficient separator** or no separator at all - **undesirable higher dew point air.**

The question that now arises, is there a 100% efficient separator? **Efficiencies** of **separators** are typically on a **bell curve.** At **low** and **high flows,** efficienies **may fall below 70%.** When this occurs, a **40% dew point may climb** to a 70°F dew point.

Precautions
Oil Varnish Coating

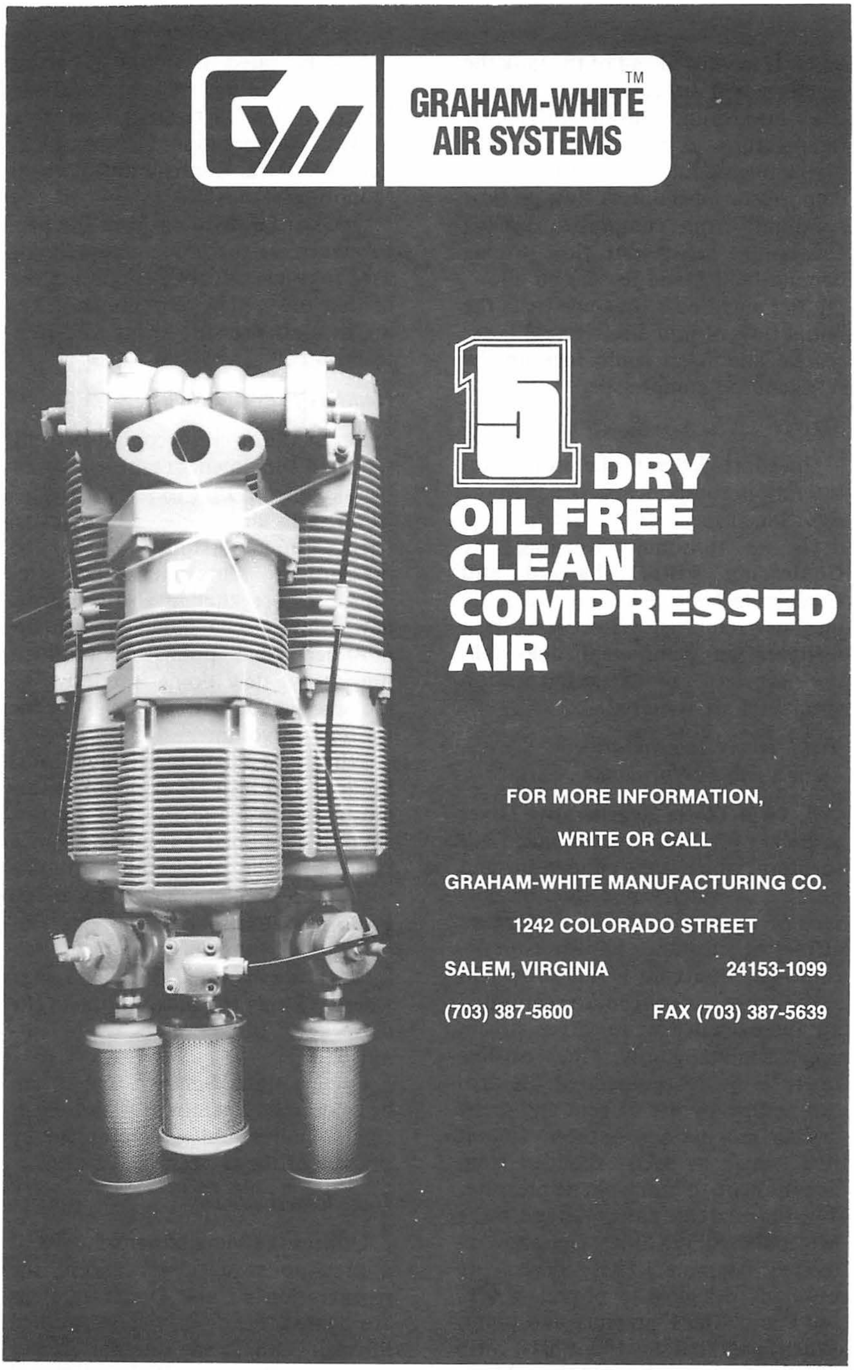
In order to maintain peak efficiency from the refrigerant to air heat exchanger it is imperative that the **inlet air** to it be **pre-conditioned** in order **to negate** the possibility of **oil varnish coating.** This **oil varnish** coating acts as a thermal insulator and **reduces the cooling** process by restricting the transfer of heat from the compressed air to the refrigerant. The most common pre-conditioning practice is to **install** a **coalescing** style pre-filter **to remove** liquid oil varnish and **oil varnish aerosols.** Although this helps eliminate the majority of the coating contaminants it is imperative that a **device also** be installed to **eliminate oil vapors.** If left unchecked, the act of **cooling** within the heat exchanger actually **creates** additional coating contaminants by transforming these oil vapors into **condensation aerosols.**

Environment

The environment Refrigerated Dryers **are placed in** is a key factor to operational longevity and efficiecny. Since the vast majority of units are supplied with air cooled condensing units the environment **must be** relatively **clean** and **ambient temperatures should not exceed 110°F.** The purpose of the **condensing unit** is to **cool** high pressure gaseous **refrigerant** supplied from the refrigeration compressor. This **cooling changes** the **gaseous refrigerant to liquid** where it is then metered into the heat exchanger to absorb heat. If allowed to remain in a gaseous state the refrigerants cooling aspects are virtually eliminated. A **dirty environment** will **clog** the **condensing unit** and **reduce its cooling efficiency.** At **ambient temperatures above 110°F** the air is just **to hot to have much of a cooling effect.**

Location

A **typical** compressed air circuit utilizing a **refrigeration** style **dryer** has the dryer **located after the receiver tank.** This **allows** the receiver **tank to act like a pre-cooler** thus lowering the inlet air temperature to the dryer. Another benefit is that the air flow through the dryer is normally more constant after the tank than before. This **permits refrigerant controls to be engaged on a continuous**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basis. **If located ahead** of the tank the **results could be catastrophic.** Since the maximum rated inlet air temperature to the unit is 120°F, **higher inlets** could cause refrigeration **compressor burn out.** A flow no flow condition from **compressor cycling causes** the **refrigerant** flow **to lag** behind the demand for dry air allowing wet air to pass. In some cases the initial flow of liquid refrigerant is excessive and if so **could lock-up** the refrigeration **compressor.**

Service

Once installed with the proper prefilteration components, the periodic servicing aspect of a refrigerated dryer is minimal. **Keeping** the **Coalescing Filter changed** and **Coalescing Unit clean** is virtually all that is required. However; if a **refrigeration component does fail,** the **services** of a refrigeration specialists are **required.**

Twin Tower Regenerative Design and Performance

A Twin Tower Regenerative Dryer utilizes a physical process called **adsorption,** which is the **condensing** and **holding of water vapor upon** the surface of a porous area of a moisture attracting substance known as **desiccant.** The desiccant is **one tower absorbs** water vapor from the saturated air and exits dry air for down stream use. Simultaneously, the **off-line tower is being regenerated** (desorption) either by use of heat and or by dry air moving across the Desiccant Bed, which as been expanded from line pressure to atmospheric pressure. Typical desiccants used are Molecular Sieve, Silica Gel and Activated Alumina. These dryers are normally **designed** to provide a **0°F, -40°F** and **-100°F pressure dew point.** When operated at **100 PSIG, with 100°F inlet air and at 100°F ambient.**

Construction consists of two A.S.M.E. rated Desiccant Charged Towers, Piping, Check Valves, Heater if heat activated, Switching Valves, Regeneration Orifice, Mufflers, Electrical Controls and Vertical Mounting Stands.

One of the **dividing lines for performance** are the numerous **methods used to regenerate** the desiccant in the off-line tower. The most common being heatless pressure swing and heat reactivated.

Heatless Pressure Swing

Regeneration is accomplished by reducing the down stream usable air by taking from 15% to 25% of the inlet air. This air is metered through an Orifice and expanded from line pressure to atmospheric pressure. This **pressure change also alters its dew point to a much lower atmospheric dew point.** As outlined previously, dew point is relative to the amount of water vapor in the air for a given volume.

When a SCF (standard cubic foot) of air at 100 PSIG is expanded to atmospheric pressure the volume this vapor is contained in is increased by a factor of eight. The result is that air with a 0°F pressure dew point at 100 PSIG has atmospheric dew point of -35°F. This **super dry air** then flows through the off-line Desiccant Tower where it **strips the moisture from the desiccant,** discharging it to atmosphere.

Cycling times between towers can be as short as 20 seconds to as long as eight minutes and is determined by the size of the towers.

Heat Reactivated

Utilizes the same basic principle of a pressure swing dryer except the **regeneration air and Desiccant Beds are heated.** Heating is accomplished through either an internal heater within the Desiccant Bed or external heater. The level of heat varies according to the desiccant type used. For **Activated Alumina** temperatures rise to **450°F** and for **Molecular Sieve** a rise to **600°F** is quite common. Since **hot air has a greater capacity to hold water vapor** with a heat reactivated unit, the purge air requirement is usually ½ of a heatless. Cycle rates range from four to as higha s 12 hours with sufficient time allowed for cooling. Because the cycle rates are much longer than a heatless style, **the size** of the Desiccant Beds are generally much **larger** as well.

Precautions
Channelling

As in the case of a Deliquesent Dryer, a Twin Tower unit whether heatless or heated are designed with **loose Desiccant Beds** which makes them **highly sensitive to excessive air flow. Sustained or temporary pulsating** high air flows may **cause channelling** (Gopher-Holing) in the Desiccant Bed. Should this happen, most of the air will then follow these channels of least resistance and for al practical purposes the **drying** aspect of the unit is **negated.**

Heat Reactivated

Both internal and external **heated styles can prove hazardous** if applied in a system utilizing a **lubricated compressor.** Since 500°F is the flash point of most compressor oils, a heat reactivated dryer is usually specific on systems with oil free compressors. Excessive **heat** will also **shorten the life of the desiccant** by as much as 50%, requiring frequent desiccant changes to maintain absorption efficiencies.

Pre-Filtering

Pre-filtering of the compressed air is required and generally constitutes the instillation of a **Centrifugal Separator, Particle Filter** and high efficiency **Coalescing Filter.** The necessity for this is that the **desiccant** is readily **ruined by** slight amounts of **oil** and **solid contaminants** and are not designed to handle **liquid water.**

After-Filtration

Particulate removal style filters are required because in a **loose Desiccant Bed desiccant carry over is inevitable.** Slight vibrations, along with pulsations of the compressed air, cause desiccant particles to strike against each other. This grinding action results in a powdering of the desiccant, which is then carried out of the tower. Unless this **powered desiccant** is removed from the air by an After Filter, it will **cause extensive damage** to down stream components.

Depressurization

Depressurization of the off-line tower must be **at a slow rate which reduces regeneration efficiencies.** This slow rate is necessitated because of a loose Desiccant Bed where Rapid depressurization will cause excessive desiccant movement and powderization.

Service

A Twin Tower Dryer's main servicing requirement is the maintenance of both Pre-filters and After Filtering devices. Once maintained, then trouble free operation is the norm. If channelling occurs, the single relief is to fill the channels which normally requires a complete desiccant change. With internal heaters, expected life of the heaters is shortened by exposure to the desiccant. Barring oil contamination and substantial desiccant loss due to powderization, the life of the desiccant if from three years with a heat activated and up to five years on heatless models.

Graham-White Air Systems

In the late 60's the Locomotive Builders requested that **Graham-White** initiate an engineering program to create a **unique air preparation system.** This system was to meet a critical need **to protect a locomotives brake system** and other pneumatic devices from the adverse effects of severely contaminated compressed air. The **performance and design criteria** was such that this new air system must:

- **Withstand the shock and vibration of a locomotive moving down a track**
- **Be designed for continuous operation**
- **Have the ability to operate under extremely dirty environments**
- **Not be affected by high and low ambient temperatures**
- **Be designed for ease of installation and maintenance**
- **Require minimal servicing**
- **Deliver continuous Dry, Oil Free, Clean compressed air**

In **1970 Graham-White Engineering developed and patented our present 5-in-1 Air System** and over the past 20 years has delivered over **4,000 units.**

Graham-White is now making a major commitment to supply these same services for stationary applications. Attached is our new Industrial Catalog D5000 and Tech Bullentin TB5000 for your review.

Design and Performance

The **Graham-White Air Systems** have been designed as a **total air preparation** package to deliver **Dry, Oil Free, Clean compressed air.** This is accomplished by our 5-in-1 systems approach that consists of 1) Tower regenerative dryer, 2) Built in Pre-Coolers, 3) Centrifugal Separators, 4) Stainless Steel 40 Micron Scrubber Filtration, 5) High Efficiency Coalescing Filter all in a Single Compact, Light Weight, Cast Aluminum Package.

Dry Compressed Air

Dry Air is guaranteed in that each system is actually **tailored to** match your **specific dew point needs** that may vary from **+50°F to -80°F Pressure Dew Points.** The **benefits** are that, for the first time drying equipment **selection** has the added value of being **based on operating conditions and Dew Point requirement needs.**

Oil Free and Clean Compressed Air

Standard with each Graham-White Air System Are:

- **Centrifugal separators** to remove liquid water and large dirt particles
- **Extended surface aluminum finned pre-coolers** which cool the air and reducing its water vapor holding capacity
- **A cleanable stainless scrubber filter** to remove liquid oil and abrasive particles above 40 microns
- **A high efficiency coalescing filter** designed with a 99.9%+ D.O.P. efficiency rating and removes abrasive particles down to .3 microns and oil aerosols down to .03 microns in size.

Uniqueness of Design
Patented Pneumatic Compactor

Desiccant material is held **under a constant mechanical hold** by a **patented pneumatic compactor.** This compactor virtually **eliminates** the **channelling** of moist air around the desiccant, greatly reduces the possibility of **desiccant grinding** and safe guards against **bed fluidization.**

Regeneration

Regeneration is accomplished through the use of a **pressure swing principle with one very unique twist.** In a **Conventional** Twin Tower dryer **depressurization** of the off-line tower is normally done **at a slow rate.** The reason behind this is that in a loose Desiccant Bed, rapid depressurization will cause excessive desiccant movement and powderization.

With the **Graham-White** pneumatic compactor stopping desiccant movement the **regeneration benefits of rapid depressurization** are an inherent part of each system. Since desiccant is a porous, with rapid depressurization the air velocity is exremely high across the desiccant surface. This high velocity air creates a venturi effect where a slight and instantaneous vacuum that actually sucks the water vapor from the desiccant discharging it to the atmosphere. Up to 60% of the regeneration process is accomplished through rapid depressurization.

The balance of the pressure swing principle utilizes a portion of the down stream dry air, expanding it from line pressure to atmospheric pressure and a much lower dew point. Regeneration rates vary from 10% to 18% and are dependent upon dryer size and required dew point performance needs.

GRAHAM-WHITE MANUFACTURING CO. AIR SYSTEM PERFORMANCE GUARANTEE

The Graham-White Manufacturing Company of Salem, Virginia will extend to the purchasers of its unique 5-in-1 Air System a Performance Guarantee extending from the date of original installation to the initial routine maintenance change of the internal Coalescing Element, not to exceed six months. This performance Guarantee will encompass the condition of the compressed air exiting the Graham-White Air System. The guarantee will provide that, when applied and operated in accordance with the published manufacturer's specifications, the system will condition the compressed air, affording the purchaser the benefits of:

Dry Compresses Air - The compressed air will be a predetermined pressure dew point that insures zero liquid water condensation from the compressed air.

Oil Free Compressed Air - The liquid oil and oil aerosol levels in the compressed air will be reduced by 99.9%+.

Clean Compressed Air - The compressed air exiting the internal coalescing element will have reduced abrasive particles to .3 microns and below.

If the Graham-White Air System fails to deliver Dry, Oil Free, Clean Compressed Air as outlined, after having been operated in compliance with the manufacturer's specifications, then Graham-White's Performance Guarantee will extend to the purchaser of the Air System the opportunity to return the Air System to Graham-White for a full refund.

V. Eliminating Oil Varnish

Solution

The obvious **solution** is **eliminate** these **aerosol varnish** contaminants **before they can cause any damage.** What is **required** is a high efficiency, sub-micron filtration device with the capacity to not only capture these sub-micron aerosols but do so on a continuous long term basis. The filtration device most commonly used is a **Coalescing Filter** and for the most part will perform extremely well, if certain precautions are taken.

Precautions

Coalescing by definition is **the joining of aerosols to form liquids.** Therefore; a coalescing filters prime function is to react to oil aerosols. The rule of thumb; however, is that the high **efficiency ratings** given **are predicted** on the basis that **inlet concentration does not exceed 90 P.P.M.** (part per million).

Allowing **liquid water,** or high concentrations of **liquid oil, floods the element** resulting in a major efficiency loss. The other problem is that **dirt particles** will **clog** the **element** and at some point, greatly **reduce efficiency** and possibly render it inactive. The **remedy** is to **install** a high efficiency **centrifugal separator** before the coalescing filter to safe guard against flooding. In addition, install a **40 micron particle filter** which would elongate the life and efficiency of the coalescing filter element.

Service

It is equally important to establish a periodic maintenance program to change the **coalescing filter element at regular intervals.** If the precautions outlined are followed under normal condition, these intervals can be once every six months. Without, as frequent as once a month may be necessary

IV. Eliminating Particle Abrasives

The selection of an effective particulate filter should not be taken lightly. Basically their are **two styles** which include **surface** and **depth style elements.**

Surface Elements

A particle abrasive is not necessarily a perfectly round sphere in fact there is no rule of thumb as to its dimensional or physical shape. A **surface** filter **element** rated for 40 microns because its **similar** to a **screen door** may retain a particle which is above 40 microns in diameter, and allow a particle that is 10 microns in diameter and 50 microns long to pass right through it. Another problem arises with the above 40 micron particle it did retain in that air velocity is continually working on it. Its tendency is to break into smaller particles thus engaging down stream.

Depth Elements

A **depth element** consists of a media which has been packed, sintered or molded in such a way that as the **air passes through** it does so in an extremely **tortuous manner.** The benefit is that its micron rating for particle retention takes into consideration both the particles diameter and length. It also stands a better chance of retaining a broken particle because of its added depth.

Location

For maximum protection a particulate filter should be installed as close as possible to the equipment it is trying to protect. A single unit installed in the main header will help in extending the life of the point of use units, but it will not remove the pipe scale present down stream of it.

Precautions

The structural integrity of the element is critical because as it does its job it will clog and create an excessive pressure differential across it. The element must be physically strong enough to withstand this differential. A weak element may collapse and in severe cases, disintegrate allowing dirt particles and pieces of the element down stream.

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Southwestern Railway Club

Started in 1946, the Southwestern Railway Club this year is celebrating its 45th 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.

C.T. KUNKEL
President
Union Pacific Railroad
Omaha, NE 68179

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

REPORT OF THE COMMITTEE ON FUEL AND LUBRICANTS

Tuesday, September 17, 1991
2:00 P.M.

Pre-Convention Presentation Southwestern Rwy. Assn.

(photo not available)

May 16, 1991 Red Lion Inn Omaha, NE

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Manager-Oil Control Labs &
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C.A. Tincher	Product Mgr.	Lyondell Petro	Houston, TX

NOTE: R. Todd Brown, Senior Research Engineer, AAR, Washington, D.C.
Guest Speaker

PERSONAL HISTORY

Ron Lodowski

Mr. Lodowski was born in Buffalo, New York on March 4, 1950. After his elementary and high school education he scholared at Canisius University in Buffalo and received a Bachelor of Science degree in chemistry in 1972.

He began his railroad career with the Penn Central as a Freight Car Man in 1975. In March 1977 he transferred to the Locomotive Department and was promoted to General Foreman in Buffalo. In July 1984 he was transferred to Selkirk, New York and was promoted to Manager-Environmental Operations. In August of 1989 he was given the additional duty of Supervisor-Oil Control Labs.

Ron's hobbies are travel, photography, and he enjoys viewing spectator sports such as hockey and football.

He has been married for 22 years and his wife's name is Susan. They have two children, Michael, 21 and Nicole, age 5.

I. INFRARED SPECTROSCOPY AS AN ANALYTICAL TOOL

Presented by: Cline Tincher

A. Introduction

The main requirement of condition monitoring of crankcase oils from locomotives is the early diagnosis of one or more of the following conditions:

1) contamination of the lubricant system,

2) undersirable changes in engine performance,

3) potential failure of mechanical components, or

4) lubricant failure.

The chemical degradation processes of in-service crankcase lubricants are very complex. They are influenced by such parameters as temperature, oxidation, combustion products, and contamination from external sources such as fuel, coolant, dust and dirt. Traditional methods of analysis involve many tests that either measure or infer that degradation/contamination has taken place. Typical tests are viscosity, total base number (TBN) or pH, flash point, pentane insolubles, and water content. Many of these tests are not absolute and changes in lubricant condition are monitored as changes in the test results. A typical example is viscosity where soot contamination and oxidation by-products can increase viscosity while fuel dilution can decrease viscosity. The net result could be all three occurring at the same time and no net change in relative viscosity while altering the lubricating ability of the oil. The interdependency of these variables is obvious from this example and therefore a method of measurement that more directly relates to the chemical changes that are involved is more desirable. The application of infrared spectroscopy to the analysis of in-service lubricants was first discussed in the 1960's. A procedure was now available to describe the chemistry and the decomposition products in lubricating oils.

B. Procedure

Electromagnetic radiation (i.e. radio waves, visible light, x-rays) will be emitted or absorbed by any body in arbitrary small amounts. Infrared light at various frequencies will cause molecular bonds to stretch and bend like little springs. By measuring the wavelength where these motions occur it is possible to determine the chemical composition of an unknown substance. This is referred to as qualitative analysis. However, in the analysis of used oils qualitative and quantitative analysis are necessary.

The quantitative analysis of used crankcase oils poses several problems to infrared spectroscopy. Lubricating oils are a complex mixture of many organic components and additives. The presence of soot and other dispersed insolubles in the used oils, contaminants which must be measured, reduces the overall transmission of the spectrum by scattering the infrared light, like sunlight through a screen door, and decreases sensitivity. These problems have been overcome with the introduction of microprocessor instrumentation in the 1980's. A beam of intense infrared light is projected through a lubricating oil sample only 0.1 mm thick. The spectrum of light thrown off by the oil sample is recorded and analyzed by the computer. The infrared spectrum of transmission (absorbance) versus wave number (cm-1) is transformed to an array of numbers and sent into the computer's memory, where it can be treated as any set of numbers. It can be plotted, expanded, smoothed, added to or subtracted from a new reference spectrum, or stored for future use. These numbers are then converted to measurements of soot and water contamination, oxidation, and by-products of combustion.

The microprocessor simultaneously compares the infrared spectrum to a representative set of over 500 pre-analyzed samples. The spectra of these calibration samples form a learning set from which the computer program attempts to find correlations with up to 25 properties or concentrations of interest. The program tries to use as much information as possible from the spectra, rather than looking at a few individual wavelengths. From these correlations the program will predict empirical data. With eight scans and calculations that take less than four minutes to complete, computer assisted infrared spectroscopy can measure components that relate to corrosion, wear, oxidation, nitration, additive depletion, sooting, fuel dilution, water, TBN, and viscosity. The infrared spectrometer and an optical emissions spectrometer for wear metal analysis provide all the information which that be needed for a thorough used oil analysis program.

C. Analytical Benefits

In addition to providing far more detailed results in less time than techniques currently in use, infrared spectroscopy will identify problems sooner, detecting chemical changes as they occur. This is particularly important in terms of fuel dilution in crankcase lubricating oils.

Detected early, leaks can be repaired while they still represent a minor problem. Left uncorrected the problem can progress to the point that the lubricating oil becomes so contaminated that the locomotive must be shut down immediately and the oil changed or serious mechanical failure will occur. Of greater importance, but normally of lesser consideration, is that diesel fuel which leaks into the lubricating system is a wasted commodity and represents lost revenue. With the energy efficiency of rail service, there is enough energy in a single drop of fuel oil to pull a 100,000-lb freight car a distance of eight inches.

The infrared spectrometer will reveal locomotive combustion problems exhibited by the presence of soot and oxidation/nitration products. Remember, a poorly timed locomotive is delivering lower horsepower and is costing your company money.

D. Cost Analysis

A comparison of the baseline year (1987) versus one year at full operation (1989) by a major eastern railroad indicated that locomotive lubricating oil drains, resulting from fuel or water contamination, had increased by approximately 350. This reduction is significant if you remember that material cost alone for each locomotive with an average volume of 250 gallons at $1.70 per gallon (1989), plus filters and overhead, will be approximately $550.00 per shopping. By including miscellaneous material expenses (i.e. laboratory chemicals and chemical disposal savings) the example cited results in an annual saving of $222,500 per year or a ROI of 1.25 years on capital equipment. With the continuing rise of lubricating oil costs the return on investment will only be accelerated. Individual savings will be determined by operational costs and maintenance procedures.

E. Additional Benefits

The disposal of spent laboratory solvents is a major concern of supervisory personnel. The use of infrared spectroscopy eliminates this problem because little to no hazardous wastes are generated during normal infrared operation. The elimination of hazardous wastes futher means no potential future liabilities from inadvertent mishandling or statute changes. Hexane is the chemical of choice during cleaning of sample cells due to its high vaporization pressure.

The reduction of laboratory chemicals further minimizes the analysts' exposure to compounds which may have deleterious effects over an extended period.

With changing regulations concerning emissions standards it will be possible, with some slight equipment modifications, to monitor the carbonaceous and nitrous exhaust gases using the spectrometer. Chambers are available which are used in the analysis of gases. What will be needed is a standardized method of obtaining the test sample as directed by regulatory agencies.

It has been observed that infrared spectroscopy is also a viable tool in the quality control of new lubricating oil. In the past the viscosity, alkalinity, and clarity of lubricating oils have been the governing characteristics of acceptance or rejection of a shipment. Now within minutes it is possible not only to monitor the physical but also the chemical distinctions, specifically additives and base oils.

In conclusion, although the condition monitoring of crankcase oils using infrared spectroscopy has been conducted for almost thirty years its application as an analytical tool in determining the operational preficiencies of today's modern diesel-electric locomotive is still in its infancy. It is hoped with its more wide spread acceptance, standardized industry spectrometric condemnation limits can be established, thus assuring that the railroads will continue to operate the most highly tuned and fuel-efficient equipment in the transportation sector.

II. DIESEL EXHAUST: HEALTH EFFECTS, RESEARCH AND REGULATIONS

by R. Todd Brown, Ph.D.
Association of American Railroads
Research and Test Department
Safety Research Division

Background

Diesel exhaust has long been suspected as an occupational carcinogen, and health effects investigations have been conducted in a number of industries where workers are regularly exposed to diesel engine emissions. Among these are mining operations, truck transport, and freight railroading. Typically, such studies have focused on the short-term consequences of exposure (e.g., headaches, dizziness, irritation of the eyes and nose, changes in cardiopulmonary function) and have not addressed long-term health effects. However, several recent studies, in which epidemiological methods were employed, have suggested an association between chronic exhaust exposure and lung cancer.

Of particular interest to the railroad industry is a series of studies sponsored by the Environmental Protection Agency (EPA), collectively referred to as the "Harvard Study", that purport to demonstrate an increased risk of lung cancer among railroad workers in "exhaust exposed" occupational categories, relative to workers in "non-exhaust exposed" categories. A similar pattern of health effects recently has been observed in long-haul truckers.

This paper will provide an overview of the research implicating disel exhaust as an occupational carcinogen, will describe the AAR's current research program on exhaust exposure and employee health, and will summarize current and future regulatory interest in the area.

Health Effects of Diesel Exhaust Exposure

Diesel exhaust consists of a mixture of organic and inorganic gases and solid particles. Included in the gaseous fraction are carbon monoxide, sulfur dioxide, oxides of nitrogen, formaldehyde, and acrolein. The solid fraction (soot) is composed of carbon particles, usually less than 1 micron in size, to which a variety of organic compounds adhere.

Observed short-term health effects (e.g., irritation, nausea) are attributable to the gaseous fraction and are transient in nature. Reduction or elimination of the gases tends to minimize complaints. Continuous, long-term exposure to exhaust gases *may* have adverse health consequences, but exposure of this sort is not representative of railroad operations and will not be addressed here.

Of greater interest is the particulate fraction. Particulates enter the lungs easily and, because of their small size, are difficult to eliminate. As many as 18,000 different chemical compounds can attach themselves to particulates, including polynuclear aromatic hydrocarbons (PNAs), some of which are known carcinogens. These compounds can contribute from 15% to 65% of the total particulate mass.

Several covergent lines of laboratory research have implicated diesel exhaust as an occupational carcinogen. Bacterial tests have demonstrated that exhaust derivatives have mutagenic properties; that is, exhaust compounds alter genetic structures in the bacteria. Such genetic alteration is believed, by some, to be a necessary precondition for the development of cancer. Studies with laboratory animals have employed skin painting and inhalation techniques to evaluate carcinogenicity. In skin painting, areas of skin on mice are cleared of hair and then painted with exhaust distillates. Lesions and tumors have been observed in the affected areas. In inhalation studies, animals (e.g., rats, mice, hamsters) are exposed to filtered (to remove particulates) and unfiltered diesel exhaust for extended periods of time. A significantly higher incidence of lesions and tumors have been observed in the lungs of animals exposed to unfiltered exhaust, relative to animals exposed to filtered exhaust. This result suggests that particulates are in some way involved in the development of cancer, either by acting as a vector for carcinogenic compounds or by increasing the mechanical burden of the lungs.

However, the results of these studies are far from conclusive. With respect to bacterial research, mutagenicity is a necessary but not sufficient condition for the development of cancer; that is, cancer does not necessarily result from genetic alterations alone. Other factors also contribute to cancer susceptibility. Animal studies have been flawed by inconsistent methods. For example, in inhalation research, the amount of exhaust to which animals were exposed and the duration of the exposure periods has varied between studies. This makes it difficult to determine a dose-response relationship between level of exposure and health impact. Additionally, in some studies, development of lung tumors appears to be species specific. For example, in one study, an increase in lesions and tumors was observed for rats and mice, but no such result was evident for hamsters exposed to the same conditions. This suggests a differential sensitivity to exhaust compounds. There is also a growing concern over the applicability of animal research to humans. The physiology of lower mammals is fundamentally different and there is increasing skepticism that the responses of rats and mice are representative of those of humans.

Studies of human response to exhaust exposure have been limited to retrospective epidemiological evaluations. In such studies, the cause of death is first detemined, usually from death certificates. Exposure to the suspected agent is then estimated and attempts are made to correct for factors that might have contributed to the disease under investigation (e.g., age, years in occupation, smoking, asbestos exposure). Finally, the contribution of the suspected agent to the disease of interest is stated in terms of statistical odds; that is, the number of cases of disease in the "exposed" group relative to the number of cases in the "non-exposed" group. The results of the EPA studies cited eariler suggest that railroad workers in "exhaust exposed" categories are 1.4 times more likely to develop lung cancer relative to workers in "non-exhaust exposed" categories.

However, the epidemiological methods employed in the studies of railroad workers and truck drivers lack sufficient experimental rigor to make direct statements of cause and effect. This is due principally to the reliance of retrospective methods of historical data; that is, the working conditions and cause of death cannot be evaluated directly. As a result, all potential contributory factors cannot be controlled. Under the best of circumstances, therefore, an epidemiological investigation can only **suggest** an association between an agent and a disease and provides a basis for subsequent, and more rigorous, research.

AAR Research Program

While the odds ratio of 1.4 noted above is only marginally significant from a statistical standpoint, the Safety Research Division of the Association of American Railroads, at the direction of our Research Steering Committee, has established a research project to determine if exhaust levels in locomotive cabs constitute a potential health risk for train crews. A three phase study is in progress to determine which exhaust compounds crews are potentially exposed to, the most effective means of measuring these compounds, and current exposure levels in the cab environment.

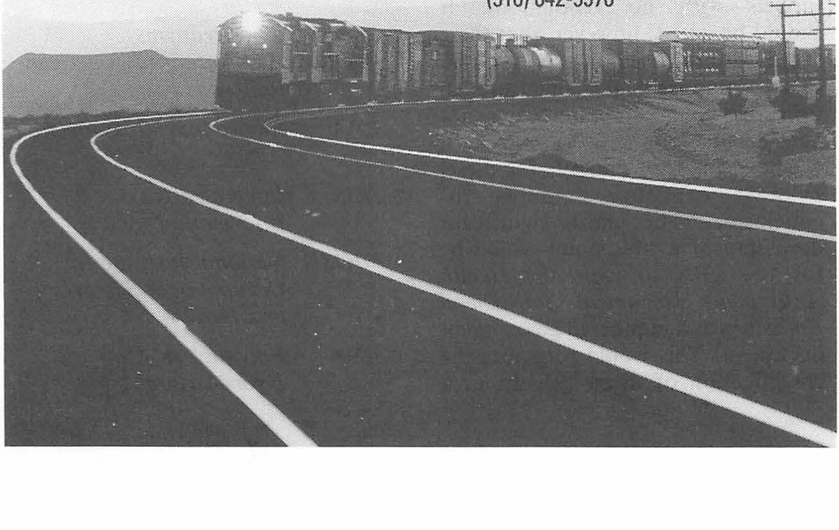
Phase I of this study, which was completed in December, included a review of the current health effects literature and exposure limits, a detailed chemical analysis of diesel exhaust, and a health risk assessment of identified exhaust compounds. During exhaust characterization, special attention was given to the identification of PNAs, resulting in the most detailed analysis of emissions from medium speed diesel engines to date. The health risk assessment was conducted against known carcinogenic compounds included in the Integrated Risk Information System (IRIS) database maintained by the EPA. Preliminary indications are that current exposure levels pose minimal, if any, health risks for locomotive cab personnel. Results of Phase I are being used to guide the selection of instruments to be included in an air sampling package.

Phase II, which is currently in progress, consists of the development of an instrument package and research protocol for air sampling in locomotive cabs. The package is intended as a relatively portable apparatus that can be used in a variety of environments. Sampling will be fully automated so as to require only minimum input from operator. Once developed, the package will undergo rigorous testing in the lab and in the field to ensure reliability and validity of results.

In Phase III, real-time samples of cab air will be obtained under a variety of operating conditions. Variables such as equipment type, climate, and operating conditions will be included as factors in the evaluation. Air samples will be analyzed and levels of exhaust compounds will be compared against current exposure guidelines. In addition, as a validity check on Phase I results, a second risk assessment will be performed to identify potential health problems. If results warrant, measures to control exposure will be identified and evaluated. These may include operating recommendations and engineering controls such as ventilation or filtration. Evaluation of other work environments (e.g., locomotive repair shops, fueling racks) will be considered in future phases of this research.

Regulatory Interest and Outlook

At present, regulatory interest in diesel exhaust exposure has been confined to NIOSH and the EPA. In 1988, NIOSH released its Current Intelligence Bulletin 50, *Carcinogenic Effects of Exposure to Diesel Exhaust*. This document provided an overview of significant research findings and recommended that whole diesel exhaust be regarded as "a potential occupational carcinogen." More recently, NIOSH has been involved in the development of a risk assessment model for lung cancer associated with diesel exhaust exposure. The model is based on animal data and is currently in the review process. No date has been set for for-



mal publication.

In 1990, the EPA published a draft document entitled *Health Assessment Document for Diesel Emissions.* This document emerged from an EPA sponsored workshop and is the most comprehensive work to date on the health effects of diesel exhaust exposure. In it the EPA recommended that diesel exhaust be classified as a B1 carcinogen; that is, on the basis of animal studies and limited epidemiological research, diesel exhaust should be considered a "probable human carcinogen."

A number of regulatory agencies and professional organizations have promulgated exposure standards for many of the compunds that comprise diesel exhaust. These include limits for acute (e.g., Short Term Exposure Limit) as well as chronic (e.g., Threshold Limit Value, Time Weighted Average) exposure. Studies by AAR member railroads indicate that the levels of these compounds measured in locomotive cabs fall well below established guidelines, except in the most extreme conditions (e.g., tunnels with no ventilation). It should be noted, however, that these standards are based on exposure to a single compound and that interactions between compounds are not considered.

The regulatory outlook for diesel exhaust exposure remains inconclusive. The most significant development as this point would be for the EPA to issue the *Health Assessment Document for Diesel Emissions* as a numbered government document. This would formalize the classification of diesel exhaust as a "probable human carcinogen" and regulation of exhaust exposure would quickly follow. At present, however, the EPA does not seem inclined to pursue this option. Federal and State air quality initiatives could have an unintended impact on exhaust exposure in that attempts to reduce diesel emissions will, *de facto,* lower the levels of exhaust to which workers are exposed. The magnitude of such reductions remains to be determined.

Exposure is the key factor in determining health consequences. For the time being, the prudent course is to monitor exhaust levels and reduce exposure wherever possible. This will provide a basis for demonstrating compliance with existing guidelines as well as establishing a benchmark for evaluating the impact of any future regulations. The AARs current research program on diesel exhaust exposure will provide a better understanding of potential health risks and will assist the industry in responding to existing and new regulation of the workplace.

Acronyms

AAR	*Association of American Railroads*
EPA	*Environmental Protection Agency*
IRIS	*Integrated Risk Information System*
NIOSH	*National Institute for Occupational Safety and Health*
PNA	*Polynuclear Aromatic Hydrocarbon*

III. TRACTION MOTOR GEAR CASE SEALS AND LUBE CONTAINMENT (OIL LUBRICANT)

Presented by: Pat Shackelford

With the improvements in gear grease that have taken place over the years, from crater compound to our present thinner greases, keeping the gear grease in the gear case is a problem.

When tests were run using oil to lubricate the traction motor gears, the need to improve containment was even more pronounced. These tests proved that the gears could be lubricated with oil, if the oil could be contained.

Both locomotive manufacturers stress that an important factor when using oil in the traction motor gear case is application of the proper lubricating oil. The primary concern is that the customer uses a lubricating oil product that has the proper viscosity, high oxidation resistance, low pour point, extreme pressure (EP) properties and adhesive properties, resists adverse effects of water and is compatible with other approved lubricating oils.

A lubricant with too low a viscosity will not provide an adequate film thickness between meshing teeth, leading to wear and scoring of the teeth. In addition, the use of a low viscosity lubricant can result in excessive leakage past the gear case seals.

The use of lubricant with too high a viscosity, although easier to seal, can result in other problems, such as channeling. Channeling occurs at low temperatures when the lubricant viscosity increases to the point where the lubricant does not slump to the bottom of the gear case to be picked up by the gear teeth. A groove is formed through the lubricant, with little or no lubricant brought into the mesh. Channeling is avoided or reduced with the use of low viscosity and low pour point lubricants.

With recent improvements in gear case sealing, oxidation restistance is becoming more important. Under the effects of time and high temperature, lubricants can oxidize and become very thick, with lubricating properties degraded. In some cases, the lubricant has thickened to the extent that gear rotation has been severly restricted. It is very important that the lubricant selected for traction gearing have a high oxidation stability and resistance to this thickening.

With the increasing loads on traction gearing, EP properties of the lubricants are becoming more important. EP additives in the lubricant chemically react with the gear metal to provide a protective film on the gear tooth. This film will shear and prevent metal to metal contact and wear when high spots on mating teeth come into contact.

The lubricant must have adhesive properties capable of retaining a lubricant film on all gear surfaces during the operating mode or when stopped. Oils having these properties are presently available.

Both manufacturers test proposed gear lubricants in a two part process, in-house testing and field testing.

The in-house portion consists of running a lubricant in test stand gear cases under both high load low speed and high speed conditions. Lubricant samples are periodically taken for analysis and the gears and pinions are frequently inspected for wear and scoring. Any leakage from the gear case is collected and measured. Seals are inspected for leakage and deterioration. If a proposed lubricant performs satisfactorily during the in-house testing, field testing is then started.

During the field testing, the lubricant is applied to units on a number of railroads in an attempt to accumulate mileage in various types of service. Gears and gear cases on these units are inspected periodically to determine the performance of the lubricant in actual service and samples of the lubricant are taken for analysis. The lubricant is typically field tested for at least one year to ensure that extremes in ambient temperatures are encountered.

Figure 1 shows the GE oil filled gear case. Changes were made to the (1) oil seals and (2) the sealer.

GE states that more than 350 gear oil filled gear cases on several railroads are currently in the field. The applications vary from drag service to high speed freight service. At the start of field testing there were a few setbacks. Several of the oil filled units that had undergone test had grease added to the gear case. To eliminate this problem and to eliminate a source of leakage, the standard hinged fill cap was modified to a pipe plug. This change will no longer allow grease to be added to an oil filled gear case.

Figure 2 shows the EMD improvements to allow oil lubrication.

(1) Gear case lower half - fill port and spring loaded cap are replaced by a flange and screw type plug. Flange and screw type plug is used for drain.

(2) Gear case upper half - a molded plastic filler cap replaces the steel cap. The plastic cap expands to fill the gear case port when the cap spring is deflected.

(3) Rope seal is replaced with RTV in the split line sealing groove between the upper and lower halves of the gear case.

(4) Old style felt pinion seal is replaced with a molded plastic seal that fits into existing gear case channels.

(5) Plastic axle seals - an additional seal lip or splash guard feature enhances sealing performance when using either grease or oil lubricants in the gear case.

(6) A plastic pinion armature seal provides a duct to protect the two drain slots in the traction motor seal face and insures continuous drainage of the lubricant back into the gear case.

EMD states that it has tested oil lubricated traction motor gear cases on three major railroads since early 1987 and has provided oil lubricated gear cases on more than 160 production locomotives since mid 1989.

Some of the advantages of using oil in the gear case are:

(1) All indications point to extended maintenance. Present experience shows that 92-day maintenance can be expected with oil filled gear cases.

(2) With oil, disassembly and cleaning of the gear cases and gears becomes an easy task compared with grease removal.

(3) The proper lubricating oil, with the addition of antioxidant, pour point depressant and tackiness agent, keeps the gears lubricated in all weather extremes.

(4) Tighter gear cases give better retention of the lubricant, therefore less contamination of the environment. Oil is easier to dispose of than grease.

REFERENCES

(1) LMOA Fuel and Lubricants Committee papers 1981, 1982 and 1984

(2) "Oil Lubrication of Locomotive Traction Gears - Theory and Practice", William D. Hewson

(3) "Locomotive Traction Motor Gear Lubricant Evaluation and Approval for Extended Maintenance", Dennis W. McAndrew

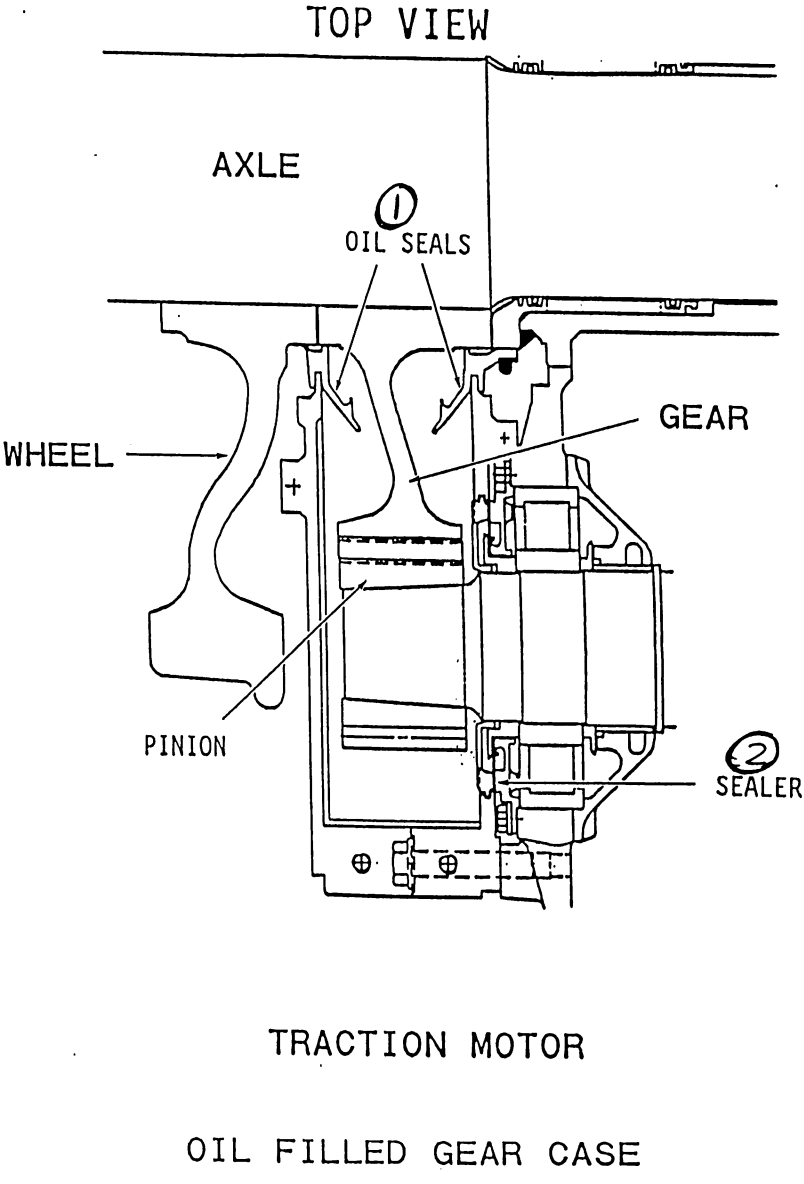

TOP VIEW
AXLE
1
OIL SEALS
GEAR
WHEEL
PINION
2
SEALER
TRACTION MOTOR
OIL FILLED GEAR CASE

FIGURE 1

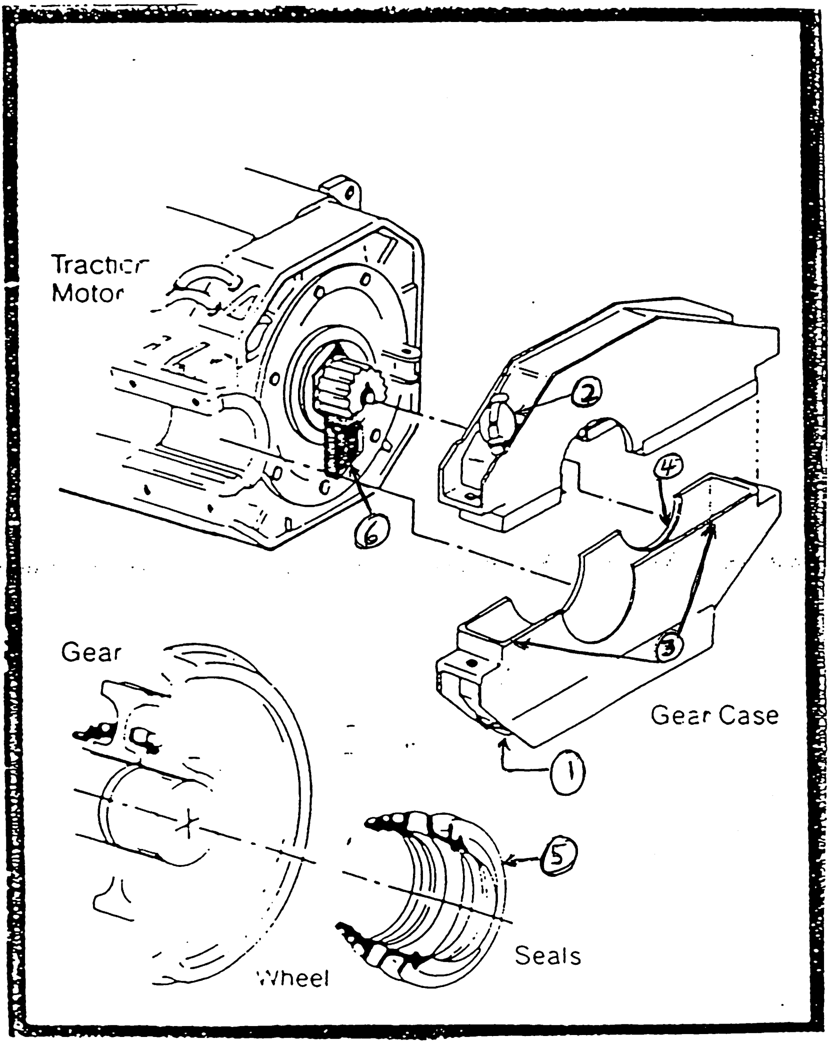


FIGURE 2

IV. PARTNERSHIP IN DEVELOPMENT

Presented by: Ron Lodowski

In response to increased competition from the trucking and inland marine industries, the railroads have implemented many changes as they seek to become more competitive. Manpower has been reduced. Maintenance shops and mechanical departments are operating at minimum manpower levels. In many cases, research and test functions have been reduced or sold to outside companies. Also, research and development budgets have been cut or eliminated.

The railroads have made other economies in addition to those listed above. They are pulling longer heavier trains with fewer but more fuel efficient locomotives. Maintenance intervals have also been increased.

The performance of Generation 4 lubricants depreciated under the more severe operating conditions required by the railroads. Therefore, newer, more oxidation resistant lubricating oils with higher TBN and better detergency and dispersancy were developed to meet the more severe operating conditions of the railroads and the requirements of newer locomotives.

Locomotive engine design changes were aimed at reducing fuel consumption and increasing engine horsepower. To make the locomotives more efficient, combustion pressures and compression ratios were increased. In addition, newer fuel injection times were developed. Also, turbochargers were improved and new piston and piston ring designs were produced. These locomotive design changes allowed the railroads to pull, longer, heavier trains with fewer, more fuel efficient locomotives. These locomotive engine design changes were field tested before they were inplemented.

Within the last three years programs to approve multigrade engine oils with newer improved additives were initiated. Benefits included reduced fuel and lube oil consumption.

When fuel and lube oil prices increased dramatically, due to events in the Middle East, multigrade railroad oils were available to help reduce costs. In fact one railroad has reported savings in the range of $400,000 after operating one year on multigrade railroad oil. None of these new railroad oils would have been available if they had not completed the EMD and GE approval procedures.

To be fully approved by the locomotive engine builders, the lubricating oil/additive formulation must satisfactorily complete the following steps:

1. Pass engine builder oxidation tests;
2. Complete stationary engine tests;
3. Complete a 1 year, 100,000 mile field test.

This procedure was devised to insure that the railroads would have effective lubricating oils for the locomotive crankcase.

New challenges facing the railroad industry in the near future will be related to maintaining the environment and conserving resources. Meeting these challenges will require mechanical changes in locomotive engines and new low emission, environmentally compatible lube oils.

Developing a railroad additive to the point where it is ready for field testing is very expensive. It is not unusual for an additive company to incur the following costs in the development of a railroad additive:

1. 500 oxidation tests at $1,000 ea.

2. 300 engine builder oxidation tests at an average cost of $400

3. 1000 bench wear tests at $150 ea.

4. 10 Caterpillar 1G-2 tests at $12,000 ea.

5. 5 EMD "2 Cyclinder" engine tests at $10,000 ea.

6. 5 Man years at $100,000/year

Therefore, an additive company has almost $1,500,000 invested in the development of a railroad engine oil additive before it approaches the railroads to run a field test. These costs are incurred if the additive is developed from existing additive components. If the additive is developed completely from new additive components the development costs can exceed three times that amount.

With reduced manpower many railroads feel that they are not in a position to participate in field testing. Some railroads are reluctant to participate in field testing because of the down time of the locomotive involved. Without proper field testing it is possible that new mechanical parts could be developed for locomotives that would not meet the railroads' durability requirements. This could be more frequent shopping of locomotives and subsequent loss of revenue producing miles.

The Clean Air Act will almost certainly be applied to railroad locomotives in the future. This will require mechanical modifications to new and existing locomotives. The equipment manufacturers want to ensure that any change made to a locomotive will not affect its durability. To do this, field testing must be conducted.

In addition, new oils for the locomotive engine will be required to help meet the more stringent Clean Air Act requirements. Many state and local governments are considering passing laws restricting the disposal of used railroad oils. For example, in some cities, restrictions on burning used lube oils for boiler feed are being considered. Also, environmental regulations may require the use of railroad oils that do not contain chlorine. Some railroads are requiring oil companies to take back used oil as a condition for purchasing new lube oil. To make sure that these new oils will meet the locomotive builders' and railroads' requirements, field testing is required. If the railroads quit running field tests these oils will not be available when they are needed.

Railroads that run field tests benefit from the information they gain by testing lubricating oils and equipment in their locomotives. These benefits include:

1. Evaluating new railroad equipment technology;

2. Determining potential problems and recommending changes;

3. Testing multiple suppliers and selecting best products;

4. Observing product performance under operating conditions.

It is well known that field testing of mechanical equipment is much easier than lubricating oil field testing. The mechanical equipment is installed in the locomotive and "forgotten about" until it is removed at the end of the field test. However, it appears that the railroads are reducing their commitment to field testing mechanical equipment.

A department at one of the locomotive engine builders said it was experiencing problems in getting the railroads to participate in the field testing of its equipment. Look around your railroad, are the same number of field tests being run today that were being run five years ago? If what we hear is true, field testing has been reduced due to railroad mergers and the resulting manpower reductions. The railroads cannot afford to avoid lube oil field tests because they are difficult to run. Locomotives cannot operate without lube oil in the crankcase. Given the demands for quality and on time performance from customers, railroads cannot afford to use unproven products in their locomotives.

The railroad additive suppliers and locomotive equipment manufacturers want to develop new products that will meet the future needs of the railroads. Whatever the cause—clean air restrictions, environmental regulations, or the development of improved locomotives—field testing is vital to make sure that new products will perform satisfactorily in today's more severe railroad environment.

To make sure that the products they need for the future are available, the railroads must actively participate in field testing. They must put the equipment or lube oil through a demanding test so that potential problems can be exposed and eliminated. The railroads need to evaluate new products to make sure that the equipment or lube oil meets th railroad's performance requirements. So that needed field test approvals and performance data can be obtained, the railroads need to work with the equipment manufacturers and additive companies so that the test data can be collected and inspections can be conducted with minimal disruption to the railroads' operations.

Field test procedures were developed when the railroads had sufficient manpower to run the necessary mechanical and lube oil field tests. With the railroads reduced in manpower, more streamlined field testing procedures need to be developed. To run field tests that are satisfactory to all, a partnership must exist among the railroads, equipment manufacturers and additive suppliers so that new products will be available when they are needed.

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

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

LMOA wishes to express its thanks to the Canadian Railroads for hosting and participating in the Pre-Convention Presentation of our New Developments Committee in Montreal on May 23, 1991.

The attendance and interest exhibited was most gratifying.

REPORT ON THE COMMITTEE ON NEW DEVELOPMENTS

Wednesday, September 18, 1991
9:00 A.M.

Pre-Convention Presentation CN/CP

MAY 23, 1991
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Montreal, PQ, Canada

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C&NW Transportation
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PERSONAL HISTORY

Michael Iden

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

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

In 1974, he resigned from Southern Railway, and joined Electro-Motive Division of General Motors in LaGrange, IL as a Mechanical Designer in the Plant Engineering department, subsequently promoted to Mechanical Engineer in 1975.

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

In 1986, he was promoted to Assistant Superintendent Motive Power in the Motive Power department, and in 1989 to Director Motive Power Engineering, his current position.

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

I. LOCOMOTIVE CAB INTEGRATION AND ACCESSORY MANAGEMENT

Presented by: George Hsu

1. Introduction

Due to the rapid advancement of electronic technology in the last two decades, many new ideas have emerged for improving train operations. Numerous accessories have sprung up to meet various needs of individual railroads. Here are some examples that are familiar to most of us: EOT receiver, slow speed controller, event recorder, alerter, digital speedometer and speed recorder, flange lubricator, electronic fuel gauge, cab signals, electronic air brake, Advanced Train control Systems (ATCS), Locomotive Analysis and Reporting System (LARS), Advanced Railroad Electronics System (ARES), etc., just to name a few. Almost all of these devices have merits to some, if not to all, railroads. Therefore, the market for these devices is a profitable one. Unfortunately meeting these various needs is not without "side effects."

The proliferation of these devices has created a difficult locomotive cab situation for the railroad industry and locomotive builders to maneuver. Competition for the limited space in or under the cab has become hard to manage. The problem is especially serious in front of the engineer. Typically, an array of stand-alone mechanical and/or electronic devices either provides information to the crew or requires data input by the crew. Placement of the equipment is governed by one rule: first come, first on, wherever is available, at the expense of cab ergonomics. Many of these devices require set-up and acknowledgements which have little consistency in format.

Another side effect, sometimes referred to as "maintenance nightmare," is due to incompatibilities among these accessories as well as the need to carry spares for the same device from different suppliers. While both the railroad industry and its supply community have been meeting these constantly changing needs, neither has yet successfully addressed the issues of compatibility and cab cluttering. Most railroads are very aware of this dilemma and are working hard toward a permanent solution.

Through the years, the search for solutions to these problems has led to two distinct approaches, namely integration and modularization. Due to the diverse needs of each railroad, these two approaches, like the century old philosophical question of centralizing or decentralizing, have actually become complementary rather than contradictory. Therefore, the "right" answer is to integrate where integration makes sense and to modularize where modularization is appropriate. Although there are no clear cut rules to define which function should be done which way, in fact, each approach has its merit for certain functions; and under certain conditions, a coordinated effort with defined guidelines for the industry to follow would be beneficial for all parties involved. This may sound like a big order but all it really takes is a little common sense plus a lot of cooperative spirit to come up with workable guidelines for railroads and their suppliers.

2. Integration

Generally speaking, the integration approach is an opportunity for both new and remanufactured locomotives. It does involve a total redesign of those parts of the locomotive's control and display system that are impractical to retrofit. All of the "standard" functions of a traditional control stand

may be integrated into a system that employs microprocessors to monitor, control, and display locomotive operations. Other functions that are common but optional can also be included in this integrated system, if they do not incur major engineering effort and expense to the integrated central processor. Otherwise, they should be done using a modular approach, which will be addressed in the next section.

Here are two examples of the integrated approach:

2.1 Integrated Cab Electronics (ICE):

General Motors Locomotive Group, in partnership with Rockwell International's Railroad Electronics, has undertaken a program to integrate the various electronic and electro-mechanical devices that reside in locomotive cabs and elsewhere on locomotives into a system called Integrated Cab Electronics or ICE.

ICE is a computer based platform, designed to combine the capabilities of the EMD's locomotive control microprocessor with Rockwell International's locomotive display and man-machine interface computer system. It replaces the standard cab gauges, meters, and warning indicators with a centralized color display screen. Interface to ICE for setups such as end-of-train identification will be done through user friendly, menu-guided function keys located below the display screens.

Key features of the ICE system include:

- Display of air brake system pressures; throttle, reverser, and dynamic brake handle positions; load and braking current; alarm and fault warnings; time; unit number; speed indication with odometer; end of train data; fuel level; train control aspects; and voice radio channel.
- Integration of alertness control; end of train device receiver; event recorder; voice radio; train length counter; ICE system diagnostics; and expandability to full Advanced Train Control Systems.

Developmental activities are currently underway to expand ICE cababilities to include other high level locomotive operating functions such as:

- Locomotive diagnostics/self-test
- Automatic cab climate control
- Integrated electronic air brake
- Integrated distributed consist management.

Figure 1 shows the general architecture of ICE with the integration of future ATCS already designed in.

2.2 Integrated Function and Display System (IFDS)

Integrated Function and Display System (IFDS), is General Electric's computerized locomotive supervisory system with color information displays. Its objectives are to improve the cab ergonomics, locomotive reliability, maintainability, and functional diagnostics. This system will coordinate cab signal, vigilance, control and diagnostic functions. It also provides for future functional expansion. The system is expandable with new software packages and peripheral equipment as required. The system is made up of two parts: a base system of core features and functions and add-on peripheral systems designed for user's special requirements.

The base system is made up of the following components: integrated function computer (IFC), interactive display units (IDU), audio-visual alarm box (AVB), the customized recorder device (CRD,) cab signal subsystem, and other components such as pressure transducers and electrical connections. The IDU is a flat, back-lit color liquid crystal display with a 10" diagonal dimension. Interactive buttons are labeled on the lower portion of the display (soft keys) for interactive input. The display offers a wide variety of graphics to enhance communication.

The base system replaces many of the "black boxes" that were traditionally mounted "somewhere" in the operator cab. Examples include ammeter, speed indicator and speed indicator interface box, axle alternator and associated hardware for speed indicator, alerter box and associated hardware, solid-state event recorder (crash-hardened), eight-track tape event recorder, associated recorder hardware such as air brake manifold box and current module, throttle clock, and cab-mounted indicating lights.

The IDU consolidates the display of ammeter current, air brake pressures, locomotive speed, engineer "alerter" function, cab signal, diagnostic information, etc. It has also been provided with ATCS compatible data link I/Os. Future integration may include such functions as electronic air brakes, flange lubrication, fuel rate and level monitoring, electronic fuel injection, and other. Figure 2 shows the general architecture of IFDS, which can be expanded also to incorporate ATCS.

Both the ICE and IFDS systems address the man machine interface (MMI) issue. They display all of the important information at a concentrated area on two CRT screens. Therefore the engineer will not have to search all over the cab for the information needed to operate the train properly.

Although it may be desirable to have a set of standard screens for the railroad industry, the various screen configurations may be programmed and stored onboard and recalled if and when needed.

3. Modularization

The main objective of modularization is accessories management. The integration examples just cited, ICE and IFDS, are both for new locomotives and can even be stretched to remanufactured locomotives. Neither of these two is a good approach for retrofitting existing locomotive fleets. A practical guideline shoud be established for all interested parties, i.e., railroads and suppliers, for accessories procurement so that the growth of these useful gadgets can be controlled. First of all, this creates a much larger potential market for each functional "black box" because of compatibility. Volume will undoubtedly increase and encourage competition and therefore, yield a much better function/price ratio. Secondly, modularization can avoid duplications among boxes, such as power supply, protective circuits, communication circuits, etc. This will further reduce the price due to lower manufacturing cost, a benefit to both buyer and seller.

This concept in the domestic commercial airline industry called form-fit-function (F^3), has been a reality since the 1950s. As a result, "the effects of competition, combined with the larger production quantities made possible by writing a given specification to satisfy multiple aircraft/multiple-airline requirements, have produced significant cost savings up to 32 percent for the airlines."[1] Application of F^3 to the railroad industry would require the acquiring organizations to establish requirements for the physical and electrical interfaces between the accessories and the locomotive. Provisions for cooling, connectors, pin assignments, automatic test equipment, and other parameters would be described in enough detail to permit a manufacturer to produce equipment that will be interchangeable with other manufacturer's equipment, despite probable differences in the internal design of the equipment.

Figure 3 shows where we are now. Each device has its own (may be internal) power supply or power conditioning board. The cable and the pin assignment of the connectors are different. Even the axle generators may be different. But functionally, there are commonalities, as shown in the left most set of boxes. We should take the advantage of such commonality in the future for the benefit of both the railroad and supply community.

Suggestions for the railroads' version of F^3 requirements in order of decreasing importance are:

3.1 Common Power Supply

As shown in Figure 4, this power supply module should provide enough power for all accessory devices. If more power is needed, another power supply module may be added independently or in parallel to satisfy the power demand. For example, the power supply module may transform the 74 vdc locomotive power to 5 vdc and ± 12 vdc regulated power outputs. All the accessory devices should be designed to use these regulated power outputs with standardized power connectors. This could be the first step in reducing incompatibilities.

3.2 Common Display

The second step is to create a common display as show in Figure 5. This will consolidate all of the critical operating information in one location so the engineer does not have to have to search all over the cab for it. Then, without all the clutter, we will have a "neat cab" in addition to a "clean cab." The engineer will be able to find the information he needs quickly. There will be no other display unit to mount or maintain. A computer acting as display driver will be needed at this level. All black boxes at this level should have a common communications link, i.e., protocol, software, and connectors.

3.3 Common Function Partitioning

The third F^3 requirement is function partitioning. At this level, the function(s) or feature(s) and its I/O connectors should be clearly defined to avoid mismatch of the functions among different boxes. This enables the railroad to mix and match black boxes from different suppliers as well as to carry fewer spare boxes without the waste of duplicating functions on different boxes.

If any one cares to go further, it should be very easy at this level to add a train control computer which interfaces with the display computer for much more enhanced operations, as shown in Figure 6.

3.4 Common physical dimensions

Common physical dimensions are highly desirable. They allow placement of the modules in an enclosure for environmental control (such as ARES). This will allow the user to literally swap boxes regardless of the manufacturer.

3.5 Common lockable enclosure

A common lockable enclosure creates an isolated environment which contributes to the performance and longevity of the electronic boxes. The lifetime and performance of individual boxes are increased by:

3.5.1 Minimizing electromagnetic and radio frequency interferences.
3.5.2 Minimizing the probability of unauthorized access to the equipment.
3.5.3 Reducing low frequency movement and shock loads to maximize component life. The common lockable enclosure would already provide consolidated vibration and shock isolation to all of the component boxes. This would ease the packaging requirements for each individual box and further reduce costs.
3.5.4 Providing filtered, forced air cooling (not necessarily conditioned air.) As a rule of thumb, reducing the temperature by 10 deg C can increase the electronics reliability two-fold.

As an example, Figure 7 shows BN's very basic communication configuration for LARS (locomotive analysis and reporting system). BN has been working with its contractor/partner for many years using this approach. Figure 8 is a picture of the full ARES version of the same enclosure. To upgrade from LARS to ARES, one needs to simply include more functions by adding black boxes, antenna, and the display units. The significance of Figure 8 is that it contains boxes manufactured by five different suppliers. From top right counter clockwise: the power supply is from company "A," end-of-train device receiver is from company "P," GPS (global positioning system) receiver is from company "T," data radio is from company "H," and the train control computer and the data management unit are from company "R."

There are no specific restrictions on the width of each box. There are, however, maximum dimensions on the height and depth. A good example is the GPS receiver shown in Figure 9. It does not even have the same height and depth with the other black boxes. But with a simple adaptor, it fits in a slot of the enclosure snugly.

4. Conclusion

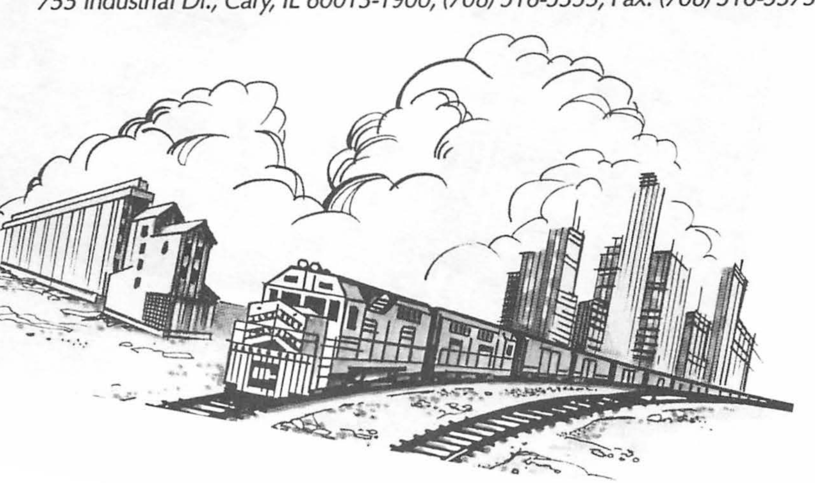
Currently, one of the AAR committees is engaged in the task of locomotive system integration. Its current objective is to consolidate all of the functions under a single umbrella system so that all man-machine interface (MMI) is done through the centralized display system. Clearly, it will be to the benefit of both railroads and suppliers to jump on the bandwagon to give the task their full support. All are encouraged to actively participate and support this effort.

However, from past experience, it is safe to say that railroad equipment is **usually** not born as a result of a committee's consensus. A defacto standard usually emerges first because either the locomotive maker decided to make them that way or certain railroads and/or suppliers decided to go ahead without waiting for the standard from the committee. There is a high probability that history is going to repeat itself on this task. Whoever, be it railroad or supplier, has the guts to go ahead is going to take some risk but for a big gain. If consensus can be reached, so much the better.

But railroads just can not wait around for another 10 years, because the less PRECISE and COST EFFECTIVE we are, the more market share we will lose to other modes of transportation. They will be more than happy to absorb every single shipment lost by us. There are voices claiming that we cannot afford all this "high tech stuff." While committees are working on the standard, some railroads have already proven, with the help of suppliers, that all of it can be done from proven technology with little risk. The real question is, therefore, can we afford NOT to do it. Because if we don't **act** fast to improve our service while lowering our cost, the "triple trailer highway train" may become the new standard operation. It will be too late to **react** by then.

We have an important decision to make. It will not be an easy one. We all try to make the best decision, or at least a good decision. Sometimes we have to live with a not-so-good decision. But even a not-so-good decision is still better than no decision. The same can be said about standards if not more so. The best standard is hard to reach. At least we should try our best to come up with a good standard. We may end up with a not-so-good standard. But even a not-so-good standard is still better than no standard.

Reference 1: F³ Standardization - Does it work? Stewart Baily, ARINC Research Corporation, November 1983, IEEE



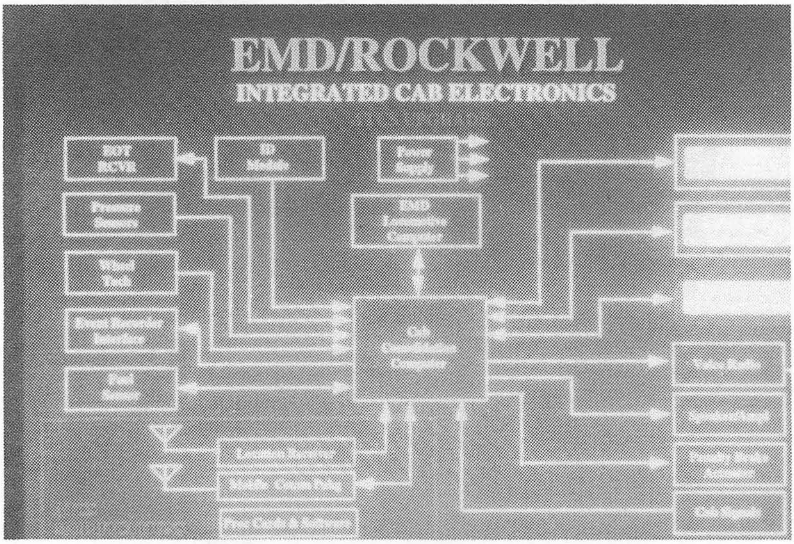

EMD/ROCKWELL
INTEGRATED CAB ELECTRONICS

Fig. 1

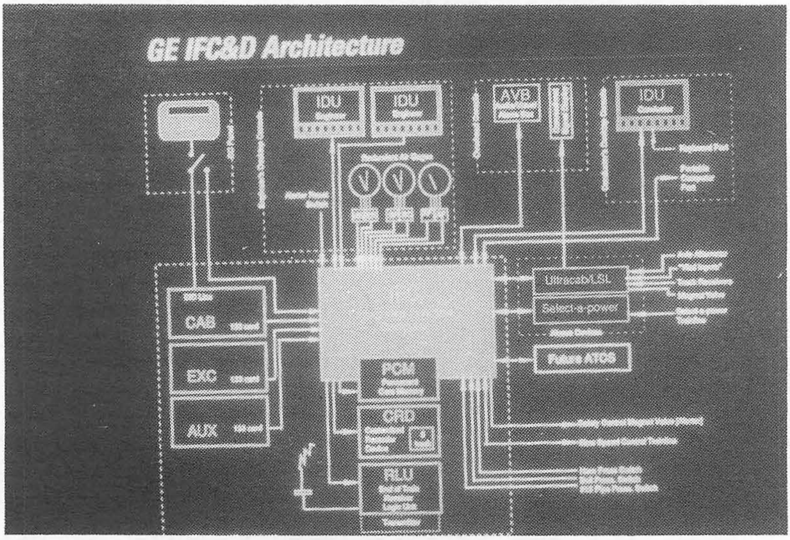

GE IFC&D Architecture
IDU
IDU
AVB
IDU
Ultracab/LSL
Select-a-power
Future ATCS
CAB
EXC
AUX
PCM
CRD
RLU

Fig. 2

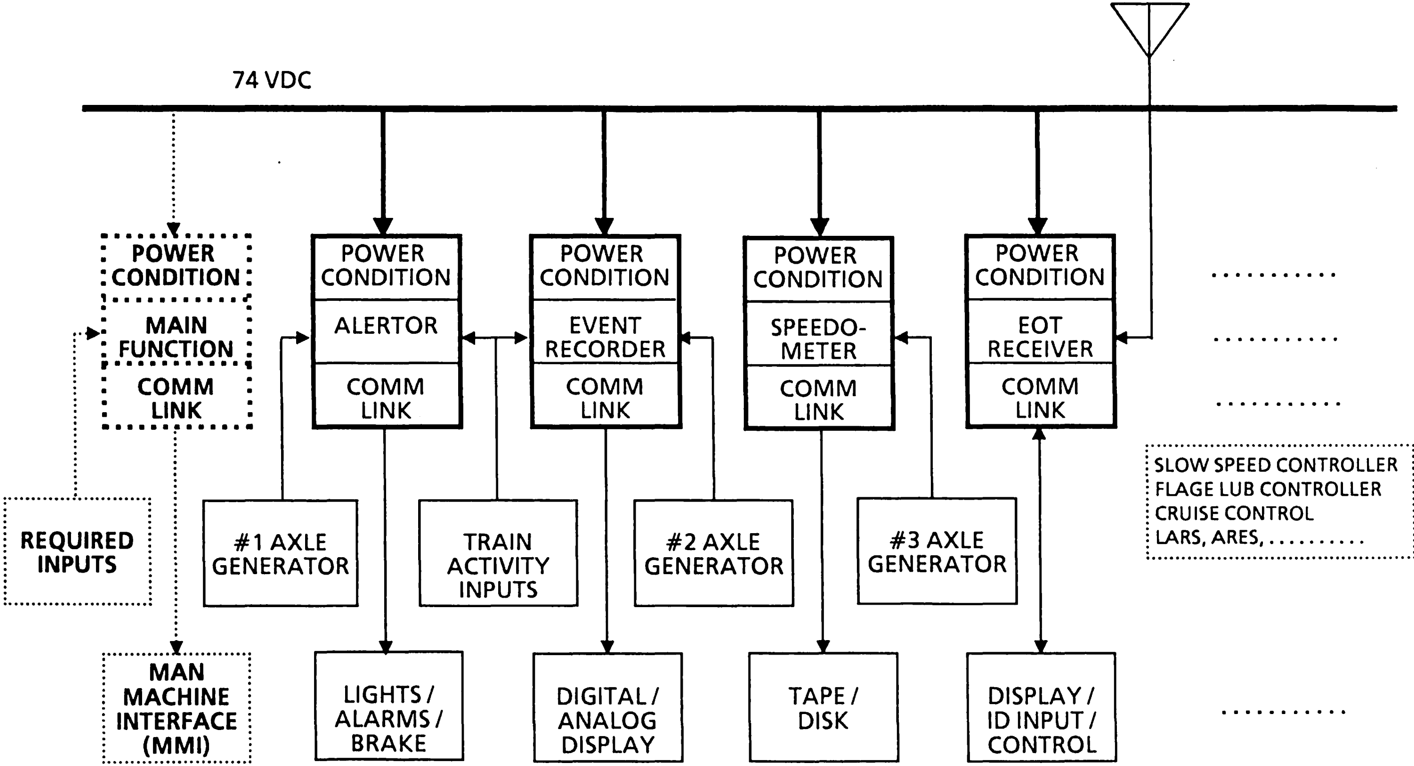

74 VDC
POWER CONDITION
MAIN FUNCTION
COMM LINK
REQUIRED INPUTS
MAN MACHINE INTERFACE (MMI)
POWER CONDITION
ALERTOR
COMM LINK
#1 AXLE GENERATOR
LIGHTS / ALARMS / BRAKE
TRAIN ACTIVITY INPUTS
POWER CONDITION
EVENT RECORDER
COMM LINK
#2 AXLE GENERATOR
DIGITAL / ANALOG DISPLAY
POWER CONDITION
SPEEDO-METER
COMM LINK
#3 AXLE GENERATOR
TAPE / DISK
POWER CONDITION
EOT RECEIVER
COMM LINK
DISPLAY / ID INPUT / CONTROL
SLOW SPEED CONTROLLER
FLAGE LUB CONTROLLER
CRUISE CONTROL
LARS, ARES, ...

FIGURE 3

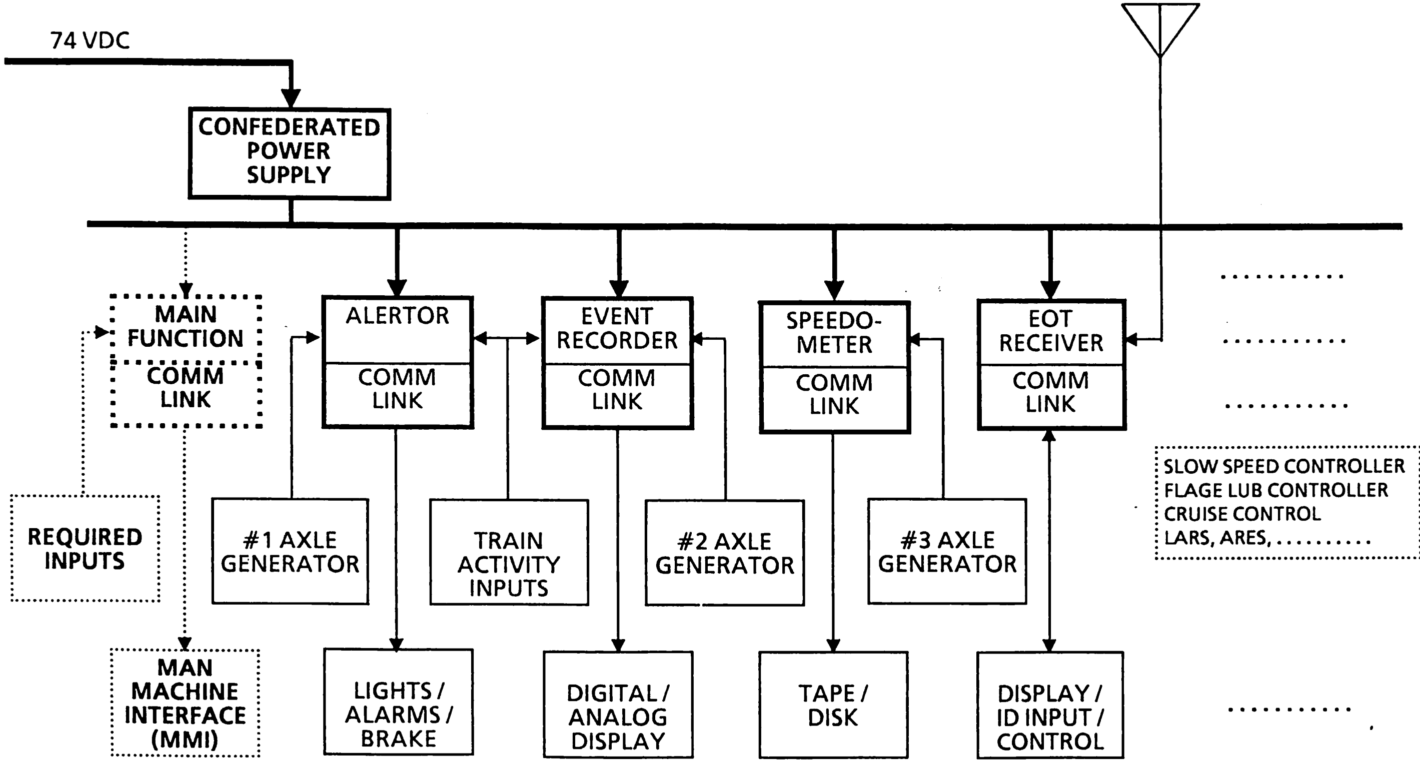

74 VDC
CONFEDERATED POWER SUPPLY
MAIN FUNCTION
COMM LINK
ALERTOR
COMM LINK
EVENT RECORDER
COMM LINK
SPEEDO-METER
COMM LINK
EOT RECEIVER
COMM LINK
REQUIRED INPUTS
#1 AXLE GENERATOR
TRAIN ACTIVITY INPUTS
#2 AXLE GENERATOR
#3 AXLE GENERATOR
SLOW SPEED CONTROLLER
FLAGE LUB CONTROLLER
CRUISE CONTROL
LARS, ARES, ...
MAN MACHINE INTERFACE (MMI)
LIGHTS / ALARMS / BRAKE
DIGITAL / ANALOG DISPLAY
TAPE / DISK
DISPLAY / ID INPUT / CONTROL

FIGURE 4

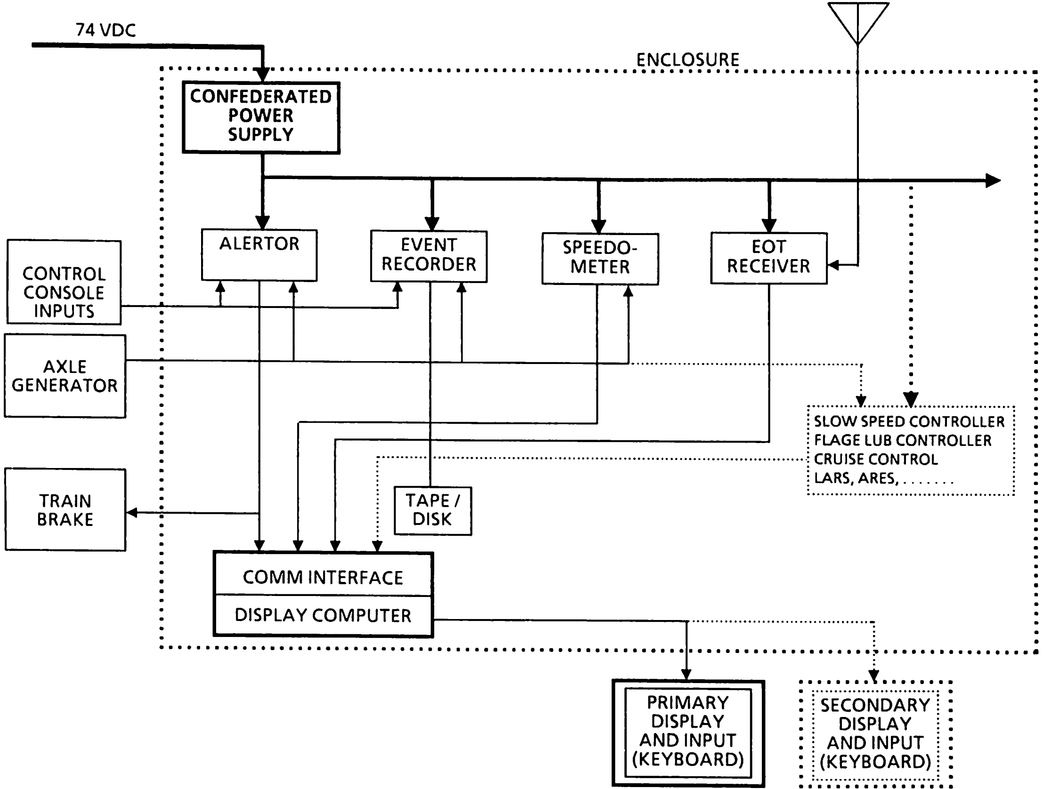

74 VDC
ENCLOSURE
CONFEDERATED POWER SUPPLY
ALERTOR
EVENT RECORDER
SPEEDO-METER
EOT RECEIVER
CONTROL CONSOLE INPUTS
AXLE GENERATOR
TRAIN BRAKE
SLOW SPEED CONTROLLER
FLAGE LUB CONTROLLER
CRUISE CONTROL
LARS, ARES, ...
TAPE / DISK
COMM INTERFACE
DISPLAY COMPUTER
PRIMARY DISPLAY AND INPUT (KEYBOARD)
SECONDARY DISPLAY AND INPUT (KEYBOARD)

FIGURE 5

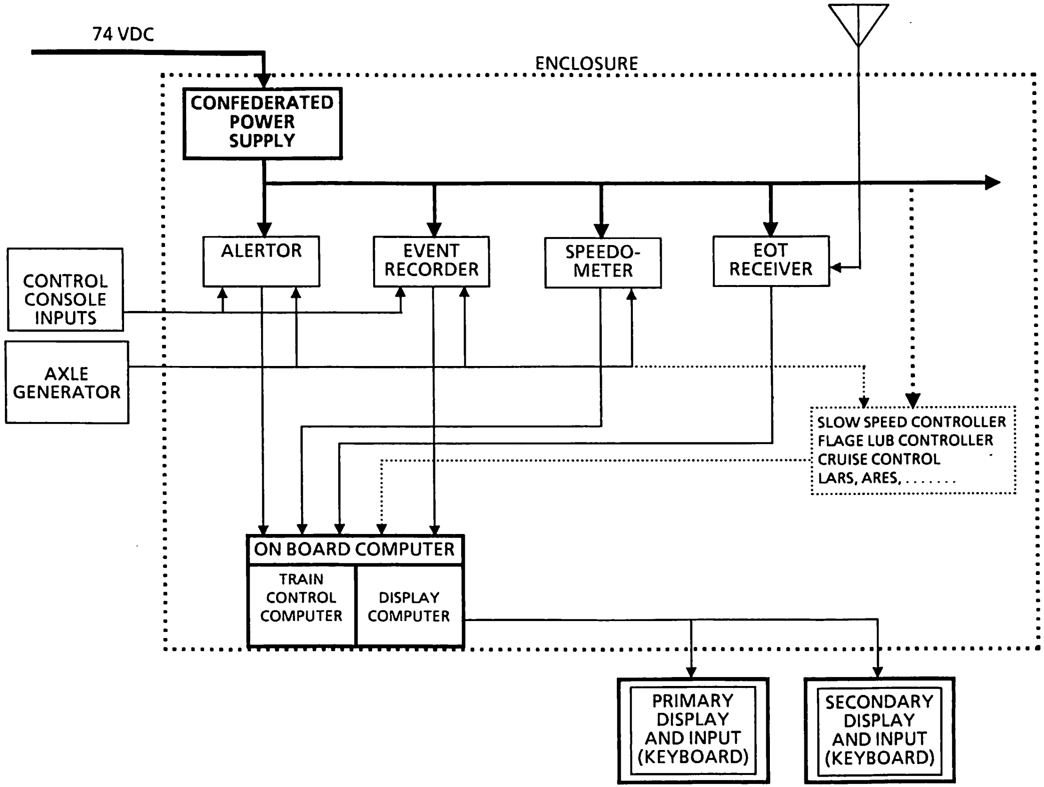

74 VDC
ENCLOSURE
CONFEDERATED POWER SUPPLY
ALERTOR
EVENT RECORDER
SPEEDO-METER
EOT RECEIVER
CONTROL CONSOLE INPUTS
AXLE GENERATOR
SLOW SPEED CONTROLLER
FLAGE LUB CONTROLLER
CRUISE CONTROL
LARS, ARES, ...
ON BOARD COMPUTER
TRAIN CONTROL COMPUTER
DISPLAY COMPUTER
PRIMARY DISPLAY AND INPUT (KEYBOARD)
SECONDARY DISPLAY AND INPUT (KEYBOARD)

FIGURE 6

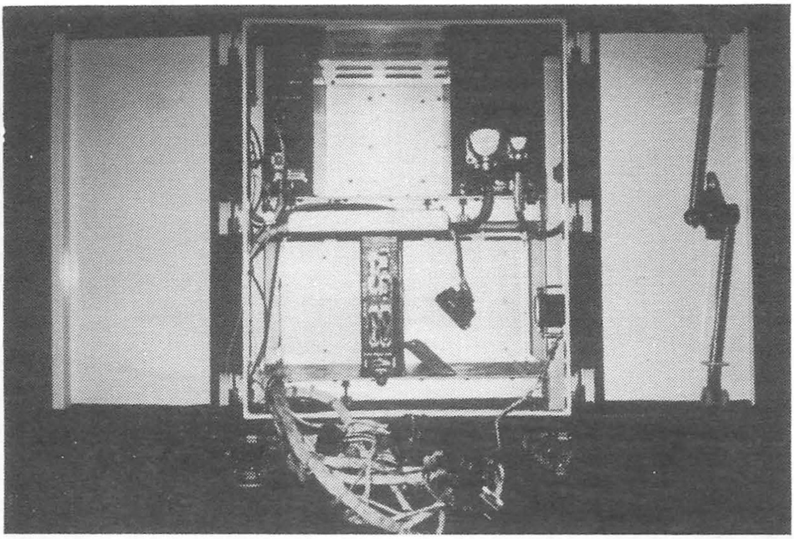


Fig. 7

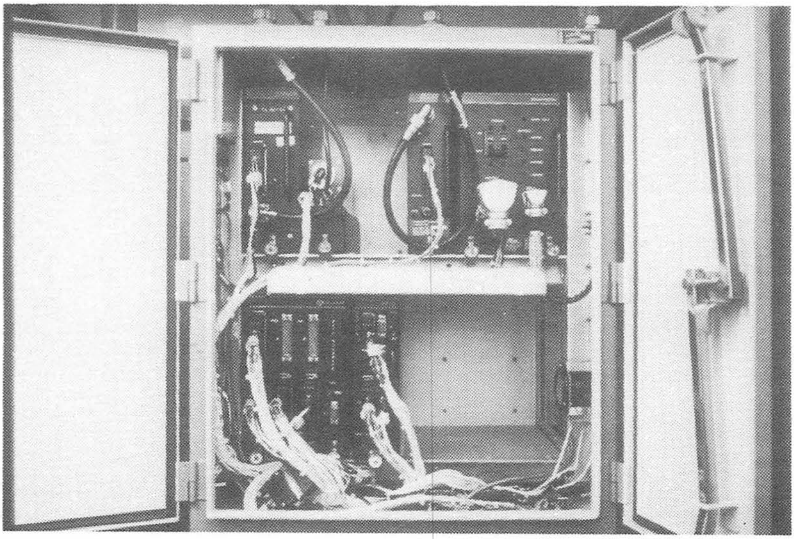


Fig. 8

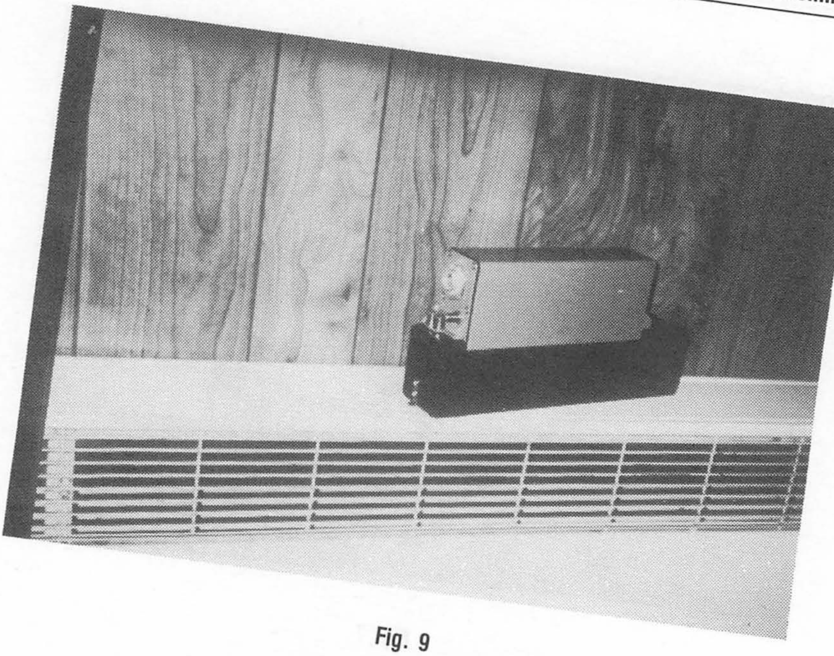


Fig. 9

II. IMPROVEMENTS IN LOCOMOTIVE ADHESION PERFORMANCE

Presented by: Mike Iden

Adhesion is the percentage of weight on powered driving wheels which a locomotive converts into usable tractive effort:

$$\text{Adhesion (ADH)} = \frac{\text{Tractive effort, pounds (TE)}}{\text{Weight on drivers, pounds (W)}} \times 100\%$$

Increasing a locomotive's adhesion performance can increase its tonnage rating. A C40-8 weighing 400,000 pounds and rated 4,000 horsepower, for example, can produce 100,000 pounds of TE at 25 percent adhesion but can achieve 120,000 pounds of TE if adhesion can be boosted to 30 percent. (Of course, the higher TE at the greater adhesion level comes at the expense of speed.)

Older locomotives, such as the SD40-2 and C30-7, were given dispatchable adhesion ratings of 18-to-21 percent by the manufacturers. These units use conventional wheel slip correcting systems and fairly large volumes of sand. Newer locomotives, such as the SD60 and C40-8 are rated at 27 to 30 percent adhesion, and use wheel creep control systems which maximize adhesion by allowing controlled creep or wheel overspeed.

However, the performance of even the newest locomotives can be compromised when rail head conditions are poor, such as during rain or blowing snow, or when organic contaminants such as grease and oil are present on the rail head.

Several technologies are either on the market or in product development which have the potential for increasing locomotive adhesion performance, which applicability to either conventional or high adhesion locomotives.

Radial Self-Steering Truck (Figure 10)

The first development is the radial self-steering locomotive truck. GMLG's 3-axle HTCR truck is designed for SD60-type locomotives. The radial design of this truck allows the two end axles to yaw or rotate with respect to the truck frame, while negotiating curved track. The self-steering design is produced by coupling the two end axles through a steering mechanism, such that the 2 end axles yaw or rotate to the truck frame. This self-steering mechanism has the potential to reduce flange forces by as much as 33 percent in a 10 degree curve, compared to a conventional HTC truck. Performance of the HTCR truck relative to the HTC truck obviously improves with greater track curvature.

The HTCR truck does not have journal pedestals like a conventional truck. The journal adapters of the HTCR extend up inside the truck frame casting, which provides lateral restraint for the axles.

Traction and braking forces developed by the wheels are transferred into the truck frame through traction rods connecting the journal adapters and the truck frame. These forces are then transmitted from the truck frame to the underframe through a center pin, which extends down much lower than a conventional center bearing. This center pin carries all longitudinal forces between truck frame and underframe, but very low lateral forces.

The HTCR truck frame supports the locomotive's weight directly through four steel-rubber compression springs, which also provide restraining forces on truck frame yaw and act against lateral forces. The HTCR truck frame does not swivel in

the sense that a conventional truck does around a center bearing, since the compression springs connecting the truck frame to the underframe provide significant resistance to yawing motion.

The HTCR truck does not have a bolster. The four compression springs which support locomotive weight are located in roughly the same plan location as the conventional HTC truck bolster springs.

GMLG estimates that the HTCR truck has the potential to increase locomotive adhesion performance by up to 3 percent as compared to a conventional truck. The first revenue use of this truck will be under three SD60MAC AC-motor locomotives now being built for the Burlington Northern.

Rail Head Cleaning Mechanism (Figure 11)

Dr. Sud Kumar, from the Railroad Engineering Laboratory at Illinois Institute of Technology, has been granted a U.S. patent for a rail head cleaning mechanism intended to be installed underneath a locomotive, typically at the front of the leading truck.

This mechanism features two loaded rollers on each rail, with the rollers skewed at slight angles relative to the centerline of the rail. Because the rollers are skewed, as the locomotive moves the rollers will roll but will also slip sideways a slight amount; this slip slide motion by the rollers will generate heat, which will burn contaminants off the railhead. The rollers would be made from a material capable of supporting the necessary loading forces and to also withstand the temperatures developed in the contact area.

Adhesion Modifying Chemicals (Figure 12)

Chemicals to alter the adhesion state of the rail head are not new. Nalco Chemical Co. produces a product call "RC" which was orginally sold in the early 1950s as a "rail conditioner." RC is a suspension of finely-ground silica powder in an alcohol base. It was tested extensively by the Reading Company in the 1950s. The Reading reported adhesion improvements even in rainy weather when using RC. The product is still sold today, but the primary use is in applying traction motor pinions to armature shafts.

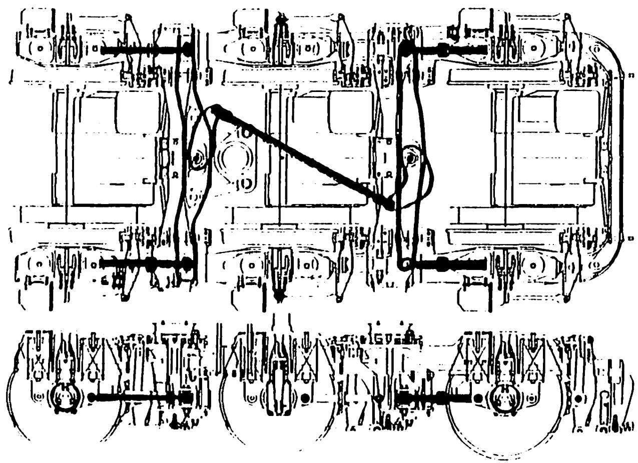
Century Lubricating Oil Co. of Kansas City is now offering "VHPF" (for very high positive friction coefficient) on a test basis. VHPF is a solid stick lubricant which has a 30-to-40 percent coefficient of friction at wheel creep rates of up to 20 percent. VHPF is applied to the locomotive wheel tread, with the stick held in a spring-loaded plastic cartridge held by a special truck-mounted bracket.

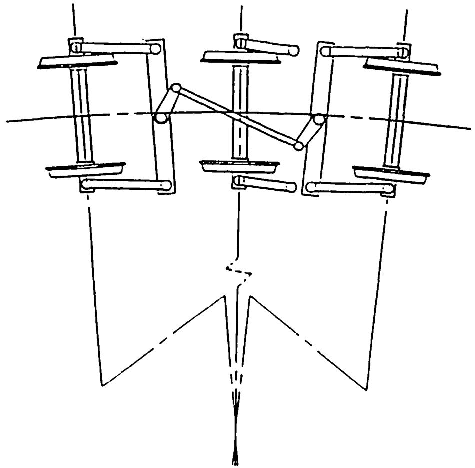
VHPF has been tested by BC Rail, which reported a significant increase in tonnage rating on 4 SD40-2s employed as a helper locomotive on the 2.2 percent grades north of Vancouver. Recently, Century has formed a task force along with 6 railroads (BN, CNW, CP, CR, NS and UP) to perform field testing of the product.

In August, a test was made on CNW with VHPF applied to four wheels of a C40-8 locomotive. The test provided base adhesion data for the C40-8 and also permitted comparison of VHPF against sand, with dry rails and also with rails artifically wetted using an onboard water tank. The C40-8 was loaded by dragging 5 GP50 locomotives in dynamic braking; all testing occurred at speeds below 6 mph to insure that the C40-8 was operating in a maximum-adhesion mode.

Results of the testing on CNW indicate that VHPF has potential for increasing adhesion performance of a high adhesion locomotive, such as a C40-8. However, the testing also showed that VHPF and the Dash 8 wheel creep control system may also be working against each other, and that a slight reformulation of the VHPF or a modification to the wheel creep algorithm of the locomotive may be necessary. Additional testing has occurred on a wheel dynamometer stand and will occur using SD40-2 and SD60 locomotives.

GMLG "HTCR"
THREE-AXLE RADIAL TRUCK





TEST RESULTS:

STEADY-STATE CURVING

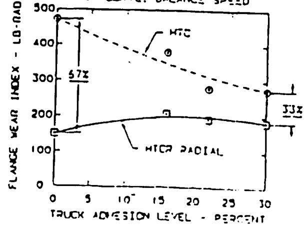


FIGURE 10

United States Patent [19]
Kumar et al.

[11] Patent Number: 4,781,121
[45] Date of Patent: Nov. 1, 1988

[54] SYSTEM FOR ENHANCING TRACTION AND ENERGY EFFICIENCY IN TRAINS

[76] Inventors: Sudhir Kumar; Shiv R. Kumar, both of 17 W. 434 Sutton Pl., Westmont, Ill. 60559

[21] Appl. No.: 30,719

[22] Filed: Mar. 25, 1987

[51] Int. Cl.⁴ B61F 19/00; B08B 1/02; B08B 3/02

[52] U.S. Cl. 104/279; 291/1; 15/256.5; 239/174

[58] Field of Search 104/279; 291/1, 2, 3; 239/173, 174

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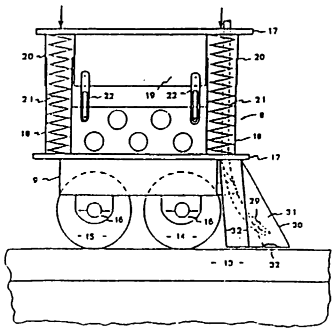
Primary Examiner—George L. Walton
Attorney, Agent, or Firm—Kinzer, Plyer, Dorn, McEachran & Jambor

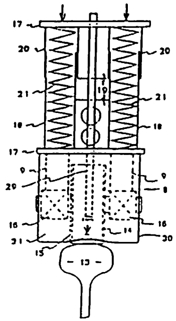
[57] ABSTRACT

A method and apparatus for enhancing traction capacity and energy efficiency of locomotives and powered cars while helping to maintain the crown of the rail profile for better ride quality of trains. This is achieved by utilizing beneficially the effects of lateral creepage of a number of small, hard nonpowered cleaning wheels with alternately opposite angles of attack. The apparatus may include deflector shields and hot air jets for cleaning and preparing the rail crown surface, when the apparatus is used in locomotives or cars. An arrangement for automatically adjusting the angle of attack of the cleaning wheels is also given. The degree of cleaning of the rails can be electrically controlled by the locomotive engineer as desired including shutting off the device altogether.

16 Claims, 9 Drawing Sheets

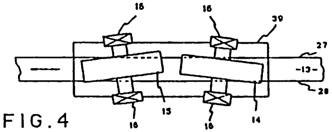


F I G. 2

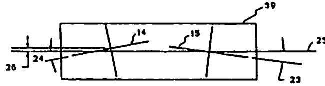


F I G. 3

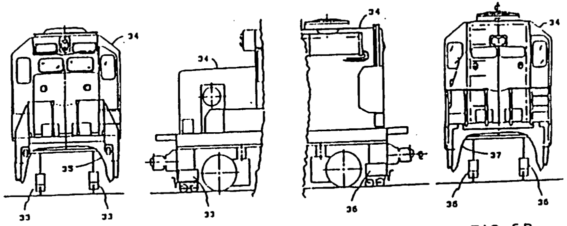
U.S. Patent Nov. 1, 1988 Sheet 3 of 9 4,781,121



F I G. 4

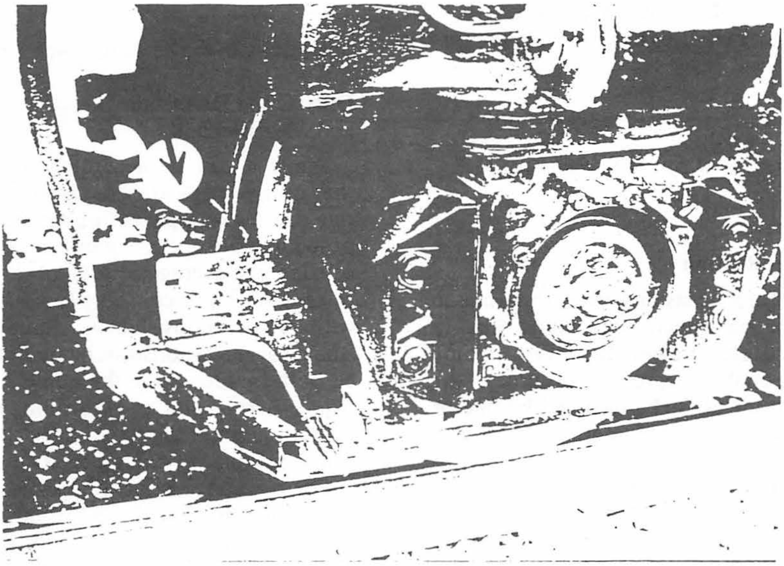


F I G. 5



F I G. 6A F I G. 6B F I G. 6C F I G. 6D

FIGURE 11



CNW C40-8 8542 L1 VHPF

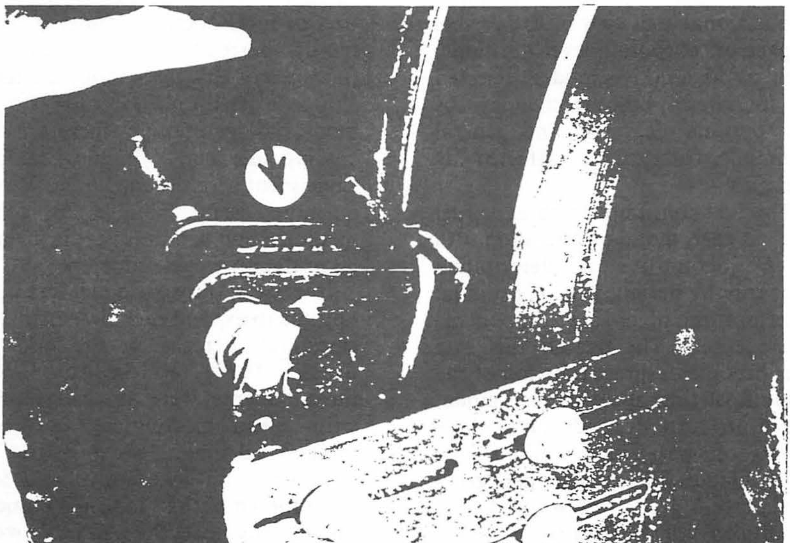


FIGURE 12

III. THE ROLE OF DUTY CYCLES IN LOCOMOTIVE FUEL CONSUMPTION

Presented by: R.S. Runyon, P.E.

Introduction

Many occasions arise from time to time on which one would like to predict, hopefully with some reasonable degree of accuracy, the amount of fuel consumed by one or more diesel locomotives during a specified period of time. The problem is complicated by the existence of eight selectable modes of operation under power, generally referred to as throttle positions, plus the non-powered modes of idle and dynamic braking, each of which can represent one or more distinct rates of fuel consumption.

The need for such information is unquestionable in view of its possible impact on corporate-level decisions, such as locomotive models selected for purchase, cost-effectiveness of any optional features, and general economic forecasts as affected by fuel cost.

The fuel consumption rate, or fuel rate, at each mode of operation of a given locomotive is determined primarily by design, if no substantial deterioration of engine components has occured. The overall fuel rate thus becomes a direct function of the amount of time spent in each mode, which in turn depends on a wide variety of operating conditions such as available horsepower per gross ton, percent grade, track speed, and conditions which require unpredictable stops or speed reductions enroute. Most of these conditions vary considerable throughout a given assignment, and some will vary among repeated and generally similar operations over the same track.

Duty Cycle Definition and Measurement

While it can be accurately stated that no two trips are exactly alike, if one can make repeated observations of locomotive operation over a series of trips, the average of such observations will tend to converge to a result with some consistency. Random statistical fluctations can be minimized both by increasing the number of trips observed and by controlling the operating conditions as necessary to achieve similarity among the trips.

For the above reasons, it is useful to measure the time that a locomotive spends in each throttle position, with such measurements to be accumulated over a length of time sufficient to smooth out the random variations. The result of such measurements, expressed for each throttle position as a percent or fraction of total operating time, is commonly referred to as a duty cycle. For purposes of this discussion, the term "throttle position" will apply to all modes of locomotive operation including idle and dynamic braking. Time spent with the engine shut down is more easily handled by other methods, and will thus not be included in the duty cycle time base.

Interest in duty cycle measurement appears to expand each time there is a sustantial increase in the cost of diesel fuel. Prior to 1980, measurements were typically made with electromechanical or electrochemical timers, which had to be installed on a locomotive and left there for a month or longer. Frequent inspections of the timers were necessary to protect against overflow or malfunction. More recently, locomotives have been introduced with ability to record and accumulate such information automatically,

eliminating the need to install special instrumentation for this purpose.

Depending on the conditions of measurement, a particular duty cycle may represent operation over an isolated segment of a railroad or an average of a much larger, perhaps systemwide operation. To minimize the amount of work involved, it is not uncommon to limit such measurements to a few local or regional jobs, thereby obtaining several representative duty cycles which can later be applied with some justification to other similar jobs. Examples of duty cycles obtained in this manner on Norfolk Southern are shown in Figure 13.

Application of Duty Cycle

Given a duty cycle, whether obtained by stipulation or actual measurement, one needs only the fuel rate at each throttle position, which is generally available from the locomotive manufacturer, to calculate the overall fuel rate. This is done simply by multiplying each individual fuel rate by the duty cycle component representing the fraction of time over which it applies, and adding the products, as illustrated in Figure 14. To the extent that the duty cycle is valid, this average fuel rate can be used to predict the total fuel consumption of a given locomotive over any specified period of time.

Quite often, however, the overall fuel rate is of little value without some measure of the work done by the locomotive. This is the case when comparing dissimilar locomotives for prospective use on a particular assignment; a locomotive that delivers more power will most likely consume fuel at a faster rate. In order to obtain a suitable figure of merit in this instance, one must also know the horsepower delivered in each throttle position. Referring again to Figure 14, the horsepower values can be multiplied by the respective duty cycle components and the results added to obtain average horsepower, as was done with the fuel rates. Only the powered throttle positions need be considered, as there will be no tractive power generated while in idle or dynamic braking.

Horsepower values for each throttle position are also generally available from the locomotive manufacturer, and frequently given in two forms: traction horsepower (THP), which is the mechanical power applied to the shaft of the main generator, and net traction horsepower (NTHP), which is the electrical power output at the generator terminals, or the rectified output if an alternator is used. The choice of which values to use is generally arbitrary, provided that consistency is maintained throughout.

A useful figure of merit, known as specific fuel consumption (SFC), is obtained by dividing the fuel rate by the corresponding horsepower delivered. The result, normally expressed in pounds or gallons per horsepower-hour, is an inverse indicator of locomotive fuel efficiency. Depending on whether traction horsepower or net traction horsepower is used, the resulting value will be traction specific fuel consumption (TSFC) or net traction specific fuel consumption (NTSFC). Such a figure is applicable to each of the eight powered throttle positions.

In most cases, only the average SFC as developed from a given duty cycle is important. It is obtained by dividing the average fuel rate by the average horsepower, both of which are determined from the duty cycle as previously described. The resulting duty cycle specific fuel consumption will be abreviated as DCTSFC or

DCNTSFC, depending on the choice of horsepower values.

It must be emphasized that a duty cycle SFC is inseparably tied to both a specific locomotive model and duty cycle, and is valid only for the operating conditions to which the duty cycle pertains.

Since 1976, locomotives have been equipped with two or more engine idle speeds, and more recently with multiple engine speeds during dynamic braking, the purpose in each case being to reduce fuel consumption during the non-powered modes. Most of the extra engine speeds are duplicates of those used in the powered throttle positions, the difference being the amount of load applied to the engine. Because a different fuel rate comes with each engine speed, the extra speeds are characteristic of additional distinct throttle positions in the duty cycle, and can be treated as such to determine the duty cycle fuel rate if the corresponding fractional time values are known.

However, the author prefers to limit the overall representation to the eight powered throttle positions plus one each for idle and dynamic braking, as shown in the examples already given. These are the primary modes of operation, being under direct control of the locomotive operator and trainlined throughout the consist. On the other hand, the engine speed selected for idle or dynamic braking is typically governed by non-trainlined parameters, and will also differ among the various locomotive models. To illustrate, one current locomotive model can operate at any of three engine speeds during dynamic braking, while another model has a choice of four speeds. A duty cycle that separately treats all dynamic braking modes of either locomotive would not directly apply to the other.

To accommodate situations of this sort, a secondary duty cycle can be defined for each locomotive in question, with the time spent at each dynamic braking speed expressed as a fraction of the total time spent just in dynamic braking. The individual fuel rates can then be multiplied by the corresponding fractions and the results added as described earlier, giving a single average fuel rate which can then be applied to the single dynamic braking component of the primary duty cycle. An example is shown in Figure 15, which shows also that multiple idle speeds can be combined in a similar fashion. While fuel rates so calculated remain dependent on a specific locomotive model, the primary duty cycle, composed of eight powered and two non-powered time components, does not.

Comparison of Two Locomotives

When comparing two locomotives of different models with respect to fuel consumption, there can be circumstances in which either one may perform more efficiently than the other, depending on the duty cycle selected for comparison. For instance, a locomotive might excel in throttle-8 efficiency and perform better in mainline drag service, but also be so encumbered with parasitic loads that it falls behind in a light mainline or switching operation. If the locomotives being compared have similar horsepower ratings, a valid duty cycle for the contemplated assignment will show which model, if either, is the more efficient.

A problem of a different sort arises if two locomotives having unequal horsepower ratings are compared as alternative choices for a given job, assuming no change in the tonnage handled. Using the same duty cycle for both will generally indicate that the higher powered locomotive burns more fuel in a given time than the other, not of itself detrimental as it also performs more work in the same time interval. However, if the comparison is made with trains of equal tonnage, the higher powered locomotive can work harder only by operating at faster track speeds and completing its assignment in less time.

While this might be the case if track speed is not otherwise limited by external factors, as a general condition the opposite should be expected. It follows that the higher powered locomotive must be operated at a smaller fraction of its rating, spending a smaller fraction of its time in the upper throttle positions, which contradicts the original application of a single duty cycle to both locomotives. Therefore, as a general rule, it is erroneous to compare unequally rated locomotives using the same duty cycle.

In the event that track speed is limited only by the horsepower available, it is conceivable that both locomotives could operate with the same duty cycle, which could then be used to calculate an SFC value for each. The results, while mathematically correct, may be misleading in that not all of the extra work done by the higher powered locomotive is useful. Friction and wind resistance become greater with increasing track speed, so a 50 percent improvement in horsepower might bring only a 20 to 30 percent reduction in time spent on the job. In a marginal situation, the locomotive having more power available might be more efficient and yet require more fuel to complete the assignment.

Duty Cycle Adjustment

In the general case, as explained above, one should expect a downward shift in the established duty cycle when replacing the locomotive with one rated at higher power. It would be out of the question to directly measure the modified duty cycle in advance of every contemplated increase of horsepower, although one is needed if fuel efficiency is to be predicted. To this end, the author proposes a method by which the downward shift can be estimated in advance with some validity.

The first task is to regard an established duty cycle as being composed of two additive time components -- a power-limted phase and a speed/distance-limited phase, the latter being governed by speed restrictions and other track conditions. Separation will be necessary because the two phases are affected differently by a change in locomotive horsepower. Only the total amount of time spent in each phase is of any consequence, despite their piecemeal occurrence in practice.

The foundation for what follows is that, by definition, all power-limited operation will occur at throttle position 8.

Returning for the moment to Figure 13, observe that time spent in the powered modes decreases somewhat steadily with increasing throttle position, through No. 7 in all three examples shown, and including No. 8 in the "yard" duty cycle. This is the expected result of operation limited by extraneous factors, which tend to be random in nature and apply throughout the range of available power. The "heavy" and "light" duty cycles both show extended time in throttle-8, and indication that more power could have been used had it been available.

The above suggests that the power-limited phase of operation can be approximately defined as the time spent in throttle-8 in excess of that predicted by extrapolation from the lower throttle positions. This leads directly to a method for separation of the two phases, as represented graphically in Figures 16 and 17 for the two examples just mentioned. The "yard" duty cycle apparently has no power-limited phase to separate, being essentially devoid of throttle-8 time -- not surprising for this type of service.

The next step is built on the assumption that the locomotive operator will run as fast as reasonably possible within assigned limits, which experience seems to confirm. This implies power-limited operation if not otherwise restricted. An increase in available horsepower under these conditions will lead to a faster track speed and shorter operating time although, as pointed out earlier, not necessarily in the same proportion. For example, a 10-mph drag service operation could practically double its speed with a twofold horsepower increase, whereas a 60-mph time freight might gain little more than 26 percent due to the predominance of wind resistance at high speeds.

The other phase of powered operation, in which speed limits and/or track conditions are the governing factors, must be given different treatment. The available horsepower is already more than sufficient for the job at hand, so any increase will merely translate a portion of the time in each throttle position to one or more lower positions. This effect is illustrated graphically in Figure 18, which also shows a reduction of the power-limited time as discussed above.

Due to the random nature of the variables that shape a duty cycle, the actual translation most likely distributes the time removed from each throttle position among two or more consecutive lower positions, the amounts and destinations being as needed to restore the original average horsepower for the speed/distance-limited phase. This criterion alone does not uniquely determine the modified duty cycle, but reasonable variations of the process, if consistently applied, will give results that are sufficiently accurate for the intended purpose.

Any reduction of time that was applied to the power-limited phase will have reduced the total duty cycle time, so the final step is to normalize; i.e., to multiply each time component by a constant to give a total of 100 percent. The result will serve as a reasonable estimate of the distorted duty cycle that comes from assigning a higher powered locomotive to a given job, and can be applied to the individual fuel rates and horsepower values of the substitute locomotive, by methods already discussed, to estimate the overall fuel rate and specific fuel consumption.

Conclusion

The foregoing discussion was deliberately kept on a general level, with emphasis placed more on underlying concepts than on specific examples. While the procedures and calculations involved are tedious, they lend themselves well to computer applications. The concept of duty cycle adjustment was introduced as a possible alternative to making a lengthy set of simulator runs or actual measurements in service, with the ultimate goal of obtaining the needed information more quickly and at lower cost.

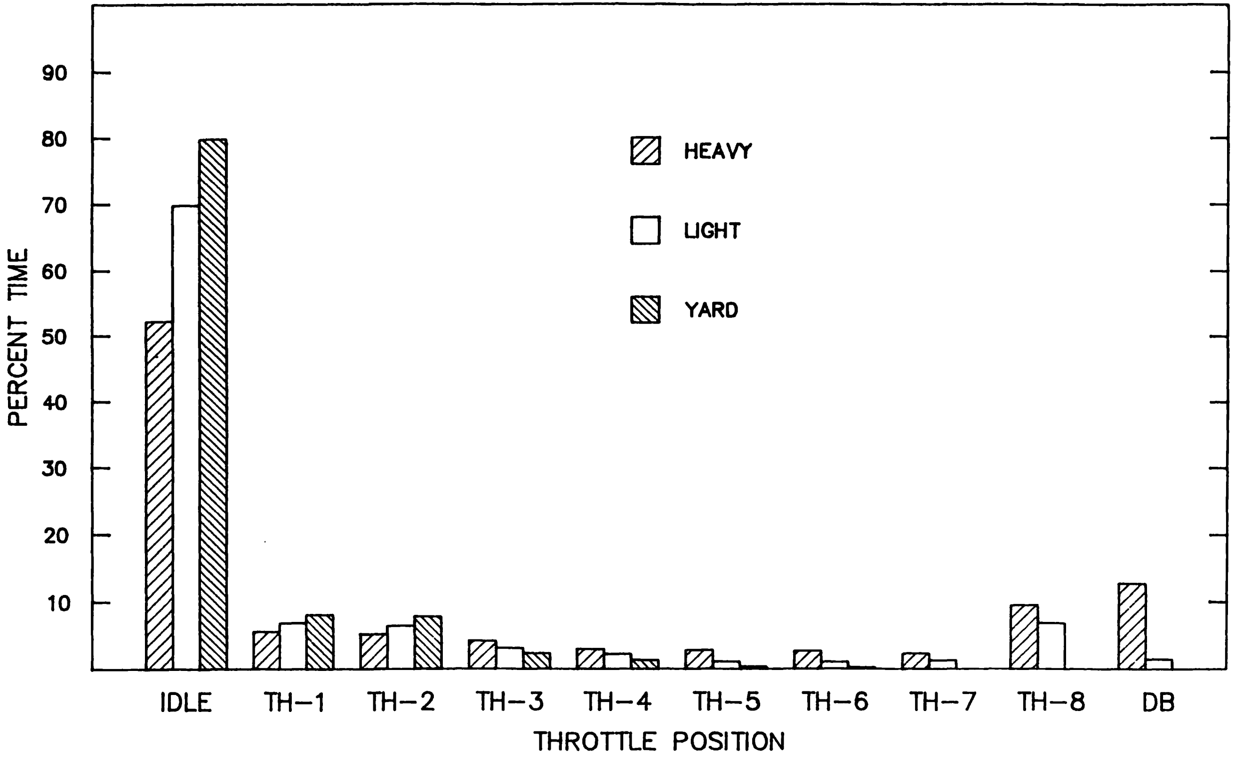


FIGURE 13 Examples of duty cycles measured in typical service

CLASS B23-7 LIGHT DUTY CYCLE

THR. POS'N	FUEL RATE (lb/hr)	POWER (HP)	SFC (lb /HP-hr)	------DUTY CYCLE------ % TIME	lb/hr	HP
IDLE	21.6	0		69.82	15.08	.0
1	50.3	82	.6134	6.85	3.45	5.6
2	110.2	233	.4730	6.44	7.10	15.0
3	227.2	493	.4609	3.05	6.93	15.0
4	354.5	829	.4276	2.19	7.76	18.2
5	499.9	1243	.4022	1.08	5.40	13.4
6	645.9	1673	.3861	1.02	6.59	17.1
7	721.6	1872	.3855	1.27	9.16	23.8
8	808.9	2122	.3812	6.83	55.25	144.9
DB	25.4	0		1.45	.37	.0
TOTALS				100.00	117.08	253.0

DUTY CYCLE SFC = .4628

FIGURE 14 Calculation of average fuel rate, horsepower, and SFC

CLASS D8-40C						HEAVY DUTY CYCLE
THR. POS'N	FUEL RATE (lb/hr)	POWER (HP)	PRI. DC % TIME	-SECONDARY DUTY CYCLE- % TIME	lb/hr	HP
DB1	29.0	0	6.28	49.45	14.34	0
DB2	49.2	0	2.42	19.06	9.38	0
DB3	72.5	0	.86	6.77	4.91	0
DB4	125.2	0	3.14	24.72	30.95	0
TOTALS			12.70	100.00	59.58	
HI IDLE	40.2	0	.00	.00	.00	0
IDLE	25.7	0	12.39	23.72	6.10	0
LO IDLE	17.6	0	39.85	76.28	13.42	0
TOTALS			52.24	100.00	19.52	

FIGURE 15 Calculation of fuel rate from secondary duty cycle in dynamic braking and idle modes

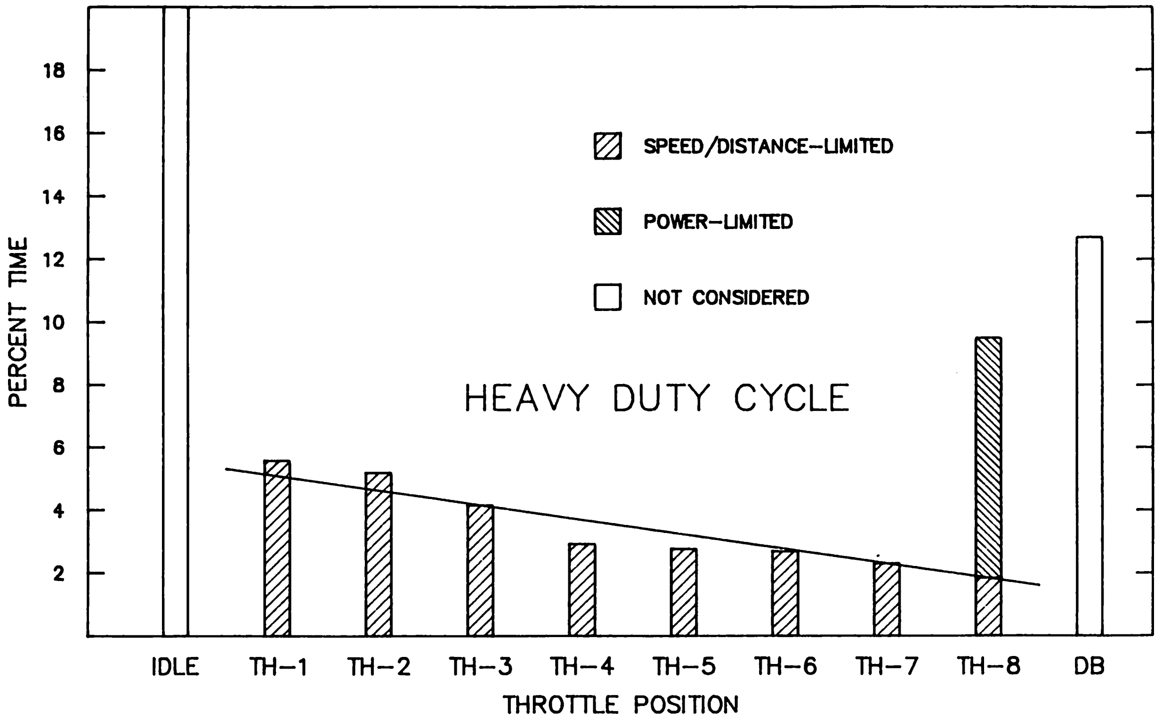


FIGURE 16 "Heavy" duty cycle identifying the separate phases of powered operation

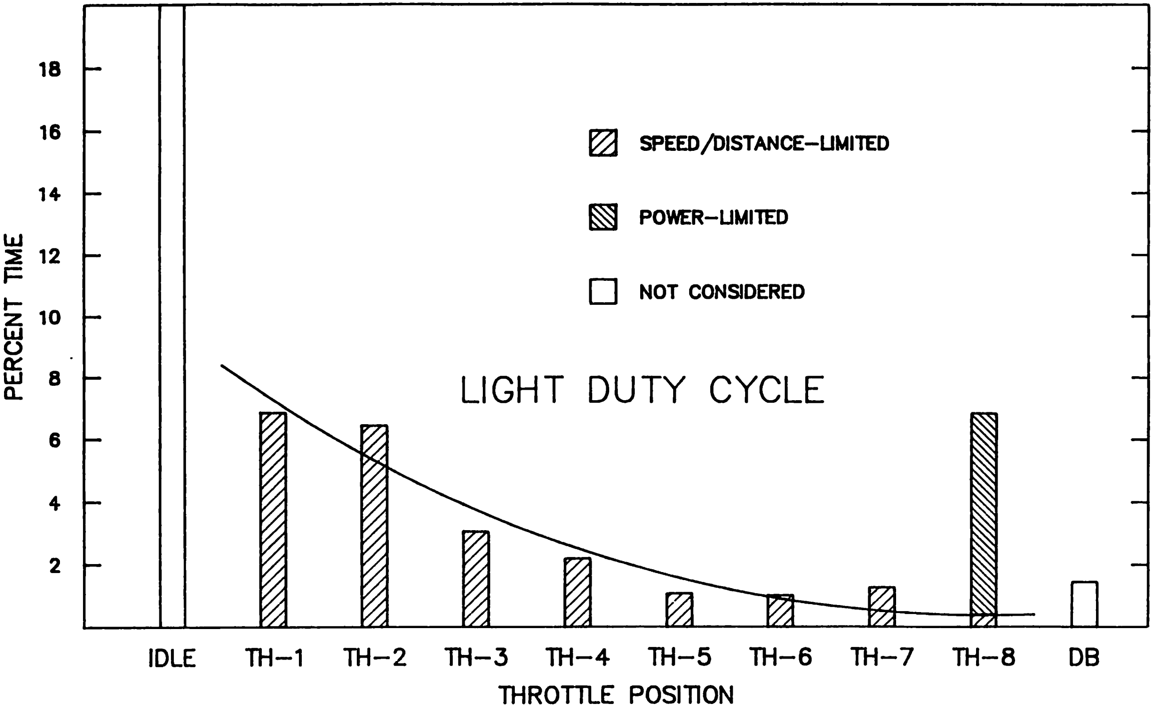


FIGURE 17 "Light" duty cycle identifying the separate phases of powered operation

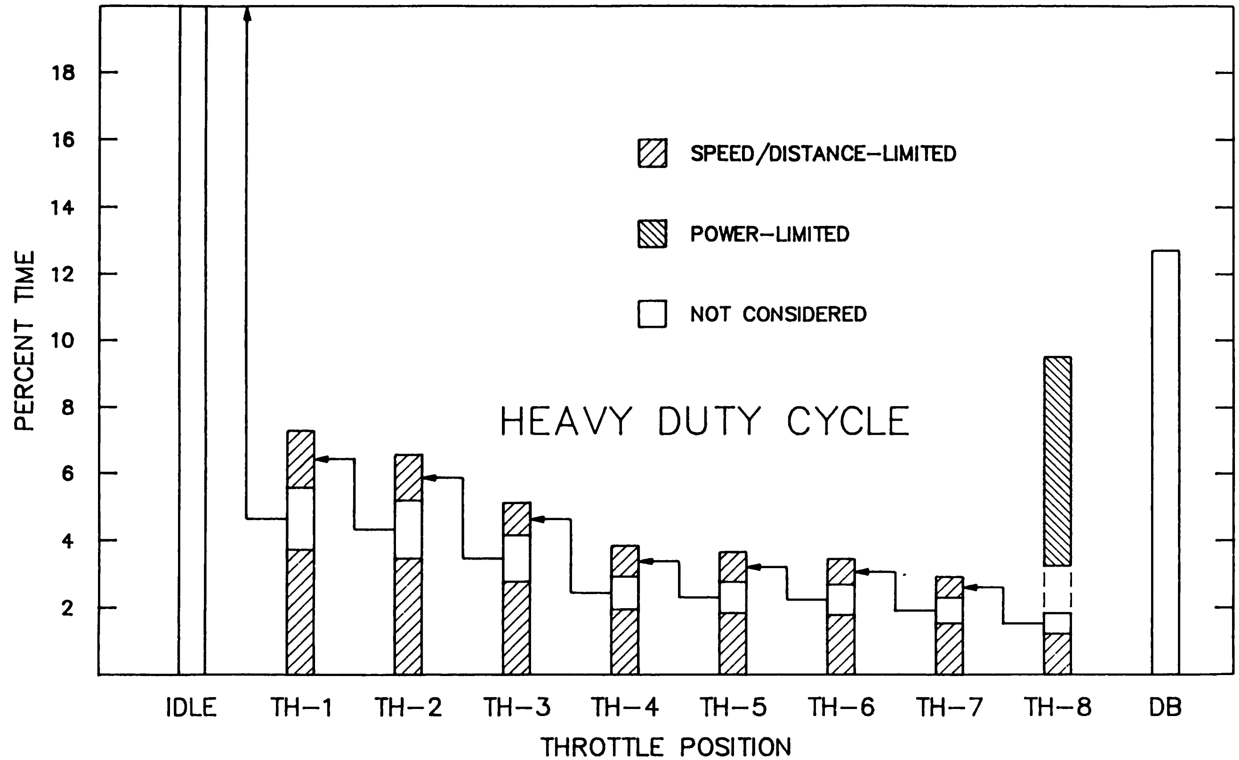


FIGURE 18 Downward shift applied to "heavy" duty cycle

IV. WHAT'S NEW IN GADGETS AND BLACK BOXES: WHAT DO OUR LOCOMOTIVES REALLY NEED?

Presented by: Blair Smith

During the early 1960s when semiconductors and transistors made their first appearance in the railroad industry, one of the first electronic gadgets was the solid state voltage regulator. The new regulator was offered by vendors to replace the troublesome mechanical auxiliary generator regulator on our early diesel locomotives. Applications were made on a few railroads, and after a brief debugging, most railroads retrofitted their fleets. One of the earlier mechanical gadgets offered for our diesel engines was the air operated engine bar-over tool. Air operated main bearing wrenches and finally hydraulic wrenches and tools appeared. Gadgets to direct and control the flow of engine cooling water to the radiators, new style engine air filters to replace the old carbody filters, all made their mark on locomotive improvements.

During the recent past we have seen more "black boxes" moving into the industry as a result of integrated circuits and microprocessors -- more static devices to replace mechanical devices. But the average fleet age on many of our railroads is over 13 years. What can we do to help them?

What do our locomotives really need? After all, they must be reliable! They must run and haul freight for 92 days without incidents or failures. If our railroads are to survive in a world-wide market place, we have to provide reliable service to our customers. Reliable service starts with reliable locomotives pulling the trains. Reliable locomotives start with reliable components and control systems, delivering required horsepower to the rail. Survival demands that locomotives be able to operate at maximum power -- even the older units.

Yes, our railroads need more gadgets and black boxes for our older fleets. But most important, they must be reliable, able to live in the most severe operating conditions. Following is a list of locomotive needs, black boxes and gadgets, many of which are now available, some of which are presently being tested, and still others which need to be addressed:

1. Now available

a. Brushless fuel transfer pump, turbo soak back pump and cab heater blower motors.

Various vendors presently offer brushless d-c motors for replacement of OEM motors. The pump motors consist of a power conversion device that converts the d-c input to a quasi-square wave a-c output and an input spike filter system that is built into the specially wound a-c motor.

The brushless blower motor employs a permanent magnet rotor and a four-phase, four-pole stator. Switching transients are used for electronic commutation. Transient suppression is also included as an integral part of the motor. Five-year maintenance-free continuous operation is claimed by some of the vendors. The General Motors Locomotive Group will introduce its version in the near future.

b. Engine cooling water freeze protection that is reliable.

Another vendor offers a new device that will dump the cooling water at approximately 34 deg F. This is done by a thermal plug that snaps out of the device, thus dumping the water. The plug may be reinserted after warming it up in your hand or pouring warm water over it; there are no electrical connections. The design also allows easy replacement of the thermal plug without dumping the water by using a check valve designed in the unit.

c. Improved exhaust manifold system for the 7FDL engines.

General Electric introduced a dual pipe exhaust manifold system in 1990 that improves performance, reliability and maintainability. Weld joints are eliminated; individual parts are smaller, lighter and easier to handle. Two mechanics can remove the old style manifold and install the new dual pipe in less than eight hours.

d. Traction motor gear case lube indicator.

General Electric has GE752AH traction motors with oil filled gear cases in service, running maintenance free for 92 days. The motor also features grease lubricated roller element axle bearings which operate without maintenance to wheel change. The General Motors Locomotive Group is currently running tests to confirm a 92-day maintenance period for oil lubricated axle and pinion gears.

Other good news is that a vendor now has a patent on a device that uses a vacuum tube probe to determine if the gear lube grease is below a predetermined level. The vacuum system is only activated if the locomotive has been at rest for a predetermined period of time, so the gear grease has time to settle. The monitor employs a minimal number of electrical devices and uses pneumatic logic where possible to insure trouble-free operation. The monitor eliminates the need for personnel to go under the locomotive and arbitrarily add bags of gear lube, thus generating substantial labor and material savings for many railroads.

e. Spin-on filters for GM 645 turbocharged engines.

One vendor currently offers a spin-on filter and adapter for the turbo lube oil filter and the turbo soak back filter. The modification will reduce oil spillage, save labor and reduce locomotive detention time for scheduled maintenance.

f. Improved efficiency of the turbo aftercoolers to increase air density in the engine air inlet manifold to improve fuel efficiency.

The GM group has incorporated a new four-pass air cooler in 710G3A diesel engine, and is currently analyzing retrofit opportunities for this design.

GE is evaluating the benefits vs costs.

g. Segmented flywheel starter gears that can be changed without alternator removal.

Segmented gears are now available from a vendor company and can be a significant labor saver.

h. Locomotive truck stability and safety improvements on older trucks.

GE and GM offer improved truck bolster stability by adding snubbers in a horizontal location as well as in the vertical. Relocation of the vertical snubbers on some truck models now allows use of wheel truing machines without removal of snubbers.

i. Getting rid of old style radiator cooling fan thermal switches, relays, interlocks and other failure-prone electromechanical devices and controls.

Several vendors offer a microprocessor based control system (black box) that senses cooling water temperature and other input signals and sends the necessary outputs to control the cooling fan contactor sequencing for optimum cooling efficiency. This eliminates many potential failure links in the chain. Application is usually on top of the existing contactor enclosure. This should improve MTBF and eliminate many costly engine failures.

GM is currently working on the development of solid state control and contactor improvements.

j. Auxiliary generator voltage regulator for older locomotives that were converted to low idle and electric heat. Keeping batteries at peak charge during winter months.

One vendor currently offers the CR-E voltage regulation system that provided a stable regulation at 74+/− 0.2 volts over the entire engine speed and auxiliary generator range. In addition, the stability of the regulator is not affected by the high temperatures found in many locomotive high voltage cabinets. Also, the vendor has avoided the use of certain components with know reliability problems.

GM recommends possible upgrade to the 18 kw generator. However, a sensed drop in battery voltage could increase engine speed or cut out some of the parasitic load until the battery voltage builds back up. Note that some of the cards fit the GM Dash 2 locomotives.

k. Improving safety of employees working on locomotives or cars in train yards or operating trains at road crossings.

One vendor offers a portable light that gives a blue flashing signal and can be carried in mechanics' tool boxes or trucks. The flashlight-sized light also has a magnetic base on one end for attachment to a car, locomotive or rail.

Several vendors now offer an automatic horn sequencer. Several railroads are using this device to ensure proper horn sequencing by their engineers. The same vendors will supply locomotive strobe lights to improve locomotive visibility at crossings.

A vendor sign company also supplies a highly reflective tape called "Diamond Reflective Tape" that will reflect light at various angles of approach for application to locomotives and car sides to improve train visibility at crossings.

Some railroads are using TV camera systems to record automobile plate numbers of crossing violators, while other railroads are taking law enforcement officers on locomotive rides to witness violations.

The builders have designed table top controls for their new locomotives that improve visibility for the train crew. An air brake supplier has also designed a table tap control in conjunction with its computer controlled electric air brakes and engine speed control that positions the engineer similarly to the clean cab controls.

Some railroads are installing hand holes in locomotives shaft covers for greasing, thus eliminating having to remove the covers, which are very cumbersome to install.

l. Diesel fuel tank gauge that transmits the fuel situation to the operator or external information system.

Running out of fuel not only causes delays but also damages the engine fuel injection equipment. Several vendors now have a monitoring system that transmits the fuel situation to the engineer; it has been used on some railroads that run slugs. Fuel is also being transferred from the trailing slugs to the mother on these units. No information is being sent out to an external information system, however.

The builders are actively developing a remote fuel monitoring device as part of their integrated cab electronics work. Transmission of this information to an external information system would be a natural development from this design.

m. Traction motor overload detection and correction device.

The current GM 60 Series

microprocessor can track and record traction motor overload based on motor temperature. The capability exists of using this information to provide automatic motor protection if the customers want it.

The Dash 8 locomotive microprocessor based system models motor temperatures based on measured values of current and time and takes protective action as required. Also available is the 17FL245 motor thermal protector (MTP) panel for retrofit to the builder's Dash 7 and Super 7 locomotives. The MTP panel calculates motor temperatures. When the pre-selected temperature limit is exceeded, a current limit output signal to the horsepower excitation control (CHEC) system limits the traction motor current.

One vendor also has a motor protection system that looks at the traction motor currents and short time ratings and makes corrections, or it could send an alarm message to the operator.

n. Microprocessor speed control systems.

General Electric has developed a microprocessor-based slow speed control as part of the integrated function control and display (IFC&D) system. It is currently undergoing field tests.

General Motors is working on incorporating the speed control into its microprocessor control system and expects to have it available in the marketplace soon.

A "dial in your speed" device may be helpful to engineers.

o. Reliable ten-event speed recorders.

GE includes the crash-hardened permanent core memory (PCM) plus a choice of customized recording devices (CRD) as part of the IFC&D system.

GM is working on reliable electronic speed recording as part of its integrated cab electronics program.

p. Draining oil out of exhaust stacks on souping engines. Stopping runaway turbos.

One supplier offers a new head seat ring that helps stop souping oil by taking the rubber seal from its customary on-the-rim position and locking it into the ring. The Durogard seal protects from rollout and rubber separation.

GM also offers a new Viton head seat ring that will help reduce oil leaking into the engine exhaust system. However, souping will still occur during long layovers or light yard service. When the locomotive is returned to regular service, raw oil will blow out of the stack.

q. Improved conditioning of the air supply to the brake system.

A filter supplier offers a conditioning filter commonly referred to as the "twin towers". It is in use by numerous railroads as a retrofit item on older locomotives. Instead of just filtering the air, this new device will also dry the air.

r. Equipment kit for hydrostatic testing of engine water cooling systems.

A cooling system test kit (GE part #41A313022G1) is offered with a fill-neck test fixture and an air pressure regulator. The fixture replaces the cooling system fill cap with a spring loaded positive sealing fitting. To test, the system is pressurized to 20 psi and checked for leaks. The regulator includes a pressure device that prevents the system for being over-pressurized. The test kit can also be used on GM locomotives.

s. A way to remove leaves and debris collected on GE cooling fan room screens.

The Dash 8 locomotives includes the capability of reversing the direction of the cooling fan, thus blowing debris clear of the screens.

2. Being tested

a. Device to detect journal and support bearing failures before derailments can occur.

A new bolt for car and locomotive journal bearings called the "Smart Bolt" is now being tested by some railroads. The bolt has a battery-powered transmitter housed inside of the end of a bolt by a compound that melts at a pre-determined temperature, thus allowing the transmitter to move out of the bolt end and transmit a radio signal that the engineer picks up on a signal receiver.

A supplier offers a "hot bearing simulator" that is installed on a track geometry car to check the calibration and operation of the hot box detectors presently installed on most railroads.

b. Simpler and more reliable wheel flange lube systems.

The GM Group is presently working with a company to develop a stick lubricator (embedded in plastic) that will get the lubricant onto the rail gauge face with little or no migration to the rest of the rail, thus maintaining good wheel/rail adhesion.

GE is evaluating the dry type flange lubricator systems. An adhesion stick is also being tested for application to the wheel tread.

c. Computer controlled electronic air brake system.

New York Air Brake Co. has tested an electronic air brake system and valve on a converted CSXT GE locomotive, which also has engine speed control and a table top control station.

GM is currently testing WABCO electronic air brakes in two units on different railroads. Several additional units are scheduled for production this year, and development work is underway with NYAB as well.

d. Quick Removal Plugs for cleaning and unplugging locomotives sand traps.

Expandable rubber plugs are currently being tested to replace the threaded pipe plug in the bottom of the sand trap. The quick removal feature will save labor and locomotive detention time.

3. Need to address

a. Device on sand tanks to indicate sand level and signal when full.

Excessive wheel slip can be very detrimental to equipment as well as to train operations. Presently, the only way we know how much sand is in the sand boxes is to climb on top of the locomotive and look into the box. With increased fuel capacity, the trend is to bypass fueling stations until fuel is actually required. In many cases, train operation suffers from our not knowing the sand situation. This information needs to be made available to Operations and included in the formula for good train operations. Again, the data could be relayed to an external data file or computer.

b. Maintenance free window wiper motors.

EMD has reviewed several electric wiper motor alternatives, but has found them cost prohibitive due to low volume. EMD currently offers the HP 100 pneumatic motor with a self-park feature.

c. Electronic governor to be retrofitted to older locomotives.

Builders see no fuel savings from using an electronic governor. Woodward, however, offers an electronic governor with its locomotive microprocessor package, and claims fuel savings with the package. An electronic governor to replace the PG governor would bring a maintenance saving.

d. Exhaust emissions monitor.

Such a device to control the fuel/air mixture for cleanest burn would also save fuel. The builders have no emissions feedback system to offer at this time. However, such a system could be used as a maintenance tool to indicate defective injectors, plugged air filters, etc.

e. An engine air intake filter that is self-cleaning.

EMD has active design programs to evaluate self-cleaning air filters and has made limited applications of its designs. An inverted group of bag filters that will collapse and dump out dirt when the engine is shut down may have some possibilities. A self-cleaning engine air filter would generate large material savings for the railroads.

f. Engine lube oil for GE locomotives that will last longer than six months, or on-board systems that can treat the oil for extended life.

This item should be considered mainly for GE FDL engines that have a short engine lube oil life. A new piston ring configuration, which extends lube oil change periods with Generation 4 Plus oil to six months or more is available; however, longer oil life is desired. Vendors should look into an on-board treatment system and additive system.

g. Antifreeze engine cooling systems and lube oil heating for locomotive shutdown in consist.

Excessive power in a consist is shut down by the crew in summer months to conserve fuel oil. However, this cannot be done in the winter months.

EMD has active programs to evaluate remote engine shutdown and freeze protection, and would respond to any customer specifications of these features.

h. Ways to use heat energy generated by engine exhaust and dynamic brake grids.

EMD has used dynamic braking energy of F69AC locomotives for head-end power for passenger service. However, fuel oil is being heated in winter months using engine water heat exchangers, cabs are heated with electric power, etc.

i. Tools and manipulators to reduce employee back injuries.

The locomotive builders are using ergonomics in their designs of cabs; but they should keep in mind the mechanics that must maintain the locomotives. Special tools and manipulators are needed to remove and apply water pumps, air brake control valves, engine lube oil coolers, etc., that comply with PRO back guide lines to reduce back injuries suffered by railroad mechanics. Fire extinguisher brackets should be located at a height to prevent bending over to pick up; engine water fill caps should be at more convenient locations and heights, etc. Many railroads are now applying tool balancers on load box cables, fueling nozzles and heavy shop tools and impact wrenches. Back injuries are costing North American railroads millions of dollars every year.

j. Electronic muffler technology to reduce engine sound emissions and back pressure on engine exhaust system

One builder is working on an improved "conventional" muffler design that will be tested in 1991 on its FDL engines. However, electronic sound wave generation to counter engine generated sound waves should be addressed by our vendors and builders. Load boxing locomotives could be a good location for such technology.

k. Three-axle, self-steering truck.

GM's steering truck committee is presently conducting truck dynamic tests on the new design.

In conclusion, as most of us have seen in the recent past, there have been many changes and improvements in the ergonomics for the train crews inside the locomotive cabs: safety glazing, sound improvements, wide cab design, crash protection improvements, HVAC systems...and the list goes on and on.

But what about the ergonomic design of the locomotives for the people who service, maintain and repair them? We ask the builders and vendors to design their equipment to be more "user friendly" for our mechanics -- to apply pro back principles in their designs. We still have mechanics climbing on the tops of locomotives to look into sand boxes to see how much sand is in them, and mechanics spending excessive time changing out sand trap pipe and unplugging sanders. Millions of dollars are lost each year by our railroads because of back injuries alone, not to mention the pain and suffering of our injured.

In addition, we ask our railway and government leaders to work together to eliminate the road crossings on our core lines to save thousands of injuries, hundreds of deaths and millions of dollars in equipment and property damage. The number of road crossings should be reduced, and the remaining ones should either go over or under the railroad.

Further, we as railroaders, builders and vendors must work together as a team to keep our customers satisfied. All of us must do a quality job by doing it right the first time, every time, with a willingness to innovate and make changes in well-planned ways. We also need to display a sense of urgency for action and problem solving. We are all partners in the transportation business with a common goal -- the satisfaction of our customers.

V. FAILURE ANALYSIS

Presented by: Richard Mackowiak

Unquestionably, there is a need for a comprehensive means of determining ways to improve component life. In studies of human mortality, there is no question of the moment of death of an individual; however to extend life, one must analyze the separate component parts. Similarly, in the types of mortality studies of physical property made in connection with the requirements of depreciation accounting the moment of retirement of, say, a cross tie, or section of rail would be evident to anyone who observed it being removed from service. This study of life testing and analysis is today referred to as reliability engineering and was first expressed during the Second World War when the military established standards for the development, qualification, and procurement of vacuum tubes.

Because of the high costs of failure, reliability studies have become more important. Take for example the capital investment in a locomotive which has dramatically increased in recent years. This higher cost has led to more efficient use of that locomotive. With fewer locomotives on trains, there is a greater dependency on the horsepower developed by each. Even a component part failure on a locomotive that only causes partial loss of effective horsepower causes delays and breakdown of schedules that in turn costs the industry a great deal of money. The value of failure analysis lies in reducing failures by determining the service life of a component, then following up with preventive maintenance, service, or replacement of the component prior to an in-service failure. With very few exceptions,. the in-service failures always cost more overall than a preventive maintenance program taht includes some form of failure analysis.

The most important aspect of any type or form of failure analysis is the collection of reliable and useful data. Most causes of failures are classified as functional factors, environmental factors, or time factors. Where the life of a manufactured product is tested for the purpose of acceptance inspection, the moment of termination of life may not be evident to a superficial observer. Elaborate test apparatus may be required to find the exact moment at which the performance of the product ceases to be satisfactory. Specifications on what constitutes satisfactory performance naturally depend on the use to which the product is to be put. For example, a particular roller bearing might have a short life under one set of specifications and a long life under another set. Too often the failure of a component part is the result of other factors not immediately obvious.

Whether a complex system like a locomotive, a subsystem like the battery charging circuit of the locomotive, or a single component like a connector between a wire and the battery, there exists a common set of assumptions about failure rate as a function of time under constant environmental operating conditions. This relationship between usage time and failure rate can be graphically represented by the "bathtub" curve. In this chart failures are plotted in relation to the usage time. The resulting curve divided into sections represents the equipment or component life periods. The first period represents early failure or infant mortality caused primarily by misdesign, processing error, quality control, or rough handling. The second period represents chance failure or useful life and is caused primarily by er-

roneous operation with routine maintenance and corrective operation being required in such cases. The third period represents wear-out failure where maintenance costs are extrememly high and replacement is generally required. Reliability engineers and analysts have a wide variety of complex formulas and other tools available for the purpose of data analysis and prediction. These tools include the "fishbone" or cause-and-effect diagram, the Pareto analysis chart, the frequency table, the histogram, the normal, log normal and exponential distributions, and the Weibull distribution (hazard plots). The Weibull distribution of probability is widely used throughout the manufacturing industry worldwide, including both North American locomotive manufacturers. It is an excellent technique for analyzing failures to determine an acceptable level of field failures.

Until recently, railroads have not played an active role in reliability analysis, partly because these studies were mainly used by manufactures, but mostly because this field is relatively new compared to the age of the railroads. In order to remain competitive today, all industries, including railroads, are making efforts to increase labor productivity, elevate the quality of services, and improve the working environment. One example is the Association of American Railroads, which has made numerous studies of the life cycles of components on rolling stock.

Locomotives operate in the harshest environment of any industry and the role of maintenance management has become more and more challenging. This is evident from the fact that a locomotive failure today has a far greater impact than it would have had, say, ten years ago. Thus, failure analysis has become a critical tool in modern maintenance management. It must be noted, however, that there is no hard and fast formula for failure analysis because of operational and environmental differences.

The most widely used source of failure analysis information is the locomotive manufacturer. The industry depends on the manufacturer as a source of service and maintenance instructions which were derived through failure analysis. Manufacturers constantly test the component parts that make up their product. They then make improvements based on this analysis and pass the information to the user, thereby making a more reliable piece of equipment and always striving to stay ahead of the competition.

In most cases, the aftermarket producer does not incorporate large testing facilities with elaborate failure analysis. The failure analysis, if it is to be completed, is left up to the individual railroad, and most railroads do not have the expertise, resources, and background for an effective failure analysis program. Although the locomotive manufacturers are not really pleased with aftermarket sources, they are always willing to help the railroads establish useful failure analysis. It aids the manufacturers in producing a better product, and helps the railroads by reducing costly locomotive failures.

WHAT'S YOUR PROBLEM PANEL

September 18, 1991

Allen Keller: We'll get started with the "What's Your Problem" session. I'd like to call on our Second Vice President, Mark Coles, who is going to Chair this session. Mark will introduce the members that are going to field questions. Mark

Mark Coles: Thank you, Allen. This will be the first time I've ever done this. We're going to wing it a bit and see if we can get through this thing successfully.

I've been coming to the LMOA "What's Your Problem Panel" sessions for quite a few years now. I've seen good ones and bad ones. So we're going to do things a little different this time. The first thing I'm going to do is introduce the people that are up here and then I'm going to tell you a little bit about how we're going to run this session.

This year, I have representatives from EMD and GE on the panel, and I'd like to introduce them. Ralph Robinson from EMD and Tom Hovious from General Electric. We also have representatives from the different technical committees. Ron Lodowski, Conrail, from the Fuel & Lube, Committee; Mike Pennell, Burlington Northern, from the Diesel Material Committee; Doug Corbin, Norfolk Southern, representing the Diesel Mechanical Committee; Mike Iden, C&NW, from the New Developments Committee; and Tom Leary, Union Pacific, who will represent the Diesel Electrical Committee.

As I said, the "What's Your Problem Panel" has been many different things. I don't want to restrict it to being just what's your problem. It can also be, What's Your Idea? As I said, we are going to do things a little bit different this year. I've asked Ralph Robinson and Tom Hovious them to take a few minutes and talk a little about their views of some of the problems we've seen in the industry, not just with new locomotives, but with old locomotives, also. And also to talk a little bit about what I consider a very important part of what both companies are doing in the areas of reliability in the development of new components and changes to the locomotives.

A lot of the effort is not visible to a lot of people. It's very visible to those of us on the railroads who deal, on a daily basis, with both companies. I'm going to open first with Ralph Robinson from EMD to make some comments regarding what's your problem, what's your idea and what some of the solutions might be. Ralph?

GM PRESENTATION

Ralph Robinson: Thank you, Mark. I want to thank all those involved with organizing this session for inviting direct GM participaton and say that I fully support the intent of this organization in having a forum where members can ask questions about issues that are important to them. There have been some problems in the past and I am hopeful that this attempt to have direct locomotive manufacturer participation will work out very well. EMD has been a supplier for years to the railway industry and as such we have the opportunity to see various railway operations, and the different ways that locomotives are used in a variety of services. Although our view as a vendor isn't necessarily the same as our customers, our perspectives hopefully are not as for apart now as maybe once they were. In recent years much better cooperation has been established and this importance of working together has become increasingly understood. In preparing for this session I thought one of the best things I could do today was to make some comments relative to my observations of the industry and what we as a vendor can do to support improved locomotive performance on the railways.

In the past number of years, as you all know, the industry has become very competitive. It has affected everyone. The bottom lines of mechanical operations have been trimmed, staffs have been trimmed and budgets have been trimmed. Often these cuts effect the railways' ability to maintain locomotives and the ability of the locomotive to perform reliably.

That's been common across the board. Big roads, small roads, everywhere. We've had our share of problems as well, with cutbacks, trimming and looking after our own issues as a manufacturer. From a Locomotive, Service Department point of view there are really two general areas of concern and activity as we view the effects of industry changes on locomotive maintenance and our roll as a manufacturer.

The first area of concern and activity is reinvestigating things that we learned a long time ago on a given railroad. Relearning what proper maintenance involves and the service limitations of given components or parts.

Some of this relearning is the result of the cutbacks. We end up with fewer people on the roads to maintain locomotives and some of the skilled people and skilled trades that you depended upon years ago are no longer there.

As the result, basic skills in diagnosing problems on locomotives are missing. We see more and more problems, it seems these days, in identifying problems with locomotives; this is true of new power in particular because the technology isn't the same as the vast majority of the power in your fleets. So getting back to basics is very important and something that we often times stray away from because of the pressures of manpower and maintenance budgets. If you want to get the design reliability out of a locomotive; that is the reliability that was designed into it in the first place, it needs to be maintained appropriately, and if there is a problem, it has to be identified correctly.

We see, across the board, problems that don't get detected the first time the locomotive shows up in the shop. The reasons for this are lack of familiarity with the locomotive and training on the part of the maintenance organization that's dealing with the locomotive, and it's our fault, too, if the diagnostics we have in the locomotives are not as useable as they could be, and our training support to the railroads is not as effective as it could be. It's not just a maintenance issue, it's a vendor-manufacturer issue as well; clearly something best worked on jointly.

The basic troubleshooting of a locomotive is very important as are the basic skills necessary to change out a component correctly. Without these skills, when the unit goes out with a changed component, either from being detected as a result of a problem or a scheduled maintenance activity, we cannot depend on its not coming back unnecessarily.

Road failures are a signficant issue, and with reduced manpower and problems maintaining adequate skills in some areas, it shows up in road failures and unscheduled shoppings. Now is sounds like I'm focusing on only our customers faults and saying "shame on you." That's not the case. These are just general observations into the industry and some of the things that happened in the last few years.

Within EMD and in the vendor community, we share a tremendous responsibility and that's where the other major area of concern and service activity is involved; trying to identify genuine problems with the power that's out there and get those problems corrected. Whether they be design-related problems, of which we've had some in the past few years, or quality related -- we've had some of those as well.

The focus of our General Motors engineering activities really is on two principal issues when it comes to the maintenance and serviceability of the locomotive, these being reliability and durability. We have had very significant programs for a number of years, and they've been amplified because of the need and the focus of the industry on reliability and durability. Today, when we develop new components we put a lot of effort into trying to ensure that it works right when it gets to you.

On the quality side of it we must insure that the component is manufactured in a way that will serve its intended purpose. In both of those areas (design and manufacturing) our ability to work with our customer and our customer's willingness to work openly with us is crucial. The problems that we've had couldn't have been solved without working closely with the operators that are experiencing problems in the field.

Unfortunately, a lot of the solutions end up being modifications. If there were a magic wand to wave, I'd love to have it to reduce the number of modifications, but I would expect another modification would be needed for the magic wand.

Overall, we have a tremendous focus on the quality and the reliability of the components and the overall systems that are in the locomotive. As we view the industry, there is an increased need for more reliability in the power, and the railway industry is having a more and more difficult time supporting technology changes with the skills that they have. We are getting back to basics and encourage the roads to get back to basics with their maintenance. Reliability stems from well designed and manufactured components being maintained properly and an ability to track problems and identify the root causes for problems.

The only way we can do it is to work together. And with that, I think the best opportunity here is for you folks to ask the questions, so I'm going to pass the mike on with that. Thank You.

Mark Coles: Thank you, Ralph. I'm going to have Tom Hovious of GE speak next, and, then we will open it up for questions and, again, I very much hope that you do have some questions that will challenge the people that are up here. Again, if it's not a question, maybe there's an idea or suggestion. So with that, I'll ask Tom to come up.

Tom Hovious: Have there been any jokes told at all during this session? No. I can tell already. Well, I'm not going to tell you a joke, but I'll tell you something. I've never been to this session before, but it was variously described to me. Last night, I came in on the airplane with one of the fellows, and I was telling him that it's the first time I was here and I heard this kind of a rough session. It's sort of late in the session and you guys get mean.

We'll see how mean you get, but

the point was, that he said "Look, all you have to do is be honest." The only problem I had with that is he had this sort of elfish glee in his eye when he said it. So we'll see how it works out.

I'm going to use a couple of slides here in a minute, but there is one very common thread (and it's sort of good as one of the suppliers to get up and talk about it a little bit) and that's to say that there really is (at least in the supplier realm-and we heard it already from EMD) some common thread to what's good for the customer. Because what's good for the customer is good for us. I think the two issues are really clear. There was a running gun battle for quite a little time on something you might call raw performance. And it became very clear that a whole lot of costs were going into the maintenance and reliability and all of the operations that surround those two factors and for quite a long time it was getting secondary kind of attention, at least from us, to be very honest. And so we saw a lot of improvement in things like fuel efficiency and horsepower and tractive effort and a number of other sorts of raw performance items.

As a result of taking a fresh look and getting sort of kicked in the shins a few times at the right time from a few, very good guys in the railroads, we re-directed some of our efforts a couple of years ago toward an effort of reliability. And I would say reliability is sort of inextricably intertwined with maintenance. Not so much the theme of how you do maintenance but how we design for it. In 1990, we sort of gathered ourselves and pulled ourselves up by our bootstraps, and we took a look at some on-going programs that we had started about the 1988 time frame and really put some pressure on trying to finish those up.

In addition to that, we started some 75 sub-tasks of reliability improvements and those are in various stages (either complete or in production). They are now coming to fruition in terms of actually being able to measure the results or, in fact, they are new programs. You heard a couple of them this morning, which will just be cut in here during 1991.

I picked three areas to talk about that were sort of what I would call really big hitters in terms of major improvements to talk about. A little less in the sense of the specifics of these, but more in the sense of trying to focus on what it is we did and what tactics and techniques we used to try to get these improvements. The problem I had is that I went to a session last night and I got more questions than I knew how to answer. So we're going to intertwine a few things. We're not going to do this in the advertising sense, but more in the sense of what should you do.

We'll look a little bit at the traction motor. I want to talk a little bit about philosophy here. Oil filled gear cases and AH motors, I'm going to throw in, not because of a realiability issue (although there was substantial problem there) but from the standpoint of getting to a 92-day maintenance period, which is a big help for the railroads. And then finally a big issue that you heard a little bit about this morning in terms of the improvements in the exhaust manifold. We'll sort of add to that a little bit, but we'll try to stick to that theme.

The first thing we want to talk about is sort of an interesting one. Things change! And it's interesting when things change it makes for difficulties for you and for us. For a long time, we produced diesel electric locomotives. They operated in a certain vein. They operated within a certain vein. They operated within a certain periphery of application and when we started to try to combine high speed service with high tractive effort application, things came unglued.

There's lots of ways to solve problems and so what we had to do is attack this on a broad front. Many of you know about the flash-over problems that occur at high speeds and high tractive effort applications and there were only a couple of ways to do that if we were going to stick with the current configuration. So we applied what's called an external device for basically quenching the flashover, itself. That has been enormously successful, as many of you know. Sort of interesting - this is an external device - we talked about a new technology this morning. Here we are applying a new technology to overlay on an old one to try to overcome this issue. I've forgotten what the ratio of failure rate is in this very most severe application, but here is a sort of time line on what happened when we applied the modification in that area. You can see the failure rate build up of this very high demanding application (Fig. 1). So this is an example of where we did not really understand how to take the fundamental device and modify it in a way that got down to the acceptable level; so we had to apply some external technologies to fix it. You can see what the result here was when we did that. This is not all of what we call the GTO flash protection device, but there was in fact also some improvements in the application of the brush and brush holder. So there's a combinatorial effect here.

There was a question that came up last night. When are you guys going to get to 92-days? Well, we're now there. And that's not in the sense of advertising, but it is more in the sense of trying to explain that we are beginning, finally, I think, to understand that maintenance intervals are an important part of your life, everyday. And although they cannot directly relate necessarily to reliability, in the long term, they do. So some of these kinds of changes in the devices that we have that allow you to get to non-intermediate kinds of work effort that you have has got to help, because you can better apply your resources.

I don't know how many of you have ever had a problem with an exhaust manifold on a GE locomotive. Raise your hand. I don't believe that. Raise your hand. Okay, now see this is honesty coming out. That ought to be almost all of you. It was really a problem. We won't go into why but I really would like to deal more, not with the result here because the result has been really phenomenal, but with the approach. I mean the improvements go from just an unacceptable level of performance down to almost no failures. However, I really want to talk about the approach more than I do about the actual result, itself. The approach here had to be to design something in a very different way and what we're finding, in conjunction with the railroads, is that finally having listened to you folks, we then take that knowledge and apply it to the approach we use.

In this case, it happens to be a modular approach. I think you heard a little bit this morning about the fact that you take the welds away, you build in a modular form (everything is in the form of a casting) and then you simply bolt the whole thing together (Fig. 2). Well, you guys have been telling us that forever, I find out. So here, we're finally starting to listen to the customer a little bit. I hate to admit that, but sometimes you have to. It went into production at the end of last year. You saw a much better view of that in actual hardware. That's just the modular approach to the manifold itself.

This was not mentioned this morning, but seals in the cylinders are an absolute problem as you're well aware, particularly for GE units. We went to the welded head-to-liner but you still have an EPDM improvement in terms of the seal that we have remaining (Fig. 3).

Somebody asked me last night, "How come you guys are only dealing with new products?" Well, this is something that when you get unit exchange you get the improvement coming around, and so the whole fleet should come up to really a substantial improvement as we go forward.

I think we have to do a whole lot more of this because we're not going to get rid of those 20,000 locomotives you guys have got to work with everyday by buying a few hunderd new locomotives every year. Interestingly, you'll notice that the welded assembly went into production in 1988 and why in the world am I talking about in a new product or a gripe session? Well, it takes about that long to find out whether that was a good product or not. And we're just beginning to find that out.

Here's my last illustration. It's kind of funny. I have to put up a couple of slides here to get to what I really want to talk about in terms of the approach for reliability and improvement.

This happens to be a view graph of the engine load rate (Ed note: No figure in publication). It has nothing to do with the reliability, maybe, but what's built into it is the single helix pumps and the dual manifold that we just talked about and some fast software along with a new turbo.

Well, the combinatorial effect of that was to get a performance increase, but it turns out that the combination also substantially improves the reliability of that system on the locomotive.

So what we're finding is ways to sort of go away from the "let's focus only on performance" to let's get performance and reliability combinations.

So it's sort of a philosophical change in our approach. In addition, as environmental restrictions come into play, in terms of our operating emissions environment, maintaining the purity of the output of the locomotive is going to be a big deal, unless we actually look at the design and deal with it in such a way that you guys stay within the regulations without having to add a whole lot of maintenance to these items. This was one of the requirements for this particular change that we just talked about in terms of the new turbo and cams and single helix pumps and so on.

So, it flies a little far afield of what you think of as normal reliability, but in a very real sense, it gets at the issue of how much time it takes you to maintain things, where you have to maintain them and how you have to maintain them with what skills.

Okay, I'm just going to wrap it up here a little bit. I really used a couple of examples here and they in themselves are worth something in the sense of having attacked a couple of really key issues that we had in front of us in terms of realiability and they made a dramatic difference.

But it points up one thing. If I had to leave this group with any message from the vendor back to the railroad, it is that I guess we're finally listening. That's one. And two, you guys, whether you know it or not, have an enormous wealth of knowledge that helps us to understand what direction we have to go in. And we recognize that that direction really has to change.

We have some working partnerships with several of the railroads. There's no question in my mind that this has to extend to the whole base of all the railroads.

Because each one of you is a different experience, a different environment, you bring different skills and knowledge to bear on these issues.

And at least if we're willing to listen we know that particularly during the last two years, we have learned an enormous amount; that as suppliers, maybe we should have known, but we didn't.

And so, we're going to continue to try to push for these partnerships to try to gain things out of it that allow, to give us direction. Because for us, we recognize it's really paying off.

There is a limited resource that we have. I think that was mentioned a few minutes ago. You've really got to get at the right big hitters.

And to be very honest with you, we don't always know that, but you do.

So I would like to thank those that we have worked with and look forward to those that we're going to set up new partnerships with.

(APPLAUSE)

Mr. Coles: Thank you, Tom.

At this point, what I'd like to do is open it up for questions. There are microphones around, not very many and unfortunately, up front we don't have the portable mike we've had in the past.

If you have a question, please step up to the mike, state your name and your question and we'll do the best we'll do the best we can to try to answer it.

I invite any questions you may have that have been triggered by the comments that have been made already this morning.

Any questions that you may have regarding any of the papers that were given or any ideas. We welcome ideas on things that we might look into for future papers that the committees might dow

We have not received very much at all in the way of questions in the suggestion box, so I really do need to get some from the audience if you have some.

We will use what we do have if we need to, but at this time, I'd like to open it up and welcome anybody's questions or comments.

Mr. Steele: I'm Dick Steele with Peaker Services. My question is, with all the talk about quality these days, could this body or panel present more papers that would demonstrate numerically the improvement of our processes and services?

Mr. Corbin: Doug Corbin, Diesel Mechanical. The Diesel Mechanical Committee has picked that as a topic for their paper next year. Locomotive reliability and the tracking of such and how we're improving numberwise.

So, hopefully, that will be some good information for next year.

Mr. Coles: Thank you, Doug. Is that a good enough answer to start with? Okay. I know that the quality issues are extremely important.

On the Union-Pacific, we have major quality efforts underway, some of the vendors present may have already been exposed to our SWAT team that comes out and performs quality audits.

Although our Quality Auditor that comes with us might say that we're doing a quality audit, in reality we're doing an entire product audit.

The way we look at it is that if you

have a good quality system, then what you have is a method to be very consistent; that the product we get today and the product we tested is the same product we'll get tomorrow.

While the quality process, on its own, may show that you're consistent, it also may mean that you can consistently put out bad material, as well as consistently put out good material.

So just as important as the basic quality process itself is, are the specifications that you feed into that quality process.

Again, some of you may have been exposed to our teams looking at the different components. We're trying to build certification of our vendors and establish partnerships.

The result is that we get much better material and more reliable material, reduce our failures and reduce our cost; even if the parts, in some cases, may be more expensive.

The results of those audits are only a part of the decision-making process.

It's no longer just the cheapest or just the one that can supply the fastest, but all of the different factors taken together.

The quality effort is absolutely essential, in my mind, to our survival. And if we can't get our quality under control, and cut our cost of quality or cost of failure, then we're not going to be competitive.

So I'm glad to hear that the committee is going to be taking up that subject. I also had talked to Dick earlier and he has volunteered to supply quite a bit of input to the committee and I hope that you can make use of some of that input.

Are there any other questions from the floor? Anything that you've heard this morning that might ring a bell, trigger a question or anything that you've heard during any of the committee presentations?

Mr. Barry: Richard Barry with CSXT. The locomotive fuel tank, its location and construction is a particular concern to the people that work in the environmental area.

Its susceptible to rupture and puncture and with its increasing capacity of up to 5,000 gallons what we're finding is that we're getting more diesel oil released to the environment every time we have an incident.

You gentlemen may not be aware of the outfall or the impact on one of these incidents. For example, the National Response Center has to be notified and also the state.

Some states require that we install a water well at that location and monitor the ground water conditions each month for a period of time to ensure that the environment and the drinking water have not been impacted.

And that's not to mention the hazardous materials response cost, plus the cost of remediating the soil of the ground at that location.

Over the past several years, CSXT has experienced quite a few of these incidents and what we're interested in or at least I'm interested in the environmental area.

Is there something that can be done to improve the construction and the reliability of the locomotive fuel tank to ensure that it can be made more durable, I guess, less susceptible to impact and rupture and therefore can protect the company?

Because the costs are getting higher and the liability to the company is getting greater every time we have one of these incidents. And I think it's an area, if we don't get proactive and do something about this, then we'll be forced into it, as we have in other environmental issues. So I'd like to just kind of throw that out; plant the seed, as you will, as an issue that should be addressed. Thank you very much.

Mr. Robinson: That's a good topic and very timely because at the last CSX/EMD Service/Mechanical Department meeting held last month, that was one of the new topics, as raised by the CSX Mechanical Department. In that meeting, fuel loss, as you have presented the question, was expanded somewhat to include fuel spillage problems at the fueling station, where tanks are overfilled because of problems with fuel valves or manpower problems.

EMD has committed with CSX to look at the fuel tank application and what can or can't be done to help avoid the contamination problems that you cite.

There are things that can be done. The construction of the fuel tank is not a magical issue, and as an example some customers already receive locomotives with reinforced edges in fuel tanks to reduce or avoid some of the problems. This subject is an agenda item for our next meeting with the CSX and we're committed to an overall review of fuel and other contaminations by locomotives.

General Motors is taking a serious look at this in general and have activity with your road, in particular. Any outcome that makes general sense would of course be offered to all railways due to the industry wide nature of the concern. Thank you.

Mr. Hovious: I think it's a very timely question. I would just expand it, if you'll allow me for a minute.

The question, I think, dealt a great deal with the fuel tank itself, the potential for an accident.

However, the way GE views it is that this the beginning of a much longer view that deals, not only with things like oil spills, but the water and every other kind of service material.

It's clear that the locomotive is going to have to change character. That may require technology change. I'm not sure that simply taking the existing geometry of a fuel tank and either making it smaller or reinforcing it is necessarily the answer.

There are other technologies available. Many of you are probably aware of that, in aircraft and so on, which can probably be applied to some degree in this area.

But there is a whole other set of issues that are parallel to this dealing with every joint and pipe and fitting in the locomotive.

And the whole character of that infrastructure is going to have to change, it's pretty clear.

As we address this question with our friends at General Motors as well, I think you're going to see a change in the character of the locomotive; the way it's piped, the way it's distributed, its whole geometry and we may have to add some technology.

It's not an easy issue to deal with. If you think for a moment about simply trying to make a fuel tank so that it withstands a major accident, you come basically to the conclusion that it is essentially impossible to do that within the current geometry and within the current structure of the produce.

We're probably going to have to change the structure if we're really serious about this. And we are, as you are and as I'm sure General Motors is.

So I think you're going to see a combination of change of the way we physically pipe and distribute the locomotive and in fact we're going to have to apply some new technology, particularly in the fuel tank area.

Mr. Coles: Are there any further comments from the floor or questions from the floor regarding that subject?

I realize that normally the people in the audience are the ones that ask the questions, but I have one along the lines of the environmental area and would welcome any comments from either up here or from the audience.

We are looking very strongly at the cost involved in cleaning up spills and drippings, from locomotives, and we are under quite a bit of pressure to install sump drain retention tanks. While we are putting these tanks on the locomotives, we are concentrating on the switcher type locomotives (smaller type locomotives) which are the ones that tend to sit at outlying points and dirty up the ground where it's not cost effective to put in drip pans and pollution facilities.

One of the problems that we deal with (and I'm looking for suggestions wherever I can get them) is that during the cold weather, once the tank is full (depending on what it's full of - water, oil, a mixture of both, etc.) we're really wrestling with the problem of draining the tanks in a timely manor and also preventing damage due to freezing in cold weather conditions. Most of the railroads that have retention tanks on a locomotives are not exposed to 30 and 40 degrees below zero weather that we contend with in some our our operating areas. I'm looking for any suggestions or solutions that anybody might have with regard to first protecting the tanks from freeze damage and second being able to, in a timely manner, remove the contents of those tanks so as not to tie up our service and maintenance facilities? So if no one has any comments right now, I would welcome anything that anybody might suggest and get back to me at any time. Any comments on that? Okay, I'll leave that open.

We have just a couple of additional questions that were submitted to us. In the Diesel Mechanical Paper on fuel testing, reference was made to tests on the UP to verify the manufacturer's fuel consumption data on GE-8 and EMD SD-60 units. The question is, what were the results? Did they obtain results equal to or close to the manufacturer's claims? Are there any comments from the panel?

Mr. Hovious: I thought the question was going to deal with the Norfolk Southern test, but I understand it's the UP test. Really, there's been quite a bit done during the last year in terms of fuel testing. It's a very complex procedure. You heard a paper on it this morning that deals with trying to understand what the ramifications of it are. As I understand it, the railroads involved would like to keep the absolute results confidential to themselves and so I can really only speak about one in which I have numerical data, and that happens to be the Norfolk Southern test. I will simply say that the published data within the degree of accuracy that it could be measured was confirmed on the GE locomotive.

I think it's inappropriate for me to talk about EMD in terms of their results, but it is a very complex issue as was dealt with this morning. I will also, if you will allow me to, expand on that just a little bit. The fuel efficiency of the locomotive and its operating environment is very important and you know we've both worked very hard, I think to do that and we've put a lot of effort into it. I think we've found something last week, in a working session, that's equally important in this same area and there would probably be a lot of cheers if there were operating people here; and that is trying to find a better way to train operators so that their actual fuel usage through operation is improved. And that's a thrust that we're going to be working with during the next year.

Mr. Coles: Thank you, Tom. One comment I will make from the UP's point of view on this. When you start talking about fuel efficiency and compare vendor X against vendor Y or one railroad against another, one of the things you have to be very careful of is how well you run your test. We went through a lot of growing pains with this to make sure our instrumentation was correct. We're ordering new equipment. Our people that did the testing found a lot of things that can affect the outcome. In addition, we found that you'd better be very, very careful about how the locomotive is maintained or the adjustments that have been made before fuel testing. We ran some tests, got some strange results, did some looking and found out that some mistakes had been made in adjustments and settings. That's one of the reasons that none of the current information is going to be published.

The testing is improving each time we do it, we get a little bit better. As Tom says, the numbers tend to agree fairly closely with what's published by both builders.

One other question that was here. States, historically both OEMs appear to have had anti-wear hydraulic oil as their primary recommendation for air compressor oil. Current OEM publications appear to make turbine oils, i.e., rust and oxidation oils the primary recommendations. Will the OEMs comment on air compressor oil specifications?

Mr. Robinson: I can't provide a detailed technical answer personally, but we have some EMD folks in the audience that may well be able to comment on the specs of the compressor oil. Would one of the EMD folks want to volunteer for that? No? In short, the turbine oil EMD has specified for compressors is consistent with the compressor OEM manufacturer's recommendations and what has been found to work successfully in the locomotive. The turbine oil has been recommended for EMD locomotives for a number of years. It's not something new --some railways adhere to that, some railways don't. But the recommendations are consistent with those of the OEM manufacturer. GM does not manufacture the compressor itself.

Mr. Coles: Are there any other questions from the floor or comments regarding this matter? Do we have any representatives from the air compressor manufacturers that would like to comment on the question?

(NO RESPONSE)

It looks like kind of a dry day for questions. We're getting close to the end of the time, so I'd like to make a couple of comments and close it out.

We did change things a little bit today with presentations from both EMD and GE. I would welcome any comments you have as to the format. The "What's Your Problem Panel" has been a fixture for a long time on the LMOA and it tends to go the same way every year. Sometimes there are good questions and sometimes we don't generate a lot of questions. I would very much welcome any suggestions on how you feel that the "What's Your Problem" session should be conducted; whether it should be changed radically. We want to know the value of this session to you. It's very obvious that we have a very high percentage of suppliers represented here as compared to the number of railroad members and, of course, that's no surprise with what's been happening in the industry.

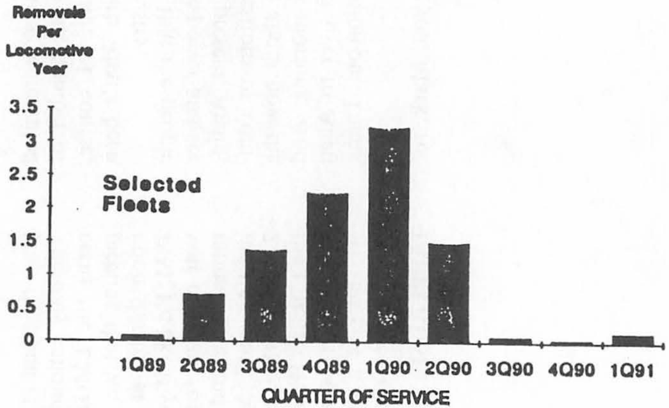
So it is very likely that the people who actually own the power and see the problems are not present. Again, I welcome any suggestions or comments you may have about how the session has gone this morning. And with that, I'll turn it over to Allen and we'll close the session out. Thank you.

Mr. Keller: Thank you, Mark, for your time and effort on this session. The only announcement I have concerns the LMOA Executive Board meeting that we will have this afternoon starting at approximately 1:30 P.M. I'd like if you'd all give a rising vote of thank for the panel's presentations here and I will adjourn the meeting until Monday, September 21, 1992, when we will reconvene at the Chicago Hilton and Towers. It is scheduled to be an exhibit year. So if we can give a rising vote of thanks now for the Committees.

(APPLAUSE)

Reliability Update

Traction Motor Removals Due to Flashovers



Status

- Design, testing, verification of following changes ;
  - GTO control mod
  - Reaction brush holders
  - T959 brush
  - Inconel bolts
- Production Incorportation - 1Q90
- Implementation of next phase changes
  - Version 3.08 software
  - Redesigned brush holders
  - New CP shim
- Production Incorporation - 2Q91

**Reliability Improvement =
3.5 F/ LYR For Most Severe Application**

Fig. 1

New Exhaust Manifold

Features

- Two pipe design with transition to turbo
- Single cast sections per cylinder
- Individual bellows between cylinders
- Joints clamped (not welded)
- 65% reduction in assembled parts
- Lighter weight parts
- Easy to maintain (20 min. c/o)
- Improves transient response
- Improves reliability

Status

- Production 4Q90

Fig. 2

Cylinder Shoulder Seal

Problem

- Water seal located between cylinder head and jacket
- Silicon, Viton material deteriorate with time

Solution

- EPDM (Ethylene Propylene Diene Monomer) has shown excellent life in this application
- EPDM material designed as hot water/steam seal
- Head/jacket gap increased to allow more coolant to seal

Status

- Production 1Q88

Fig. 3

FUEL AND LUBRICANTS COMMITTEE
TEN-YEAR INDEX

1990

1. The Responsibility of Railroads and Facility Managers in the Handling and Disposal of Hazardous Materials
2. Update on Diesel Fuel Regulations
3. Diesel Exhaust and Worker Exposure
4. Field Experience with Multigrade Railroad Locomotive Oils
5. Conrail Wheel/Rail Lubrication Update

1989

1. Field Test Data Follow-Up and Description of "Generation 5" Locomotive Crankcase Oil.
2. Diesel Emissions: Regulations and Fuel Quality.
3. Petroleum Storage Tank Regulations - Guest Speaker - George Kitchen, International Lube & Fuel Consultants.

1988
Theme: "Lubrication '88 — The Vital Link To Successful Railroading"

1. Used Oil Analysis and Condemning Limits.
2. Review of A.A.R. Procedure RP-503, "Locomotive Diesel Fuel Additive Evaluation Procedure."
3. Update on Improved Oils — Multigrade.
4. Wheel Flange Lubrication Update — Lubricants Being Used.
5. Survey of Disposable Practices for Locomotive Engine Lube Oil and Lube Oil Filters.
6. Speaker on Overview of Environmental Requirements for The Use of Petroleum Products in The Railroad Industry. — Peter Conlon-AAR

1987
Improved Products Through Technology

1. Common Fuel Additives and their Effectiveness.
2. History of LMOA Lubricating Oil Classification System.
3. Performance Requirements Needed by the Railroads for a New Generation Lube Oil.
4. How do we Provide the Performance Needed for a New Generation Oil.

1986
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.

NEW DEVELOPMENTS COMMITTEE
EIGHT-YEAR INDEX

DIESEL ELECTRICAL MAINTENANCE COMMITTEE
TEN-YEAR INDEX

1990

1. Moden Tooling of Electrical Troubleshooting
2. Maintaining Solid State Event Recorders
3. Why Can't We Have One Central Computer?
4. EPA and Regulation Driven Cleaning

1989

1. Modern Tooling for the Troubleshooting Electrician: a) test meters available (single function); b) test meters available (multiple functional); c) analysis and diagnostic tools.
2. Sound Electrical Repairs and Practices for: a) traction motors; b) grids and fans; c) wire and cable solderless termination.
3. Guidelines for Preparing Electricians for the 1990s.

1988

Theme: "Locomotive Data Acquisition and Its Relationship to Maintenance

1. Utilizing Magnetic Tape Event Recorders for Locomotive Maintenance.
2. Solid State Locomotive Data Recorder.
3. Improved Utilization of GE DASH 8 Data Recording Systems.
4. Locomotive Health Data and Its Uses To The Railroad.
5. Improved Data Acquisition From EMD'S 60 Series Display Computer.

1987

Maximizing Fuel Efficiency Through Quality Electrical Maintenance Program

1. Proper Maintenance of Electrical Fuel Saving Options.
2. Preliminary Report on AAR Traction Motor Study.

1986

Cleaning, Handling and Storage of Electrical Equipment

1. Solid State Components.
2. Rotating Equipment.

Qualification of Locomotive Power Plants Through Self Load

GE Load Test.
EMD SD40-2 Load Test.

1985

Innovations, Maintenance and Troubleshooting Locomotive Electrical Systems

1. Locomotive Microprocessor Technology in Retrospect.
2. Dynamic Brake Protective Devices and Trouble-Shooting EMD-2 and GE-7 Locomotives.
3. Indicators and Recorders for Locomotive Retrofit Application — Fuel, Speed, Power and Selected Events.

1984

Electrical Technology To Improve Performance

1. On-Board Diagnostics.
2. GE's CATS (Computer Aided Troubleshooting System).
3. Fuel Conservation Through Electrical Modifications.
4. Performance of Locomotives After Storage.

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.
3. Onboard Diagnostic Systems.
4. Starting Systems.

1981
Innovation: Past and Present Traction Motors

1. Evaluation of Improved Test Methods.
2. Teflon Bands.
3. New Generation Locomotives.
4. Electrical Troubleshooting.
5. Batteries and Charging Systems.
6. Troubleshooting EMD AC Auxiliary Generator System.
7. Selection of Locomotives for Major Locomotive Overhauls.

SHOP EQUIPMENT COMMITTEE
TEN-YEAR INDEX

1990

1. EMD Valve Bridge Machine
2. GE Traction Motor Roller Suspension Bearing Replacement Equipment and Procedure
3. Locomotive Component Replacement Forklift Attachment
4. Locomotive Sanding, Fueling and Drop Tables
5. Hazardous Waste Disposal

1989

1. Automated Locomotive Wheel Shop.
2. Laser Guided Material Handling Vehicles.
3. Bulk Rail Lubrication Storage & Fill System.
4. Pilot Plate Straightening Equipment.

1988

Theme: "Streamlined Systems for Locomotive Servicing"

1. Fuel Management Control Systems
2. Locomotive Mounted Rail Lubrication Fill Systems.
3. Comparison of Shop Air Compressors.
4. Locomotive Toilet Servicing Equipment.
5. Innovations in Blue Flag and Derail Protection.

1987

Productivity and Quality Improvement in Shop Facilities

1. Modern Servicing Facility for Improved Reliability and Availability.
2. New Developments in GE Tools.
3. Implementation of a Quality Process.
4. A Quality Traction Motor Shop.
5. Wheel Truing Machine Technology.

1986

Low Cost Through Quality Tools and Equipment

1. Robotics Update 1986 — Now What?
2. CNC Machine Tools.
3. A new GE Power Assembly Area.
4. Locomotive Wash System — 1986.

1985

Improved Methods of Maintenance Management and Material Movement

1. Computer-Assisted Preventative Maintenance.
3. New Tools for Material Handling and Overview of Balancing Technology.
3. Effect of Governmental Regulations on Locomotive Finishing.

1984

More Productivity At Lower Cost

1. Shop Tools.
   A. New Tools.
   B. Shop-Made Tools.
2. Traction Motor Shop Equipment Up-Date.
3. Hazardous Waste Handling and Disposal.

1983

Training and Tools Will Do The Job

1. Locomotive Maintenance Using a Production Line Process.
2. Shop Tools to Increase Productivity and Improve Quality.
3. Dynamic On-Line Performance of Locomotives Without On-Board Tele-Metering.
4. Management in Action.
5. New GE Training Center.
6. Welding Qualifications.

1982

Quality Maintenance Through Modern Tools

1. Tools.
2. Rebuild line for EMD turbochargers.
3. Air brake equipment line.
4. Industrial robots.
5. Automated machines.
6. Safety related items and equipment.

1981

1. Training Aids.
2. Testing Devices Inspired by New FRA Laws.
3. Tools and Training for Productivity.
4. Changes to Shop Facilities Required by Newly Adopted EPA & OSHA Regulations.
5. Tour Through Conrail Altoona Shop.
6. Supply/Service Facilities.
7. GE Assembly Shop.

DIESEL MECHANICAL MAINTENANCE COMMITTEE
TEN-YEAR INDEX

1990

1. Caterpillar Power in Remanufactured Locomotives
2. The EMD 710G3A Engine
3. Improving Performance of Traction Motor Friction Suspension Bearings
4. Fluid Leaks on GE 7FDL Engine
5. Rebuild of the EMD F3B Fuel Injector

1989

1. Wheel Axle Gear Wear/impact on Traction Motor Life.
2. 710 Engine - Operational and Overhaul Update.
3. GE Power Assembly Improvements on Welded Head-to-Liner Assembly Rework Procedures.
4. EMD Engine Oil Leaks.
5. Secondary Air Filtration - Barrier vs. Impingement.

1988

Theme: "Locomotive Mechanical Officers Developing Extended Maintenance Programs — The Vital Link."

1. Low-idle Operating Costs vs. Fuel Savings.
2. Rebuilding GE's EB Liner.
3. The Extended Maintenance Truck.
4. Flange Lubricator Update.
5. Permaspray II — Cylinder Liner.

1987

Managing Productivity and Quality For Cost Efficiency

1. EMD Water Pump Rebuilding.
2. On Board Flange Lubricators.
3. Gear Case, Bull Gear and Pinion Gear Longevity in the 1980's — Gear Cases — Canadian National Experience.
4. Maintenance of Locomotive Fueling Systems for a Spill Free Operation.

1986

1. Rebuild of Valve Bridge Assemblies.
2. Update of New Locomotive Service Problems, EMD and GE Effecting Quality Performance.
3. Chromium Plating and Its Uses.
4. Development of a New Diesel Engine for Heavy-Duty Locomotive Service.

1985

Maintaining Today's New Technology For Quality Performance

1. Procedures for Storing Serviceable Locomotives for Quality Performance.
2. New Locomotive Service Problems, EMD and GE.
3. 92 Day Service Requirements: EMD, GE and Bombardier.

1984

Will Today's New Technology Simplify Tomorrow's Maintenance?

1. Mechanical Aspects of New Locomotive Designs.
2. Maintenance of Locomotive Components.

1983
Cost Control and Extended Service Through Improved Maintenance

1. Leaks: Cooling Water, Lube Oil, Fuel Oil and Air.

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.

DIESEL MATERIAL CONTROL COMMITTEE
TEN-YEAR INDEX

1990

Theme: Be a Part of the Solution - Not a Part of the Problem

1. Waste Minimization
2. Hazardous Materials End Cost
3. The Role of the Suppliers

1989

1. Packaging and Containerization for Today's Railroad.
2. Innovations in Material Distribution Resulting from Shop Consolidations.
3. Outsourcing! Does Anyone Really Understand the Difference Between UTEX and Repair and Return and the Affect on the Budget?
4. "Stuff" Happens! - A Skit About the Necessity of Feedback from Suppliers - Suppliers to the End User.

1988

Theme: "Communications — fhe Vital Link in Materials Acquisition."

1. Communication — The Vital Link in Materials Acquisition.
2. Quality Assurance Through Communication and Feedback.
3. Paperless Requisitions.
4. A Practical Application of Bar Coding in The Railroad Industry.

1987

Materials — The Link Between Productivity and Quality

1. Supplier Selection from Component Failure Analysis.
2. Vendor Performance or Service Level.
3. Bar Codes.
4. Bar Coding — Railroads.
5. Material Handling Innovations by the Airline Industry.

1986

Electronics: New Methods For Handling Material — With Proper Quality and Sources

1. The In-House Electronic Requisition System.
2. Electronic Data Interchange.
3. RAILING and Electronic Purchasing.
4. Quality Evaluation of Material Sourcing Decisions.

1985

Controlling the Material Investment — A Requirement For Deregulation

1. Evaluating Locomotive Maintenance Projects.
2. Reconditioning Material: In-House vs. Vendor.
3. Identification and Disposition of Surplus Material.
4. Cost of Carrying Surplus.
5. Evolution and Future Directions of Material Handling Equipment in Railroad Use.

1984

Material Control In A Changing Environment

1. Bar Coding of Material.
2. Forcasting Material Requirements.
3. a. Fuel Security — Are You Getting What You Pay For?
   b. Fuel oil Is Expensive.
4. Pros and Cons of Material Purchasing Contracts (Single Source — Just In Time Inventory).

1983
Material Systems — Action Through New Ideas

1. Improved Locomotive Productivity Through Computerized Data.
2. Inbound Material Inspection.
3. Minimize Maintenance Cost Through Material Management Systems.
4. New Ideas In Material Storage Containers.

1982
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.

CONSTITUTION AND BY-LAWS LOCOMOTIVE MAINTENANCE OFFICERS ASSOCIATION

Article I - Title:

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

Article II - Purpose of the Association

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

Article III - Membership

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

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

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

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

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

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

Article IV - Officers

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

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

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

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

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

Article V - Officer, Nomination and Election of

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

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

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

Article VI - Officers - Duties of

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

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

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

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

Section 3 - The Secretary-Treasurer shall:

A. Keep all the records of the Association.

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

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

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

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

A. Assist and advise the President in long-range Association planning.
B. Contract for the services and compensation of a Secretary-Treasurer.
C. Serve as the Nominating Committee.
D. Serve as the Auditing and Finance Committee.
E. Determine the number and name of the Technical Committee.
F. Exercise general supervision over all Association activites.
G. Handle all matters of Association business not specifically herein assigned.
H. The Vice President shall perform such other duties as are assigned them by the President.
I. Those present at any meeting called on not less than thirty days advance written notice, shall constitute a quorum.

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

A. Participate in the General Executive Committee meetings.
B. Monitor material to be presented by the technical committees to ensure reports are accurate and pertinent to the goals of the Association.
C. Represent LMOA in their respective regions.
D. Promote Association activities, especially those held within their assigned region and monitor membership activities on those railroads so assigned.
E. Promote and solicit support for LMOA by helping to obtain advertisers.

Section 6 - Duties of General Executive Committee:

A. Monitoring technical papers for material considered unworthy or inaccurate for publication.
B. Approve topics for the **Annual Proceedings** and Annual Meeting program.
C. Approve the schedule for the Annual program.
D. Administer all Association activities not specifically assigned to the Board of Directors.

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

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

Article VII - Technical Committees

The technical committees will consist of:

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

Section 2 - A vice chairperson, selected by the chairperson and approved by the President.

Section 3 - Committee members will be made up of:

A. Representatives of operating railroads and regional transit authorities submitted by their Senior Mechanical and Materials Officers and approved by the President of LMOA.
B. Representatives of locomotive builders designing and manufacturing locomotives in North America.
C. The Fuel and Lube Committee will include members from major oil companies or their subsidiaries as

approved by the General Executive Committee.

D. At the discretion of the General Executive Committee, non-railroad personnel may be allowed to participate in committee activities, subject to annual review.

E. All individuals who are on technical committees must be LMOA members in good standing. (See dues and fees, Article 3, Section 5).

Subjects for technical papers will be selected and approved by the General Executive Committee.

Article VIII - Proceedings

The Locomotive Maintenance Officers Association encourages the free interchange of ideas and discussion by all attendees for mutual benefits to the railroad industry. It is understood that the expression of opinion, or statements by attendees in the meeting, and the recording of papers containing the same, shall not be construed as representations or statements ratified by the Association.

Article IX - Rules of Order

The proceedings and business transactions of this Association shall be governed by Roberts Rules of Order, except as otherwise herein provided.

Article X - Amendments

The Constitution may be amended by a two-thirds vote of the active members present at the Annual Meeting.

Article XI - The Constitution and By-Laws have been amended at the Annual Convention on September 19, 1988.

PAST PRESIDENTS

1939 & 1949—F. B. DOWNEY (Deceased) Asst. to Shop Supt., C & O Ry.
1941— J. C. MILLER (Deceased) MM, N.Y.C. & St. L R.R.
1942-1946, Inc.—J. E. GOODWIN (Deceased) Exec. Vice President, C.& N.W. Ry.
1947— S. O. RENTSCHILER (Deceased) Chief Mechanical Officer, Bessemer and Lake Erie R.R.
1948— C. D. ALLEN (Deceased) Asst. C.M.O. — Locomotive, C. & O. Ry. & B. & O. R.R.
1949— J. W. HAWTHORNE, Retired, Asst. Vice-Pres.-Equipment, Seaboard Coast Line R.R., 206 Strongbow Court, Sun City Center, FL 33570
1950— G.E. BENNET (Deceased) Vice-Pres.-Gen. Purchasing Agent, C. & E. I. Ry.
1951— P. H. VERD (Deceased) Vice-Pres.-Personnel, E. J & E. Ry.
1952— H. H. MAGILL (Deceased) Master Mechanic, C. & N. W. Ry.
1953— S. M. HOUSTON (Deceased) Gen. Supt. Mech. Dept. Southern Pacific Co.
1954 & 1955—F. D. SINEATH, Retired Chief of Motive Power, Seaboard Coast Line R.R., 1061 Nelson Ave., Jacksonville, FL 32205
1956— T. T. BLICKLE (Deceased) General Manager-Mechanical, A. T. & S. F. Ry.
1957— J. T. DAILEY (Deceased) Asst. to Pres.-Mech., Alton & Southern R.R.
1958— F. E. MOLLOY (Deceased) Supt. Motive Power, Southern Pacific Co.
1958— F. R. DENNY (Deceased) Mechanical Supt., New Orleans Union Passenger Terminal
1959— E. V. MYERS (Deceased) Supt. Mechanical Dept., St. Louis-Southwestern Ry.
1960— W. E. LEHR, Retired Chief Mechanical Officer, Pennsylvania R.R., 313 Hayden Street, Sayre, PA 18840
1961— O. L. HOPE, Retired Asst. Chief Mechanical Officer, Missouri Pacific R.R., 523 Hidden Harbor, Houston, TX 77079
1962— R. E. HARRISON (Deceased) Manager-Maintenance Planning & Control, Southern Pacific Co.
1963— C. A. LOVE, Retired Chief Mechanical Officer, Louisville & Nashville R.R.
1964— H. N. CHASTAIN, Retired Gen. Manager-Mechanical, A. T. & S. F. Ry., 909 Connecticut, Manhattan, KS 66502
1965— J. J. EKIN, JR. (Deceased) Supt. Marine & Pier Maintenance, B. & O. R.R.
1966— F. A. UPTON II (Deceased) Asst. Vice-President-Mechanical, C. M. St. P. & P. R.R.
1967— G. M. BEISCHER, Retired Chief Mechanical Officer, National Railroad Passenger Corp., Washington, D.C. 20024
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.
1970— G. R. WEAVER, Retired Director Equipment Engineering, Penn Central Co., 516 Bryn Mawr Ave., Bryn Mawr, PA 19010
1971— G. W. NIEMEYER (Deceased) Mechanical Superintendent, Texas & Pacific Railway
1972— KY PRUCHNICKI (Deceased) General Supervisor Locomotive Maintenance, Southern Pacific Transportation Company
1973— W. F. DADD, (Deceased) Chief Mechanical Officer, Chessie System
1974— C. P. STENDAHL, Retired General Manager M.P.-Electrical, Burlington Northern Railroad, 1052 W. California Ave., St. Paul, MN 55117
1975— L. H. BOOTH, Retired Assistant C.M.O.-Locomotive, Chessie System, 906-13th Ave., Huntington, W.V. 25701
1976— J. D. SCHROEDER, Retired Assistant C.M.O.-Locomotive, Burlington Northern Railroad, 244 Carrie Drive, Grass Valley, CA 95942
1977— T. A. TENNYSON (Deceased) Asst. Manager Engineering-Technical, Southern Pacific Transportation Co.
1978— E. E. DENT, Retired Superintendent Motive Power, Missouri Pacific Railroad, 13500 S. Outer 40 Rd., Apt. 116 East, Chesterfield, MO 63017
1979— E. T. HARLEY, Retired Senior Vice President Equipment, Trailer Train Company, 289 Belmont Road, King of Prussia, PA 19406
1980— J. H. LONG, Retired Manager Locomotive Dept., Chessie System, 5454 Cleander Drive, Cincinnati, OH 45238
1981— R. G. CLEVENGER, Retired General Electrical Foreman, Atchison, Topeka & Sante Fe Rwy., 5802 W. 157th Terrace, Overland Pk., KS 66223

PAST PRESIDENTS (Con't.)

1982— N. A. BUSKEY (Deceased) Asst. General Manager-Locomotive, Chessie System
1983— F. D. BRUNER (Deceased) Asst. Chief Mechanical Officer-R. & D., Union Pacific Railroad
1984— R. R. HOLMES, Retired Director Chemical Labs and Environment, Union Pacific Railroad, 688 J. E. George Blvd., Omaha, NE 68132
1985— D. M. WALKER, Asst. Shop Manager, Norfolk Southern Corporation, 793 Windsor St., Atlanta, GA 30315
1986— D. H. PROPP, Dir.-Loco. Opns., Burlington Northern Railroad, 373 Inverness Drive South, Englewood, CO 80112
1987— D. L. WARD, Asst. General Foreman, Burlington Northern Railroad, 3253 E. Chestnut Expressway, Springfield, MO 65802
1988— D. G. GOEHRING, Supt. Loco. Maintenance, National RR Passenger Corp., 30th Street Station, 4th Floor, Philadelphia, PA 19104
1989— WILLIAM A. BROWN, Shop Engineer, Burlington Northern RR West Burlington, IA 52655
1990— P. F. HOERATH, Retired Sr. Mech. Engr. Shops, Conrail, Box 134, R.R. 4, Hollidaysburg, PA 16648

HONORARY LIFE MEMBERS

KJELL AXELSON, Retired Superintendent Motive Power, Burlington Northern, 36-716 Bluebird Ave., Rancho Mirage, CA 92270
F. W. BUNCE, Retired Chief Mech. Officer, Milwaukee Road.
J. J. BUTLER, Retired Chief Mechanical Officer, Consolidated Rail Corp., 158 Woodgate Lane, Paoli, PA 19301
OWEN CLARKE, Retired Vice-President, Chesapeake & Ohio Ry., Cleveland, Ohio
B. A. CUMBEA, Retired Mgr. Locomotive Maintenance-Engineering, Chessie System, 310 Cherokee Trail, Huntington, WV 25705
J. J. Dwyer, Retired Engineer Environmental Control, Chessie System, Huntington, W. VA 25712 (P. O. Box 907)
N. C. ECKERLE, Sales Manager, Specialty Chemicals, Nalco Chemical Co., 2901 Butterfield Road, Oak Brook, IL 60521
W. T. Farley, Retired Chairman of the Board. A.A.R.
J. G. GERMAN, Retired Vice-President-Engineering, Missouri Pacific Railroad Company, 19 Holloway Dr., Lake St. Louis, MO 63367
J. J. GREGORY, Retired Project Manager-Heavy Repair Shop, Consolidated Rail Corp., 603 Ruskin Drive, Altoona PA 16602
S. GRAHAM HAMILTON, President, Global Group, Inc., P.O. Box 2024, Winter Park, FL 32790
E. R. HAFLING, Retired Engineering Assistant, Santa Fe Rwy., 2711 James St., Topeka, KS 66614
W. J. HARRIS, Retired Vice-President, Research & Test Dept., Assn. of American Railroads, Washington, D.C.
H. W. HAYWARD, Retired Chief M.P. & R.S., CP Rail, Montreal 101, Quebec, Canada
D. W. HENDERSON, V.P.-Technology, Engineering & Maintenance, Burlington Northern RR, 9401 Indian Creek Pkwy., Overland Park, KS 66210
JOHN H. HERTOG, Retired Vice-President-Operations, Burlington Northern, Inc., St. Paul, MN 55101
JOHN W. INGRAM, Retired President and Chief Executive Officer, Chicago, Rock Island and Pacific Railroad Co.
A. W. JOHNSTON, Retired Vice-President of Operations and Maintenance, Association of American Railroads, Washington, D.C.
JOSEPH J. T. KOERNER, Secretary-Treasurer (Retired), LMOA, 3144 Brereton Ct., Huntington, WV 25705
JACK L. KUHNS, Retired Manager Planning & Maintenance, CSX Transportation, 400 Deerfield, Louisville, KY 40207
R. M. McDONALD, Retired Director of Operations, Board of Transport, Commissioners for Canada, Ottawa, Ont., Canada
J. F. McDONOUGH, Retired Asst. Vice-President-Mechanical, Union Pacific Railroad, 12225 Farnum St., Omaha, NE 68154
F. K. MITCHELL, Retired Asst. Vice-President, New York Central Sys., Sleights Wildwood, Manitowish Waters, WI 54545
R. G. RAYBURN, Retired Executive Vice-President-Operations, Chessie System, Baltimore, MD
H. P. RODES, President, General Motors Institute, Flint, MI 48502
F. E. RUSSELL, Retired Chief Mechanical Officer, Southern Pacific Co., San Francisco, CA
H. L. SCOTT, JR., Retired Sr. Vice-President and Chief Mechanical Officer, Norfolk Southern Corp., P.O. Box 3609, Norfolk, VA 23514
C. M. SMITH, Retired Manager-Mechanical Engineering-Passenger and Locomotive, Consolidated Rail Corp., 3 Princeton Road, Strafford-Wayne, PA 19087
R. D. SPENCE, Retired Executive Vice-President-Operations, Seaboard System R.R.
J. TAGGART, Retired System Mechanical Officer-Motive Power, CN Rail, 655 Richmond Road, Unit 45, Ottawa, Ontario K2A 3Y3
C. N. WIGGINS, Retired Vice-President and Asst to President, Louisville & Nashville R.R., Louisville, KY