ORTH

1974 TECHNICAL PROCEEDINGS

INTERACTION FOR ADVANCEMENT

COOPERATIVE RESEARCH EFFORT AMONG RAILROADS, RAILROAD ASSOCIATIONS, INDUSTRY AND GOVERNMENT

11TH ANNUAL RAILROAD ENGINEERING CONFERENCE

SPONSORED BY

DEPARTMENT OF TRANSPORTATION

FEDERAL RAILROAD ADMINISTRATION

TABLE OF CONTENTS

OPENING SESSION

EVENING SESSION

SESSION III
NEW DEVELOPMENTS

PROCEEDINGS
OF THE 11TH ANNUAL
RAILROAD ENGINEERING CONFERENCE
HELD AT SOUTHERN COLORADO STATE COLLEGE
PUEBLO, COLORADO, OCTOBER 23-24, 1974

THEME: *COOPERATIVE RESEARCH EFFORT AMONG RAILROADS, RAILROAD ASSOCIATIONS, INDUSTRY, AND GOVERNMENT*

PURPOSE: *TO PROVIDE A FORUM FOR PARTIES INTERESTED IN THE PROMOTION, WELL-BEING, AND PROGRESS OF THE FREE SYSTEM OF TRANSPORT BY RAIL TO DISCUSS THE ENGINEERING ASPECTS OF RAILWAY FREIGHT EQUIPMENT AND ITS INTERFACE WITH THE TRACK STRUCTURE . . . AND THEREBY FORMULATE ANSWERS TO PROBLEMS AND DEVELOP ADVANCEMENTS IN THE STATE OF THE ART.*

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John W. Ingram
Administrator
U.S. Department of Transportation
Federal Railroad Administration

John W. Ingram has served three major railroads, as well as the U.S. Department of Transportation, in executive capacities. Prior to being named head of the DOT's Federal Railroad Administration in 1971, he was Vice President for Marketing at the Illinois Central Railroad. He has also served as Director of Cost and Price Analysis for the Southern Railway and as Director of Profit Analysis for the New York Central System.

A native of Cleveland, Ohio, Ingram received his BS in Business Administration from Syracuse University in 1952 and a Master's degree in Transportation Economics from the Columbia University graduate school in 1955.

Ingram is a resident of Washington, D.C., and a member of the Transportation Research Forum, the American Economics Association, and the National Association of Business Economists.

Edward J. Ward
Acting Associate Administrator for Research, Development, and Demonstration
U.S. Department of Transportation
Federal Railroad Administration

Edward J. Ward is Acting Associate Administrator for Research, Development, and Demonstration of the Federal Railroad Administration. He has been responsible for planning and carrying out the high-speed ground transportation R&D program for the Department of Transportation since the passage of the High Speed Ground Transportation Act in the fall of 1965.

Ward holds Master's degrees in Civil Engineering from the University of Illinois and in Industrial Management from the Sloan Fellowship program at Massachusetts Institute of Technology. He has had a long association with the Air Force, serving as an R&D officer assigned to the Materials Laboratory during the Korean War and as head of the fatigue research group. In 1963 he joined the Office of the Assistant Secretary of Defense–Comptroller as Director of Program Systems Development.

Jack B. Stauffer
Director-High Speed Ground Test Center
U.S. Department of Transportation
Federal Railroad Administration

Jack B. Stauffer is Director of the High Speed Ground Test Center, DOT/FRA, Pueblo, Colorado. He is responsible for the overall operation of the Test Center, as well as relationships with users and nearby communities. He was assigned as Director in April of 1974.

Stauffer is a graduate of the University of Illinois and did graduate work at the University of New Mexico. Prior to his assignment to the Test Center, he managed the research and development activities of the Rail Systems Division of the Federal Railroad Administration in Washington, D.C. He joined Federal Rail in August of 1972 after four years with Westinghouse Electric Company, as manager of a major underwater weapon program. Before that, he worked for the U.S. Atomic Energy Commission and ACF Industries, Inc., in the nuclear propulsion and weapons fields.

John D. Loftis
Consultant

John D. Loftis is a consultant to the transportation industry. John D. Loftis was educated at the University of Utah, and was awarded Tau Beta Pi for accomplishments in engineering by Drake University. He is a member of ASME and numerous transportation associations.

Loftis has held positions in operations and maintenance with the Denver and Rio Grande Western, the Atlantic Coast Line, and the Chicago, Rock Island and Pacific. In the equipment industry he has been associated with Baldwin Locomotive Works, ACF Industries/AMCAR Division, and Symington Wayne Corporation. He has also served the Office of Defense Transportation. His latest position was Vice President, Transportation Equipment Division, Dresser Industries, Inc., from which position he retired during February of 1974. In addition to his work as Consultant to Dresser, he is also consulting with the Association of American Railroads, Research and Test Department.

OPENING SESSION

The opening technical program session of the 1974 11th Annual Railroad Engineering Conference, conducted and sponsored by the Department of Transportation of the Federal Railroad Administration, was called to order by the Conference Program Moderator, John D. Loftis, Consultant. Loftis gave details of the operating procedures for the Conference sessions and pointed out that the first three sessions were to be held at Southern Colorado State University. The fourth session was an inspection of the Department of Transportation's High Speed Ground Test Center near Pueblo, Colo. For the welcome speech, Loftis called on John W. Ingram, Administrator, Federal Railroad Administration.

WELCOME ADDRESS

by
John W. Ingram
Administrator
Federal Railroad Administration

Thank you very much, Jack, that's the shortest introduction I have ever had, and that's the kind I like. Good morning, I am certainly delighted to welcome you here, officially, to what will become an annual Engineering Conference sponsored by the Federal Railroad Administration. We are happy that you found your way to Pueblo; it is a somewhat different setting from DePew, New York. We hope you find that your stay here is time well spent.

This Conference, as you are well aware, is new to the Federal Railroad Administration but not new to railroading. We have taken the baton, as in a relay race, from the very successful Conferences that have been sponsored in the fall of the past ten years by Dresser Industries. This Conference is the successor to the outstanding Dresser series, and we in government are proud that Dresser sought us out to sustain a very worthwhile tradition. I hasten to warn you, though, that a government-sponsored conference in the United States seldom provides all the amenities of a privately sponsored affair. Dresser is being most hospitable and gracious in making the transition an easy one, and their help is certainly greatly appreciated.

The government may not have the kind of money that we usually see expended on some of the hospitality aspects of such conferences, but we do have a 50-sq. mi. Test Center here in Pueblo. Our FRA people are looking forward with keen anticipation to tomorrow afternoon's tour and demonstration of what has been carved out of the desert about 20 miles east of here. It is officially called the High Speed Ground Test Center. However, you will see that much of what is going on is not necessarily high speed but is certainly high priority in terms of improving conventional rail technology.

While we are still in our formative years at the Test Center, there is more activity and testing underway now than ever before, and I am certain you will find tomorrow's visit interesting. At the same time our people from the FRA Office of Research Development and Demonstrations (RD&D, we call it) take a keen interest in the matters that are to be discussed here at these proceedings. I think it is safe to say that when the proceedings of this Conference are published, the volume will find a key place on the desks and bookshelves throughout our RD&D office and, I am sure, in your offices as well. I am confident that those volumes will do more than just gather dust. FRA is extremely fortunate to have one of the most imaginative and enthusiastic groups of research people that I have seen anywhere in government, and I know that they are delighted to have such top-level people as you at this gathering of rail technology people here in Pueblo this week. The list of delegates to this conference is impressive and imposing; we have represented here some of the best talents in the world in the field of rail technology. In American railroading in the seventies, however, technological ability is not enough. I am reminded of the saying that is stenciled on the wall of the Coast Guard shipyard in Curtis Bay near Baltimore: "We have done so much, with so little, for so long, that sooner or later we are going to be doing everything with nothing." Incidentally, those of you who don't know that the Department of Transportation includes the Coast Guard will find it includes not only the Coast Guard but a lot of other things as well.

I don't need to belabor you this morning with comments on American rail industry and its financial problems and the corollary ability of that industry to implement new technology. In far too many cases, the railroads do not have enough money to finance routine implementation of yesterday's technology. But in Washington we see signs, definite signs I think, of the tide turning. We see a Congress that has come to realize that good railroading is good politics. We have come to see a greater recognition on the part of the general public that railroading is a vital part of the national economy. We are seeing among the railroad unions a realization that organized labor's greatest enemy is an employer that fails to make a fair profit. I agree with the growing body of influential people who sense a turnaround in railroading in the not too distant future in this country, and in that regard this Conference becomes doubly important. When railroading becomes ready for sharply upgraded technology and ready to invest in the hardware that will be necessary, you, the engineering arm of this great mode of transportation, will be ready for the railroads. The ideas and concepts that have bloomed in the past at DePew and that will bloom at these FRA conferences this year and on into the future will, I know, bear fruit that will benefit the entire nation as well as the railroad industry.

As we start this first in a long series of FRA Railroading Engineering Conferences, you have my sincere wishes for success, for good luck, and for good railroading.

SESSION I
RAILWAY FREIGHT CAR DYNAMICS

Program Moderator Loftis introduced the topic of Session I, Railway Freight Car Dynamics, and noted that in this session we would deal with some of today's problems and some actions being undertaken to solve them. Loftis introduced the keynote speaker for Session I, Richard L. Lich, President, Dresser Transportation Equipment Division, Dresser Industries, Inc.

KEYNOTE ADDRESS

The New Direction

Richard L. Lich
President
Dresser Transportation Equipment Division
Dresser Industries, Inc.

Richard L. Lich is President of the Transportation Equipment Division of Dresser Industries, Inc., DePew, N.Y., which produces Symington, Gould, Waugh, and Hydra-Cushion products. He has been actively involved in the railroad and mass transit industries for 25 years.

Lich received Bachelors and Masters degrees in Engineering from Washington University in St. Louis and attended the Harvard Advanced Management program. He is a Registered Professional Engineer and holds numerous U.S. and overseas patents on railroad and mass transit equipment.

He has traveled extensively and is familiar with railroad and mass transit developments in many parts of the world. Most importantly, as a long-time firm believer in the railroad industry, he is convinced that it is on the threshold of a great opportunity for service to the nation.

Good morning, gentlemen. I see from the program that I am the keynote speaker for Session I—Railroad Freight Car Dynamics. For my comments I am going to change this to Group Dynamics.

The railroad industry played a major role in helping to mold our nation to meet the demanding challenges and great opportunities of the past. It can play a major role in helping to remold our nation to meet the new and critical challenges and even greater opportunities of today and of the future.

The foundation of the railroad industry is the basic efficiency of the steel wheel against the steel rail, combined with high-capacity cars, long train consists, high-rating motive power, and exclusive rights of way. This enables railroad systems to provide high-volume transportation services for a wide range of ladings more economically than other modes of transportation can. This is particularly significant today and will be increasingly so in the future, in view of the necessity of conserving our nation's energy supplies and promoting the development of our natural mineral and energy resources.

The railroad industry has a great new opportunity and responsibility to effectively apply itself in beneficial service to our nation. However, the realization of this opportunity will require accelerated technological advancement in railroad plant and equipment. Research and development efforts will have to be greatly increased.

The railroad industry today has many basic, down-to-earth problems. We need basic, down-to-earth research and development to produce the necessary basic, down-to-earth technical solutions.

The need is not for space exploration type technology but for practical new technology which will advance the development of reliable and economic railroad systems that can perform a superior job, starting now. The real need is for intelligent technological *evolution,* rather than *revolution.*

Three different types of research and development working in concert are required for effective technological evolution:

First, efforts to increase fundamental understanding of railroad plant and equipment relationships and performance requirements.

Second, efforts to practically apply such increased understanding in railroad operations.

And third, efforts to produce innovative hardware based on the practical application of this increased fundamental understanding.

It is logical, I believe, that the first efforts be carried out principally by the Federal Railroad Administration, in view of the magnitude of the experimental scale that is required and the budgets that are required. These are witnessed by the tremendous facilities that are taking shape here at Pueblo.

It is logical, I believe, that the second efforts be carried out principally by the railroads and the Association of American Railroads, which have at their disposal the massive proof-testing laboratory of the American railroad system.

And it is logical, I believe, that the third efforts be carried out principally by the many specialized individual suppliers which make up the railroad supply industry.

It is, therefore, essential that means be achieved to encourage these three efforts to the fullest extent and to effectively mesh them cooperatively together. This can produce a powerful combination which can maximize technological progress for the railroad industry.

The Dresser Transportation Equipment Division is committed to the railroad industry. This is where our heart is and where it has been for 82 years, since our Division's founder, the Gould

Coupler Company, was established in 1892. We believe that a key element of our national strength and well-being is a strong railroad industry based on sound practical technology.

In the interest of technological progress, our Division has sponsored and has successfully maintained the Annual Railroad Engineering Conference for the past ten years. We at Dresser believe that these Conferences, by providing a practical technical forum, have produced significant benefits for the railroad industry.

We have now arrived at the conclusion, however, that the time has come for the Annual Railroad Engineering Conference to take a *New Direction.* We believe that the technological forum must be broadened to include all groups which are involved in carrying out the three research and development efforts essential to railroad technological advancement.

We believe that such a forum can provide overall practical direction and unifying purpose to industry research and development. It can help to guide each of us in the direction in which we can most beneficially apply our particular capabilities.

Our objective at Dresser therefore has become the establishment of a *New Direction* technological forum. After long consideration we went to the FRA to propose that they sponsor, with our support, the 1974 11th Annual Railroad Engineering Conference and bring all of the groups together here at Pueblo. Most fortunately for the railroad industry, the FRA accepted.

We at Dresser hope that this Conference will be the beginning of a *New Direction* in the Railroad Engineering Conferences in which the FRA (under its leadership), the railroads and the AAR, and the railroad supply industry can participate in jointly providing a dynamic thrust to railroad research and development in order to produce the greatest practical results for the great American railroad industry.

We at Dresser are pleased that so many of you came to Pueblo. We wish all of you a rewarding Conference during the next two days and urge your active participation in the Conference dialogue.

Thank you very much.

Moderator Loftis: Thank you, Dick for your interesting presentation. Our next speaker will be Mr. Robert Kessler, representative of the Department of Transportation.

MESSAGE FROM U.S. SECRETARY OF TRANSPORTATION

Presented by Robert Kessler, Secretarial Representative

Thank you, Jack. I am very pleased to be with you this morning. As some of you know, I am a graduate of the Federal Railroad Administration. A couple to three years ago I was the Chief Counsel there, which may seem strange for a guy who spent 12 years in the engineering profession.

When the Department of Transportation Secretary Claude Stout Brinegar was here in Pueblo at the Test Center visiting with us last week he asked me to bring to you his special greetings and best wishes for a most successful Conference. He suggested also that I bring a few of his thoughts on cooperation to this hallmark of cooperative ventures. One of the most important roles for the Department of Transportation is its capacity for supporting research and development in aid of the railroad industry. Where the technological fruits of this effort can be turned to significant improvements in the delivery of goods and services in the private sector at a high-quality level and at a reasonable cost, it is clear that the down-the-drain dollars, the subsidy dollars in operations, would not be necessary.

The cooperative nature so necessary to this work is exemplified by the very structure of the Department and of the FRA. Each is only eight years old. When formed, the Department, while constructed of transportation modes, was really a heterogeneous mixture of disparate transportation agencies–some promotive, some research oriented, some operational, and some regulatory. Through the intense efforts of the people of the Department, we are fast becoming a strong cooperative team, one member of which complements the work of another.

The High Speed Ground Test Center is an example. Much of the early design and construction work were handled by the Federal Highway Administration. The Transportation Systems Center has been directly and intimately involved in research and development work here. The National Highway Traffic Safety Administration is conducting experimental testing with some of their automobiles here, with the assistance of Test Center personnel. The Urban Mass Transportation Administration's transit development work and the FRA's rail development work will be shown to you all before the Conference closes. Even the Federal Aviation Administration is helping by preventing SST flights from landing here and disturbing our work.

Such facts often lead us to think of the Center as a DOT property, and of course it is, in the sense that anything which is a part of one of the modes is also part of the Department of Transportation. Nevertheless, the Test Center in the immediate sense belongs to the FRA. The FRA is the operating agency and is host to the other constituent elements of the Department. As such, the Center is organizationally as much a part of FRA as the Northeast Corridor Study, the Office of Safety, the Office of Research, Development and Demonstration, and, indeed, the Alaskan Railroad.

Secretary Brinegar is extremely proud of the work of the FRA. He is most pleased to be associated with John Ingram and the FRA in their extraordinarily fine efforts to assist the rejuvenation of the railroad industry. The Office of the Secretary and particularly the Secretary himself support the great work of the Railroad Administration and its cooperative venture with you in carrying on this extremely fine Conference. The Secretary wishes you great success in continuing your marvelous work through this, the 11th year, and expects to see you all again in the 12th year.

Moderator Loftis: Thank you, Mr. Kessler. I would now like to introduce our next speaker, Mr. George Rousseau of Pullman-Standard.

Development and Production of Bessemer and Lake Erie Quick-Drop Self-Clearing Open-Top Hopper Cars

George L. Rousseau
Vice President-Freight Car Engineering
Pullman-Standard Division
Pullman, Inc.

George L. Rousseau is Vice President for Freight Car Engineering of Pullman-Standard, Hammond, Indiana. He has been associated with the firm since 1940. During the first 20 years, in which he was concerned with the engineering and manufacture of passenger cars, he became Assistant Manager of Production-Passenger Cars. More recently he has served as Project Engineer and Manager of Product Development for freight cars and as General Manager-Freight Car Engineering.

A native of Massachusetts, Rousseau attended Worcester schools, including the Engineering Division of Worcester Junior College and the School of Industrial Management of Worcester Polytechnic Institute.

Thank you, Jack, for the opportunity to speak to this important group of railroad people. My presentation is about development and production of the Bessemer and Lake Erie Railroad's "Quick-Drop, Self-Clearing Open-Top Hopper Car." These remarks are based partly on my experience but mostly on information furnished to me by Herman Aquino and Jim Schuller of Pullman-Standard, who were the engineers for the carbuilder. They, along with Charles Beaver, Assistant Superintendent of the Car Department, and Michael Manion, Chief Industrial Engineer, for the Bessemer and Lake Erie Railroad—and other talented and dedicated people—made this car a reality. All of the combined resources of the Bessemer and Lake Erie and Pullman-Standard which could be effectively utilized were employed on this program.

The Bessemer system transports a variety of bulk commodities in open-top hopper cars. Principal among these are coal and iron ore of various types. In 1966 Bessemer decided to go the technical route to develop a special car, and it fell upon a group of Bessemer mechanical and industrial engineers to study the problems of coal and ore handling as part of a systems approach. They viewed an open-top hopper car as a "bin on wheels" and set out to learn all about "mass flow" of granular materials, as related to stationary bins, to assure that the car would be self-clearing. The study also encompassed theory and calculations for material behavior under the effects of weather conditions, compaction, and car geometry. This phase lasted about three years, during which time hundreds of car unloadings, using many different types of cars, were studied. After exhaustive effort the car specifications were written. Bessemer and Lake Erie Railroad turned to Pullman-Standard for assistance to design and build a prototype car that would satisfy the known operational parameters.

Critical to the rapid discharge of lading from a car is the mechanism for operating the large gates to provide sufficient opening for material to quickly pass through. We jointly looked at all promising arrangement concepts. This study encompassed a large range of designs, models, and mock-ups, some of which are shown in the following figures.

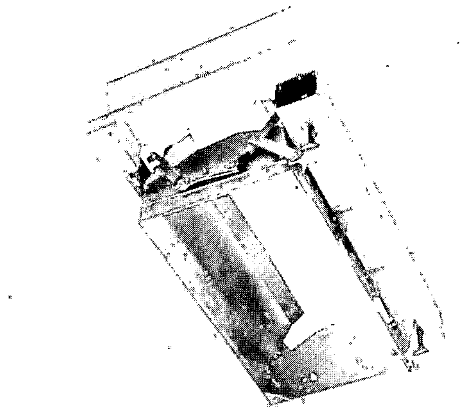

Fig. 1. Model gate arrangement.

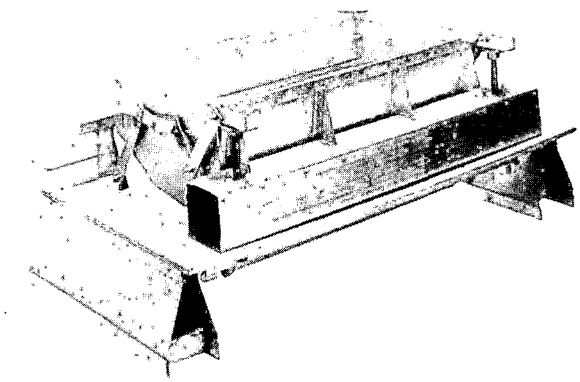

Fig. 2. Model gate arrangement.

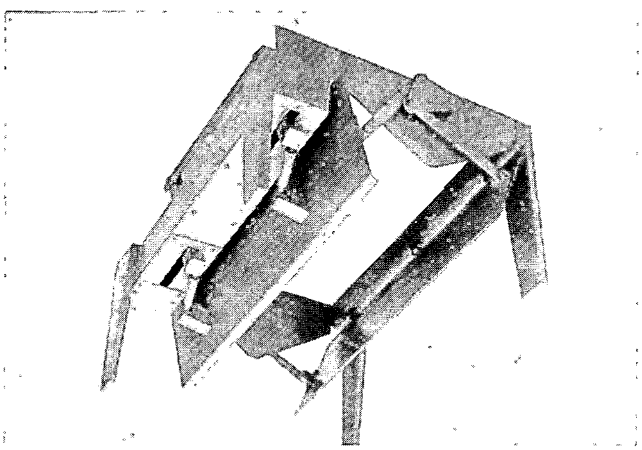

Fig. 3. Model gates and mechanism.

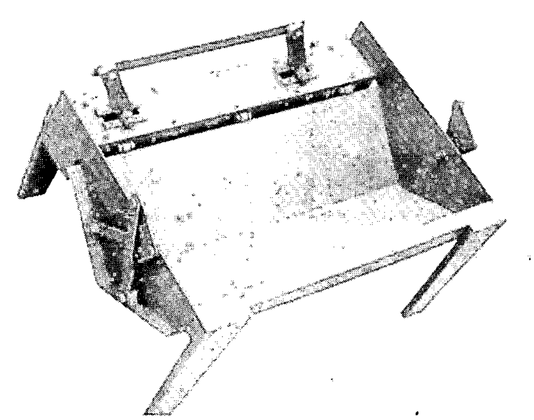

Fig. 4. Gate model.

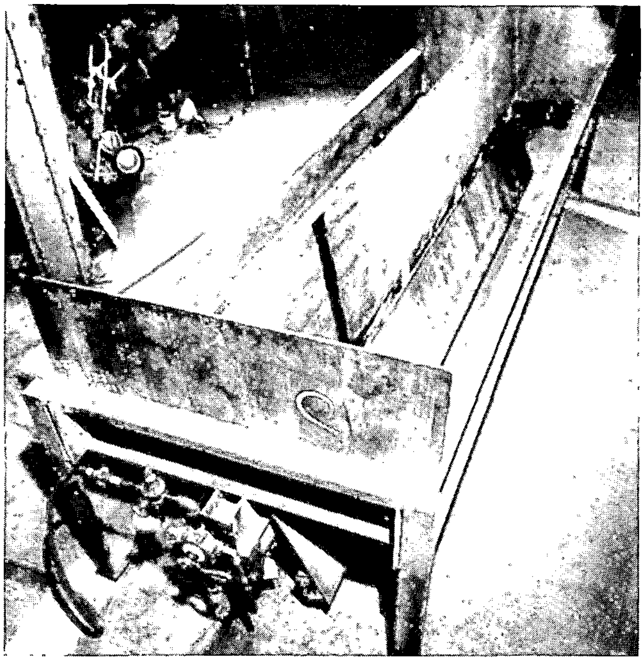

Fig. 5. Gate and mechanism model.

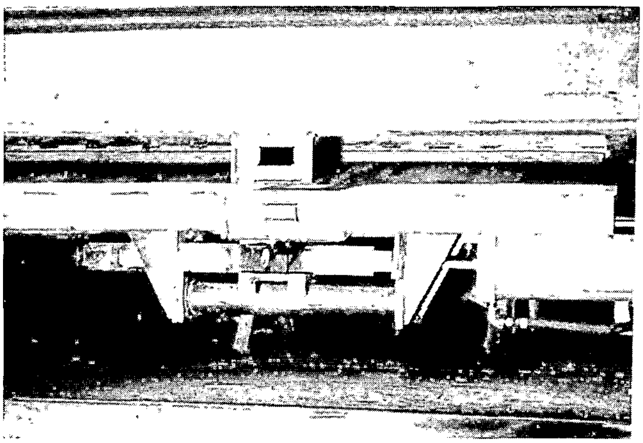

Fig. 6. Mechanism model.

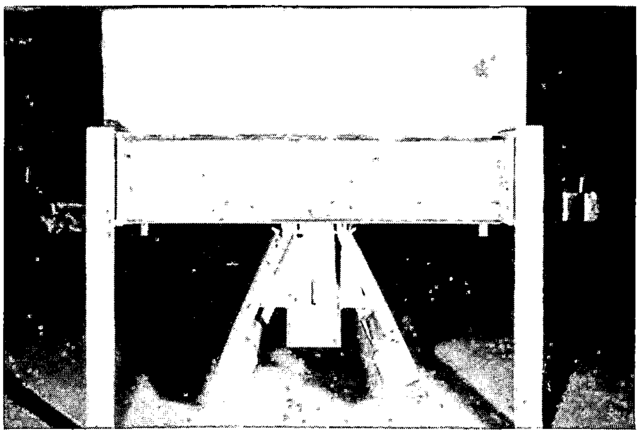

Fig. 7. Gate model.

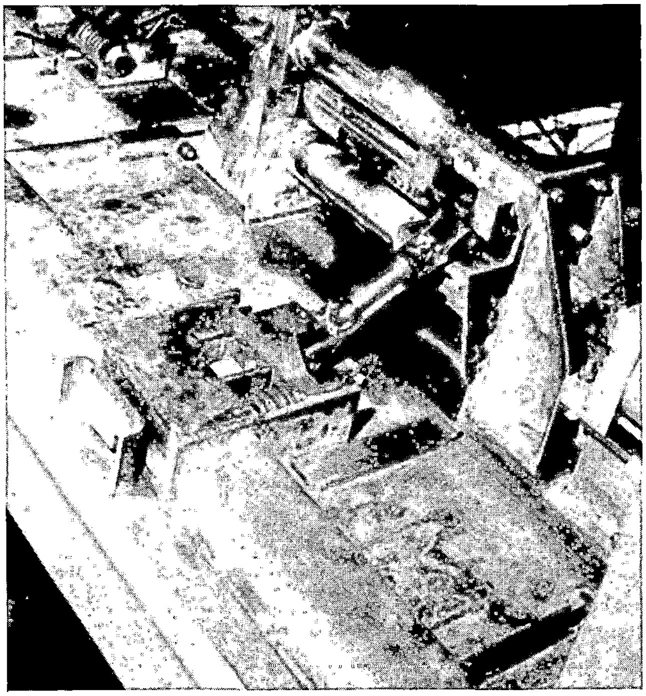

Fig. 8. Mock-up gates and mechanism.

Fig. 9. Mock-up gates and mechanism.

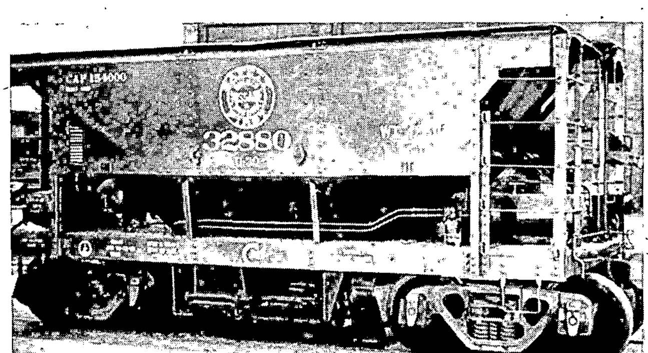

Fig. 10. Gates and mechanism application to ore car.

When our understanding of the mechanical concept was sufficiently developed, we made a full-size mock-up for functional testing in our laboratory. During and between these various phases of mechanical development, numerous meetings and conversations were held with Bessemer, and modifications were made as the need was developed. Finally we evolved a mechanism and door arrangement which accomplished the design intent. It did not resemble in detail any of the individual mock-ups or models; rather it was a mechanism on paper that was used on the prototype quick-drop, self-clearing car. We engineered and built a car, embodying the features and configuration resulting from all of the foregoing study.

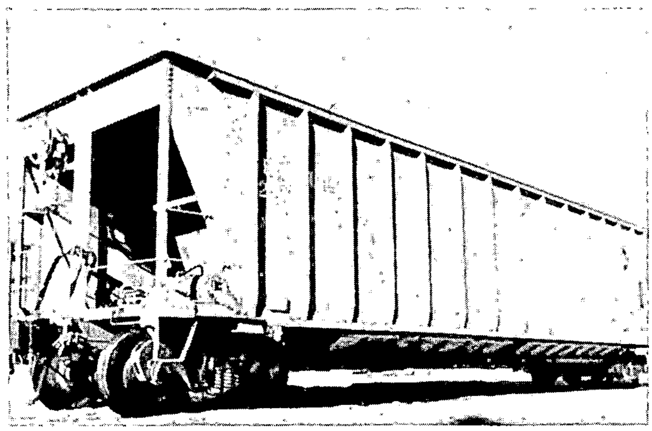

Fig. 11. Prototype car #2004.

This shows the prototype, which resembles the Pullman-Standard PS-3 open-top hopper and uses many modified PS-3 parts. Features of the car are:

Capacity	3,300 C.F.
Load limit	90 Tons
Maximum height above rail	12′3″
Length over strikers	51′3″
Inside length	46′3½″
Truck centers	40′9″
Door openings	4 at 14′4½″ x 2′7″
Angle of longitudinal hood slope sheets	80°
Angle of end slope sheets	52°

This arrangement is capable of unloading half of the car at a time, and a 90-ton load of coal in 12 seconds. The unloading system is operated by air, with air tank capacity sufficient for two complete operating cycles.

Fig. 12. Plug-in electrical device.

A "plug in" electrical device operates the doors. This device prevents the doors from opening accidentally.

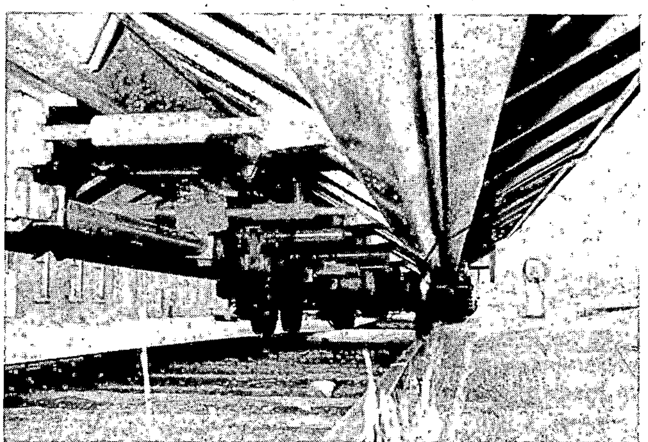

Fig. 13. Door mechanism—doors closed.

Two main mechanical features were used—the Pullman-Standard spherical end-strut type mechanism, and outside doors supported and powered by inside doors.

The prototype car was shipped to the ore docks at Conneaut, Ohio, for testing. During the empty-car impact test, the door mechanism had a tendency to unlock. So, before loading the car, B&LE and Pullman jointly designed, fabricated, and applied an "empty-car lock."

The first test load revealed that the outside door had excessive "slip down" with respect to the supporting inside door. This caused excessive gaps at the closing edges on this inside door, resulting in marginal support of the outside door. Rather than risk a door opening and loss of a load, we clamshelled the load out and modified the door support arrangement. The modification proved sufficient for handling ore.

In the load test with coal, visual and photographic information revealed large deflection of the outside doors during coal unloading. Door edge reinforcements were added to reduce the deflection. The car then completed field tests of all anticipated loading and unloadings.

The prototype car was then brought to our Champ Carry Technical Center for conventional impact tests and for further evaluation of the operating mechanism to determine wear, operating forces, and mechanical performance. As a result of lab tests, further modifications were made to improve the performance and reliability of the door mechanism. The prototype car was then released for in-service testing.

The first production run of cars incorporated all improvements made to the prototype car. Mass producing this car was something else; we had problems like Custer had Indians—they were all over the place. For awhile we were swamped, until we organized to handle the problems systematically.

The source of most problems was the operating mechanism—and the doors—because the supporting means for the doors and mechanisms are located on various components of the carbody and doors. These supporting means were located in subassembly positions with inherent variations in locations. The subassemblies were then brought to the main assembly line and attached to each other, adding to the manufacturing variations. This total variation of assembly tolerance was provided for in design by the use of adjustable elements in the mechanism. The exact nature of the adjustment, as well as the response of the mechanism to this adjustment, was very difficult to determine during the initial production phase. It was found that additional adjustable elements had to be provided.

One of the first cars built on the production line was sent to an ore-loading facility for accelerated load testing. Loading is done in one of two methods, the most severe of which is to drop 50 tons of ore into the car from about 16 feet above the bottom of the carbody. This load drop caused the doors to gap in excess of specifications. A baffle arrangement was designed and applied to all cars. The cars were subsequently placed in service throughout the Bessemer system, and for a time no major problems were encountered.

An indication of a mechanism problem was first disclosed when high operating pressures were found during door-closing operations. When we received reports of permanent set on the inside door due to bending and permanent set of the connecting link, a full-scale field and lab investigation was undertaken. Field measurements of strain gauges indicated excessively high stresses in doors and connecting links. A major modification program was necessary to correct the cars in service. A new design was developed for the spherical end struts, door reinforcements were added, door connecting links were reinforced, and auxiliary locks were improved.

A second production run of over 800 cars incorporated design changes to correct all the problems that had been encountered. Again, one of the first cars produced was transported to an ore-loading facility for accelerated testing. This testing indicated friction forces at certain areas, and minor modifications were made to these areas on all cars. No further difficulties were encountered.

After awhile, Bessemer began to report certain minor problems on the 800-car second run, as well as on the 200-car first run. The problems were varied, and information as to the extent of the problems was vague. It was imperative that we have information to determine the appropriate action, so we developed an inspection program to give a maximum of statistical data on both groups of cars for use in analysis of the problems reported. The program adopted was 100% inspection of the 800 cars, and a random inspection of the 200 cars. This inspection was conducted along with a complete environmental study of the Bessemer system's facilities. The study included impact speeds, car-handling techniques, shaker usage, and other data that would be of assistance in determining the cause of the problems reported.

The vast majority of the problems reported were isolated cases, as opposed to problems prevalent throughout the lot. We did, however, discover a functional problem in the mechanism. The most extensive statistical evaluation was conducted on the element of the mechanism called the actuator. The purpose of statistical evaluation was to determine, by random inspection, the extent of the actual problems prevalent in this group of cars. It was designed to give us information on the type of problems, location, and some clue as to the cause. A group of randomly selected cars was inspected 100% in the area of interest. The sample size gave 95% confidence that the number being looked at was within plus or minus 10% of the number that existed in the entire population.

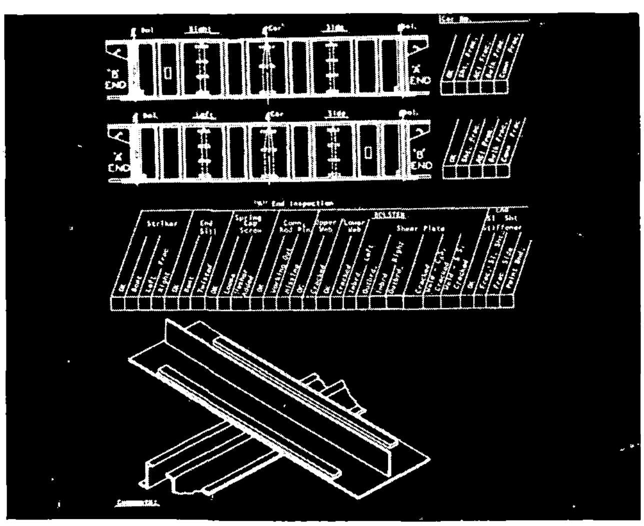

Fig. 14. Inspection sheet.

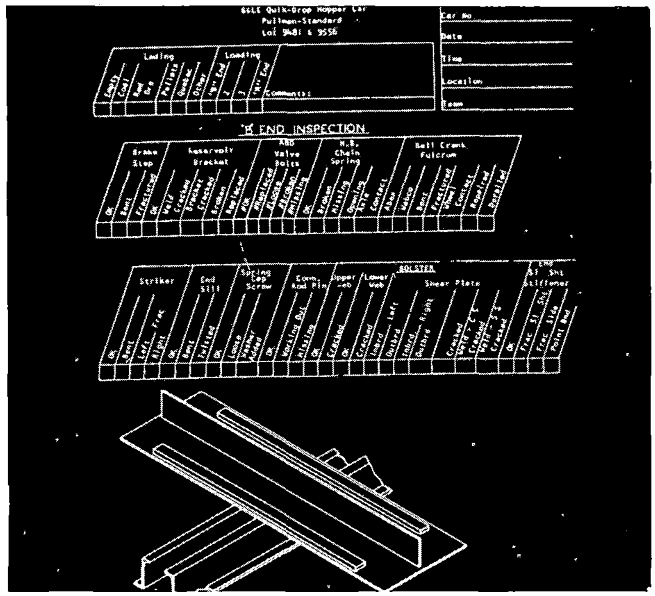

Fig. 15. Inspection sheet.

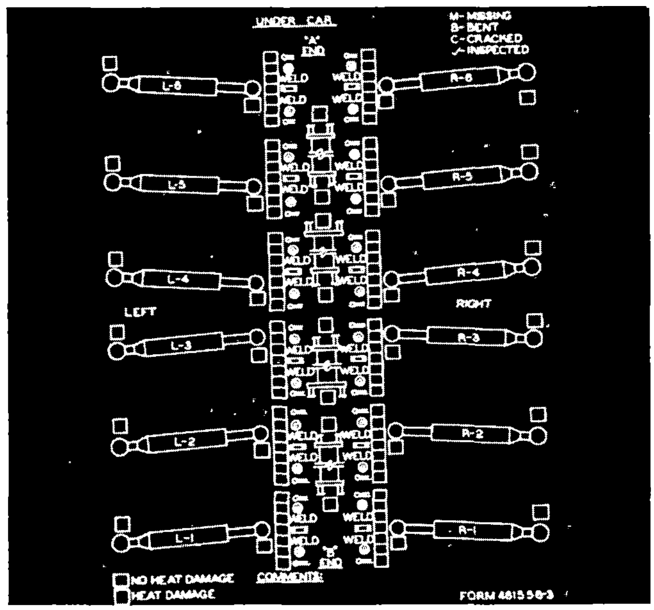

Fig. 16. Inspection sheet.

The study revealed that the problems were partially caused by dimensional variations. Such problems occurred early in the production run and were the result of the learning process during manufacturing. It further revealed that periodic maintenance and adjustments are required to maintain good mechanism operation.

The foregoing is intended to give an idea of the scope of a program required to develop a satisfactory new product. It also shows that total commitment and cooperation are needed between the railroad and the carbuilder.

These cars have now been in service over three years, with virtually no reports of problems. Maintenance programs have been developed by Bessemer and are being carried out. Car-handling techniques have been perfected, and Bessemer's customer acceptance has been excellent.

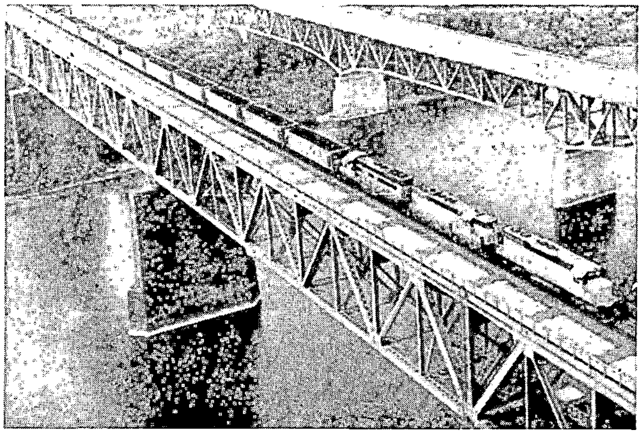

Fig. 17. Unit train.

This illustration of a unit train of these cars shows a train which is loaded every 2.4 days, compared to a train which was loaded every 10 days with the previous cars. This indicates the improved efficiency of these cars in the Bessemer system.

Moderator Loftis: Thank you, George. Our next speaker is Bob Billingsley of ACF Industries.

Freight Car Dynamics—One Carbuilder's Approach

Robert H. Billingsley, Jr.
Director of Engineering and Research
AMCAR Division
AFC Industries, Inc.

Robert H. Billingsley, Jr., is Director of Engineering and Research for AMCAR Division, AFC Industries, Inc., St. Charles, Missouri. He joined AFC in February 1971 as a product engineer with the AMCAR Division, was named Assistant Director of Engineering and Research in July of that year, and was promoted to his present post as director one year later.

Billingsley received his BS degree in Mechanical Engineering at the University of Florida in 1952 and served in engineering positions with Combustion Engineering, A.O. Smith Corporation, and Erie Strayer Company before joining AFC. He is a resident of Hermann, Missouri. An active member of the American Society of Mechanical Engineers, he has served on the Subcommittee for Jacketed Vessels.

It is a privilege to address this forum, particularly as we begin its second decade. Significantly, we are also entering a second phase in our consideration of dynamics problems in the railroad industry. In past Conferences we have dealt with dynamics problems, but from a defensive stance; now we are mounting a frontal attack. Where heretofore we were preoccupied with investigating and correcting field problem cases, now our attention is directed toward design and test to prevent such problems and, ultimately, to the use of these design and test tools for greater design efficiency and advancement.

The topic for this morning's session, "Railway Freight Car Dynamics: Design, Test, Confirmation," no doubt carries a somewhat different meaning to each of us, depending upon one's affiliation with the railroad industry. This is healthy and typical, and it is what makes these conferences tick. Our varied viewpoints, however, do focus on a prevailing common objective and interest: to most efficiently develop reliable freight equipment that meets customer, safety, and competitive demands.

The carbuilders are continuing to take on additional responsibilities for all aspects of car dynamics design. However, they are uniquely concerned and singularly responsible for the structural design of the carbody proper. As a carbuilder representative, then, I am venturing at this time to explore with you the current status of freight car dynamics design and test, primarily with respect to the carbody structure. I hope that presenting this view, at least as one carbuilder sees it, will add some helpful perspective to the total picture.

We are all, I believe, painfully familiar with how fatigue, wear, and stability problems surfaced on relatively new cars that were designed and tested to meet static criteria. These problems came to the fore with the trends to larger and heavier cars, longer and heavier trains, higher strength steels, and improved car utilization. This combination of trends, in effect, overpowered the load factors and test requirements set forth in the

AAR's "Specifications for Design, Fabrication and Construction of Freight Cars." These specifications were first published only ten years ago. There were no requirements for fatigue design considerations. Rather, there was reliance on the built-in conservatism of the load factors and peak impact test loads. Through revisions, more stringent load requirements have been introduced in the specifications over the years to update this conservatism in critical areas.

The AAR is currently actively engaged in programs with the supply industry and the FRA to evaluate the road environment and to formulate dynamics design and testing specifications. The fatigue methodology developed at ACF which I will describe is specifically applicable in these areas. Although supplementary requirements of this kind obviously represent added engineering costs, it should be borne in mind that the ACF methods were necessarily evolved within engineering budgetary limitations typical in our industry.

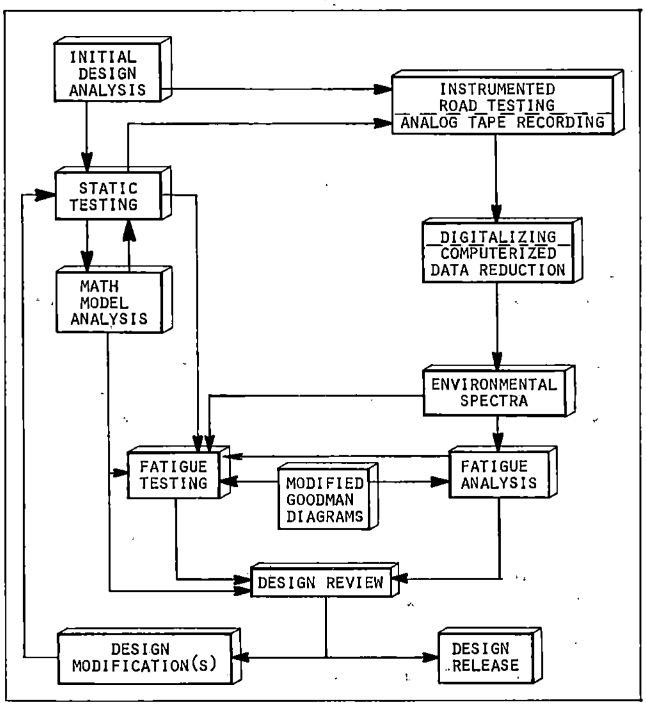

Fig. 1. Typical fatigue design flow chart.

The current ACF practices in carbody structural dynamics design, design analysis, and testing were initiated and developed specifically to combat fatigue problems. Briefly, the program, which is shown on the flow chart in Fig. 1, includes the following:

1. Collecting environmental dynamic load and response histories by instrumented road testing and from available literature.
2. Reducing the road test data to provide environmental spectra and representative cyclic frequencies.
3. Collecting realistic material endurance data from the literature in the form of Modified Goodman Diagrams applicable to typical structural members and connections.
4. Performing fatigue analyses using the environmental spectra and applicable Modified Goodman Diagram data.
5. Conducting programmed fatigue tests on subassemblies using the environmental spectra.

More recently, computer-aided structural design analysis has been added to our arsenal. Using detailed math modeling, the local load path and stress profiles of complex structures can be evaluated and critical areas pinpointed. Not only is this a powerful aid to screening and improving designs, it serves also as a guide to more critical and realistic testing.

A rather interesting example of this latter type of application of computer model analysis was encountered recently at ACF. At last year's Conference we described a program to improve the body bolster-centerplate design for stub sill tank cars. As follow-up since then a program was undertaken for fatigue testing the new body bolster-centerplate configuration as a separate component. Conventional analysis, treating the bolster as a component, considered it as a simply supported beam, as illustrated in Fig. 2(a). When the bolster was separated out from the total car cross-section using computer math modeling techniques, it was found that the loading on the bolster resolved to vectors acting angularly inward, as shown in Fig. 2(b), and that about 20% of the centerplate load was taken out through the center sill.

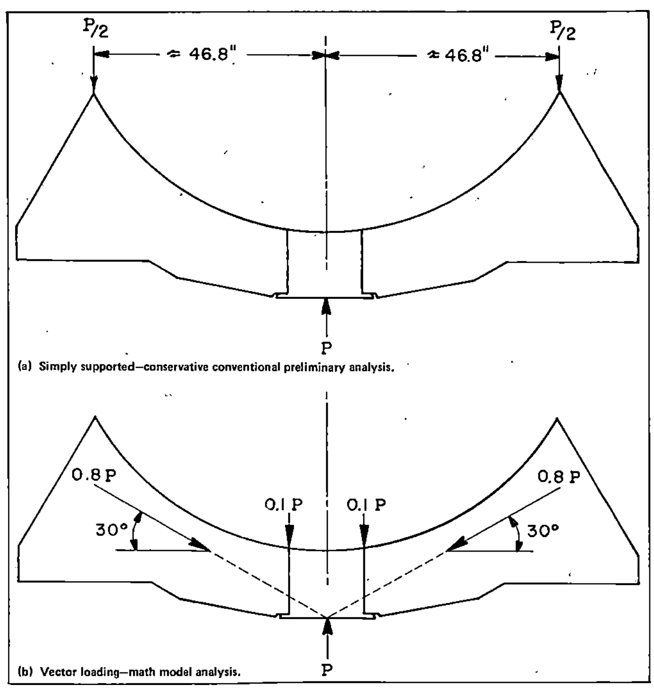

Fig. 2. Two methods of component loading of tank car bolster.

A bolster subassembly was built and checked statically for strains developed at key locations for both the simple support and "vector" load arrangements. These strains were compared to the strains measured on the actual car and those predicted by the math model. Fig. 3 shows a plot of such a comparison for stresses in the bolster bottom cover plate 4″ outboard of the center sill flange toe, clearly verifying the validity of the math model analysis. Fig. 4 pictures the specimen installed in ACF's MTS fatigue test machine for "vector" loading in accord with the math model analysis.

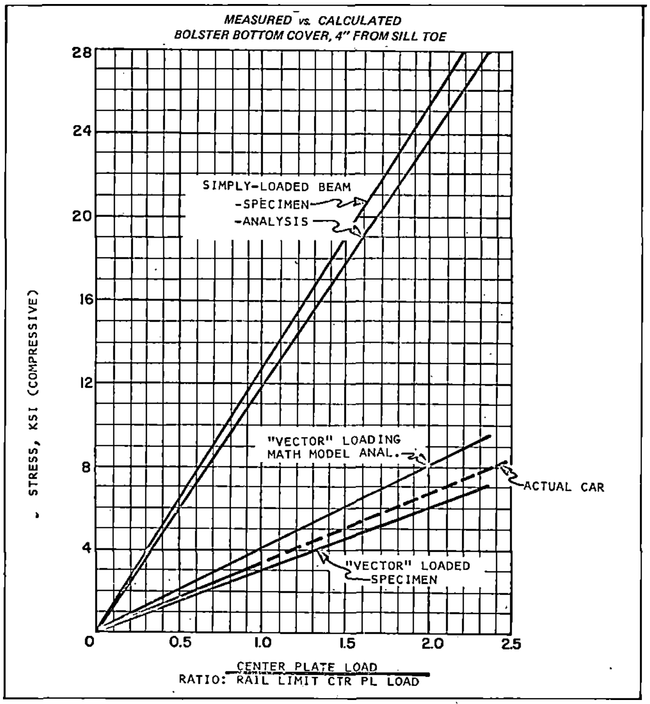

Fig. 3. Stress comparison, measured vs. calculated, bolster bottom cover, 4" from sill toe, 100-ton tank car revised bolster.

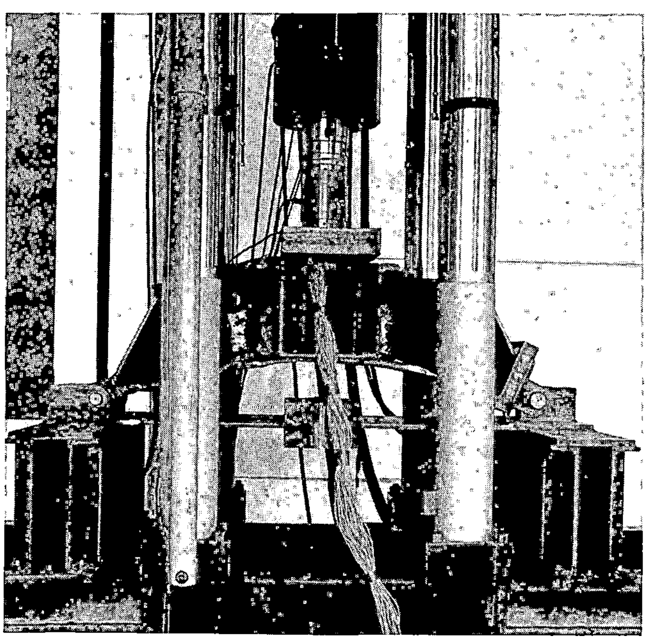

Fig. 4. Tank car bolster specimen, "Vector" load installation—fatigue test set-up.

This example illustrates how math modeling analysis techniques can assist component fatigue testing—in this case it was in a preliminary static calibration stage. The importance of preliminary static analysis is often underrated. It is an essential foundation to the dynamics design and test phases, both to provide the necessary datum data and for initial validation of the math model. The static model, besides, is the stepping-stone to the dynamics model.

Returning to the features of the ACF fatigue design method, the first item, road testing to collect environmental data, is conducted in revenue trains. The data are continuously recorded in analog form on magnetic tape and are also monitored by an oscillograph. The analog recordings enable qualitative and visual evaluation of the load and response behavior of the car while under test as well as flexibility in future quantitative evaluation and utilization of the data. At present, we have 23 data channels available, with a potential of 78 channels through additional multiplexing. Provisions for switching to other gauging hookups during a test provide for coverage of extensive gauging. The ACF instrument car is also equipped with closed circuit TV and videotape recorder. The instrument car, pictured in Fig. 5, was specifically built and equipped so that it could accompany a test car in any regular freight train service for prolonged periods.

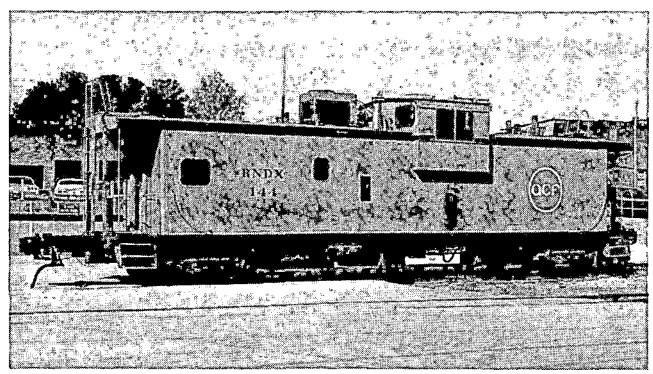

Fig. 5. ACF instrument car.

The analog tape recording produced during the revenue road test is subsequently digitized, and digital tapes become input to a data reduction computer program which counts and sorts the cyclic peaks. These data result in two tables, of which the one shown in Fig. 6 gives percent occurrences of actual peaks. The data provide for each channel the number of occurrences per mile, both for each speed range and total speed range. A speed spectrum, the average speed, and total miles recorded are shown. Details regarding calibrations and data exceeding the tabular ranges may be included if desired. Fig. 6 also shows a typical histogram representing the results as reported in the last column and covering the whole speed range. Corresponding histograms may be prepared for each of the 10 mph speed ranges covered by the other columns. The speed spectrum and its histogram are also shown.

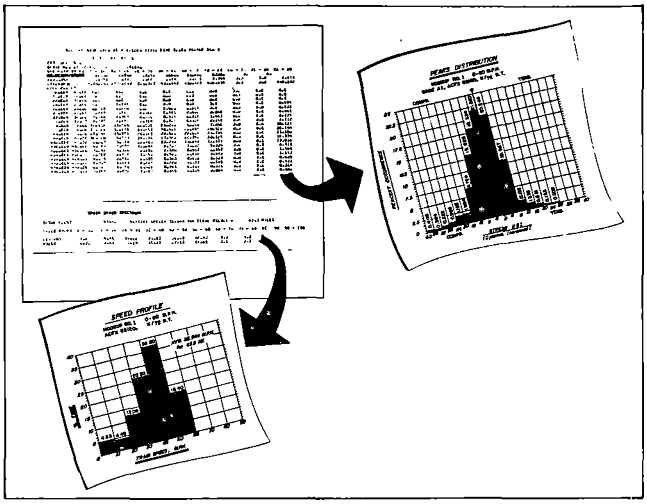

Fig. 6. Typical histograms from road environment computer-reduced data.

The second table (Fig. 7) gives the distribution of the cyclic peak combinations. This is additional elaboration of the histogram of Fig. 6—each of the Fig. 6 bars is detailed in terms of the percent occurrence of combinations with peaks from the other bars. The purpose of this table is to supply data in a format which corresponds to the Modified Goodman Diagram. The environmental data is formatted from this table into the environmental spectrum to be used for fatigue analysis, shown in Fig. 8. Incidentally, this environmental data is from a road test of the ACF retrofit centerplate for tank cars reported last year. The gauge was on the toe of the bowl radius and on the center line of the bolster. In some cases, this data may be manipulated to give loads imposed on the structure, as well as stresses. Accelerometers may be used for this purpose. Similar tests on similar equipment are combined to build our environmental data file.

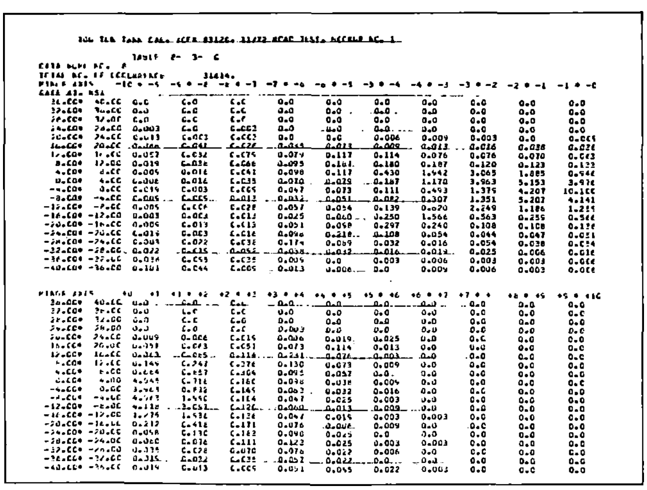

Fig. 7. Example of computer printout—1% occurrences of sequential peak combinations.

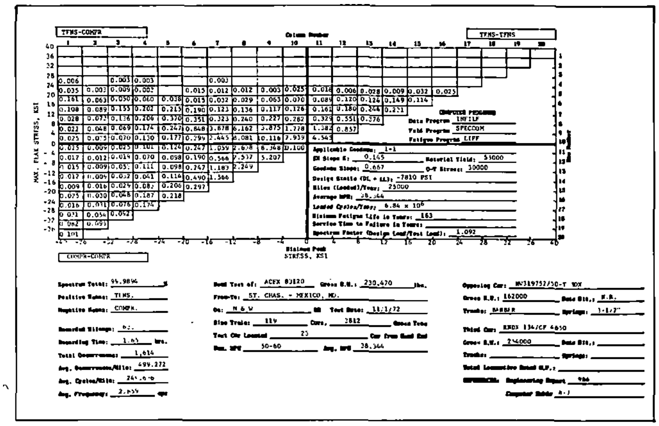

Fig. 8. Road environment—1% occurrence spectrum.

Without going into great detail, this environmental spectrum is then inputed to a computer program for calculating fatigue life. We input an applicable Modified Goodman Diagram and other essential information, such as the additional static stress, dynamic factor for maximum rail load limit, and anticipated yearly mileage. The computer program then calculates induced fatigue damage, based upon Miner's Linear Cumulative Damage Hypothesis, and reports the result in expected years of life or as "No Damage."

The same environmental spectrum and Modified Goodman Diagram background is used for fatigue testing. With limited testing facilities such as at ACF/AMCAR this generally reduces to component testing, or perhaps localized loading of the car structure, and it usually includes a generous amount of ingenuity. What is done is the region is loaded in a manner closely representative of the environmental loading. The specimen is subjected to only those cyclic loads deemed potentially damaging in fatigue. Fig. 9 shows a typical environmental spectrum with the related Modified Goodman Diagram superimposed. The sets of cycles above the damage line comprise the blocks that should be used for fatigue testing. In this case this is only 0.104% of the total environment, permitting a relatively short test period–about 32 hours of cycling to accrue the anticipated minimum fatigue life.

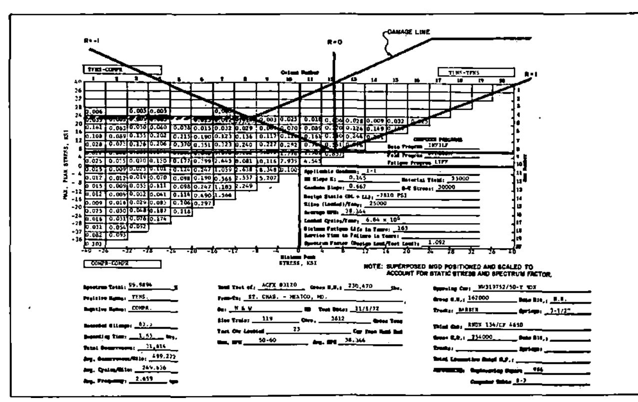

Fig. 9. Mod. Goodman diagram superposed on road environment—1% occurrence spectrum.

At ACF/AMCAR, an MTS servo-hydraulic fatigue test system equipped with a ten-block programmer is employed to apply these cyclic loads in a dispersed manner. This is accomplished by sequencing a small percentage of each cyclic condition and then repeating the sequence. This is repeated until the total life expectancy is reached. If and when fatigue cracking occurs, the testing may be continued to track the rate of growth.

I have referred to "applicable Modified Goodman Diagrams," and a collection of such diagrams is obviously a requisite in this fatigue analysis method. While many such diagrams are available through the literature, the collection is nevertheless limited, and testing to originate such diagrams for special structural members or connections is a slow and expensive undertaking. One alternative is to work with very local stresses as determined by fine-mesh math model analysis and photoelastic or strain gauge studies. Then the Modified Goodman Diagram for the as-received plate, forged, or cast base material may be utilized with the maximum stress for fatigue analysis and testing.

1. QUALITATIVE AND QUANTITATIVE EVALUATION OF ENVIRONMENTAL LOAD HISTORIES.
2. DETAILED RESPONSE OF THE STRUCTURAL SYSTEM TO THE DYNAMIC LOADS.
3. COMPUTER AIDED DESIGN AND TEST ANALYSIS TO EVALUATE THE CAPABILITY OF THE STRUCTURE FOR ENDURING THE ENVIRONMENTAL LOADINGS.
4. CONFIRMATION TESTING BASED UPON THE ENVIRONMENTAL LOADINGS.

Fig. 10. Basic ingredients of dynamics design and testing.

This is a brief outline of the ACF approach to prevent fatigue failures. This approach has proven practical and effective and can be employed within individual capabilities of this industry. It should be recognized that this method is still essentially quasi-dynamic (or, "equivalent static") in nature. It does, however, embrace the fundamental elements (shown in Fig. 10) of more sophisticated dynamics design and testing. The environmental load histories (item 1) include channels recording vertical, lateral, and longitudinal accelerations at the car bolster, and coupler and side bearing forces, in addition to strain gauge responses at selected critical locations. Since these were simultaneously recorded in analog form, the original recordings are adaptable to a variety of in-depth analyses (items 2 and 3) of carbody dynamics and may also be used for simulation testing (item 4). This fatigue design method has the virtue of basic compatibility with more advanced dynamics design and test technology.

Numerous cooperative activities are actively being pursued by the AAR, FRA, various universities, railroads, equipment manufacturers, and carbuilders. Many of these programs will embrace or augment the ACF data indicated here. One program at Washington University is directed toward development of a more efficient, and cost effective, finite element computer program. This program is co-sponsored by the DOT, AAR, Pullman-Standard, and ACF. Another important program is the AAR-coordinated Track/Train Dynamics ten-year program, now entering its second phase. This program is a joint effort of the AAR, FRA, RPI, and Canada's Transportation Development Agency. It is in this Phase II, devoted to the development of equipment specifications, that a specification for fatigue analysis is expected to be produced. ACF will provide the accumulated environmental and related background I have outlined to this important program. It is hoped this material, together with cooperative input from other sources, will expedite the formulation of an effective first-edition fatigue specification.

Looking forward, the DOT facility here at Pueblo will allow us to perform truly dynamic analysis and tests. We will, under carefully controlled test conditions, be able to determine how our equipment behaves and the importance of the dynamic responses of our structures. The full-scale dynamic test capabilities will make it feasible to test the total car for dynamic load response, durability, and lading protection.

Moderator Loftis: I want to remind you that our theme is Cooperative Research Effort between Railroads, Railroad Associations, Industry, and Government. We are going to take about ten minutes now, under the leadership of Stanley Fillion, Consultant to Dresser T.E.D., for comments.

DISCUSSION LEADER
Stanley H. Fillion
Consultant
Dresser Transportation Equipment Division
Dresser Industries, Inc.

Stanley H. Fillion is a Consultant to the Transportation Equipment Division of Dresser Industries, Inc., DePew, N.Y. His BS degree in Civil Engineering was received from Worcester Polytechnic Institute in 1930, and his MSE in Engineering Mechanics from the University of Michigan four years later.

Fillion taught Engineering Mechanics and Structural Design at Worcester Polytechnic Institute before becoming associated with Waugh Equipment Company, where he served in various engineering capacities before being appointed Chief Engineer in 1958. From 1969 to 1972 he was Chief Engineer, Special Products, for the Dresser Transportation Equipment Division.

He holds 15 patents in freight car cushioning and underframe design. He has been a member of the American Welding Society and is a Registered Professional Engineer in Massachusetts.

Discussion Leader Fillion: Thank you. Before I ask for questions, I want to pay my compliments to the first two authors on their papers. I can't remember when we have had two opening papers as fine as these. Mr. Rousseau's paper tells all of us how we ought to go about developing a new product, and Mr. Billingsley's paper is very close to my heart because for years I have been saying that we have got to modify our AAR Specification for Design and Construction of Cars to reflect what we do know about fatigue, and we must use more advanced fatigue design methods. Now I am ready to have questions.

Delegate Comment: Regarding the data gathered during environmental over-the-road testing, how do you relate the results that you record to various conditions of car components, such as wheels, springs, or truck snubbers?

Speaker Response: Sometimes that's not easy to relate. Basically, we are recording the performance of the truck, or our data could be specification of what the truck will put into the car. We are measuring the output of the truck system. We have done some limited testing on truck components and we do have some data in that area. However, we would look to the suppliers of these components to provide that portion of the data for their equipment.

Delegate Comment: In measuring the track conditions over the years, have you noticed any deterioration, and if so, how much?

Speaker Response: I would say that we are seeing deterioration, although indirectly, since we do not measure the track conditions, per se. Much of our data is of rather recent vintage, and of course we have limited capabilities to cover all the rails in the country. I hesitate to put any value in that area, although there is an effect from deterioration of the rails. There is also an effect from what the engineer at the head of the train can do to us, speed restrictions for rough track, what the consist and the terrain characteristics can do. There are so many variables that you really can't quantitatively separate the track deterioration feature out by itself from measurements on the carbody. Over the long haul these effects tend to balance out and the environmental spectra have tended to reach a stable distribution, according to our data.

Speaker Response: I think some of these questions might at least be touched upon this afternoon in the track/train dynamics portion.

Delegate Comment: I think this presentation is very timely because, as you know, fatigue analysis is a current concern of the Car Construction Committee, which recognizes that the present requirement is not adequate. Of course, it is a sort of blanket requirement that holds you, as carbuilders, responsible for fatigue problems that occur anywhere in the car structure. Now, the approach that you are taking is considerably more sophisticated than the approach that is currently called for in the specifications for design fabrication and construction of freight cars. My question is this: While there are obviously some components like centerplates and body bolsters where you, I presume, routinely do fatigue analysis in a car design, which represents a major departure from past practice, how do you identify the components which need to be analyzed from the fatigue standpoint without going overboard on your engineering costs?

Speaker Response: This would be determined by the skill of the analyst. We have to use our judgment, and I have to admit we make mistakes in that area. Basically, we start by looking at the fundamental load path through the structure. The bolster and the centerplate areas certainly are the more critical ones, but the effects on the remainder of the structure cannot be underestimated.

Speaker Response: Of course, in any revision of the specification it is going to be a little bit difficult to pin down those portions of the car structure that will be required to be analyzed for fatigue.

Speaker Response: Your question is a very valid one. It depends on the experience of the people doing the analysis, and an oversight there can be very expensive to the parties involved. The analyses are to be performed, though, within the budget limitations we have in this industry. We cannot approach the problem as with a new airplane and do a complete fatigue analysis of the total body structure. This is an almost impossible, or at least an impractical, approach. Experience and judgment are needed to conduct effective and practical fatigue analyses.

Delegate Comment: If your coal car were filled with ore, it would be grossly overloaded. In practice, does this ever happen?

Speaker Response: That is correct, the car would be grossly overloaded if this occurred. The loading operation has been organized so that overloading cannot occur, however. Part of the environmental study of the facilities was to study coal loadings. Controls were initiated to prevent overloading when these cars went into service.

Speaker Response: I think they answered the gentleman's question. The car was built with a partition on either side so it has an ore zone and it couldn't be overloaded. If the whole car were filled, it would be filled with coal outside of the ore zone as well as in the ore zone. This is the way overloading is prevented.

Delegate Comment: Someone mentioned using Miner's Hypothesis and the modified Goodman Diagram on their cumulative damage. These normally don't take into consideration peculiar sequencing of loads, and the literature indicates that if you sequence identical loads in different manners, you will do different amounts of damage. Have you been able to mathematically put this into meaningful guideline formulas?

Speaker Response: We have been able to use Miner's Hypothesis rather directly and with good results. I know the literature you are speaking of, but we have not found that our approach in sequencing is giving us incorrect results at this time. Besides, we always work to the conservative side, and employ a safety factor to cover such uncertainties as these in fatigue analysis.

Moderator Loftis: I would like to introduce our next speaker, Mr. William Ruprecht, of ACF Industries.

Freight Car Maintenance: Material—Energy—Cost Conservation

William J. Ruprecht
Director-Engineering
Shippers Car Line Division
ACF Industries, Inc.

William J. Ruprecht is Director of Engineering for the Shippers Car Line Division of ACF Industries, Inc., St. Charles, Missouri. He joined ACF in 1954 as Senior Metallurgist and progressed through various technical and management assignments to his present position. He previously was Assistant Director of Engineering for the AMCAR Division of ACF Industries.

Ruprecht was graduated from the University of Missouri with BS and MS degrees in Metallurgical Engineering. He has been associated with various trade and professional groups and is presently a member of the American Society of Mechanical Engineers, the American Society of Metals, the British Iron and Steel Institute, and the British Institute of Metals.

Good morning, gentlemen. My portion of the discussion will be somewhat of a change of pace from the more learned presentations preceding this one. Our purpose will be to consider material, energy (labor and power), dollars (cost), and conservation. This subject is not new to the railroad industry. In fact, the railroad industry has had to practice material, energy, and cost conservation long before these became catch words within the government. The railroads have been downgrading items such as rail cars, trucks and other components, and have been removing and repairing and replacing and recycling material for many years.

We will attempt to limit our discussion today to the freight car truck and running gear, to suggesting possible modifications to achieve an optimum life of the truck and running gear components.

You will be hearing of tomorrow's truck and carbody from others, but we must also get by today in an atmosphere of severe shortages in almost every maintenance area.

Let me suggest we are not doing this well.

To illustrate, and perhaps put into a framework the rest of my discussion, I'd like to tell a brief story. It concerns a farming community in the southern bootheel area of Missouri. I had many years ago thought this was the origin of the story, but since traveling around the country, I have heard it attributed to almost every state in the union.

It appears there was this preacher who had a small parish in a very poor farming district in southern Missouri, and his receipts at church were always very low. One day he thought, if I could only get my parishioners to farm better they would become more wealthy, and I, in turn, would receive more contributions for the church and hence could do more work for the community. To this end, he asked one of the State Farm Bureau experts to come to his community church and to discuss with his people how they could farm better.

The informally accepted leader of the church members was a gentleman by the name of Rufus, who attended the conference. After the expert began his talk, Rufus fell asleep, which was not too bad, except he was also snoring. So the preacher went over and woke up Rufus, admonishing him saying, "Rufus, why are you not listening to this man? He is trying to tell you how to farm better." And many of you know the answer. Rufus stated to the preacher, "Preacher, I'm not listening because shucks, I'm not farming now half as well as I know how to."

As one railroader to another, I would suggest that we are not "railroading now" half as well as we know how to. Why, I wonder why?

Before we get into the detail and a suggested approach to conservation, let me qualify the background for my comments and data. Shippers Car Line operates a fleet of about 36,000 freight cars, that is 2% of the total railroad fleet. We have seven service-maintenance facilities and use about 18-20 contract shops for additional service-maintenance work. Our fleet cars are shopped on a planned basis, depending on the type of car, lading involved, and service.

Shippers Car Line normally services and maintains about 7,000 of our fleet cars in our facilities each year. In any one month, Shippers Car Line receives from railroads—the roads you represent—about 8,000 to 10,000 AAR in-bills. These bills contain somewhere between 35,000 and 40,000 items of repair, service, and maintenance.

In addition, Shippers Car Line maintains three field engineers who spend about 90% of their time in lessee and railroad facilities. Insofar as the railroad facilities are concerned, the field engineers are in your classification yards, rip tracks, and heavy maintenance facilities. Our purpose for the field engineers is to assist lessees and railroad personnel in service and maintenance of our equipment.

In addition, the field engineers verify AAR billing and inspect our equipment to evaluate the bad order designations by various railroads.

Several years ago, I was privileged to participate in this Conference at DePew, New York, when it was sponsored solely by the Symington Wayne Company. At that Conference, the main subject was car wear and tear, specifically in the truck area.

In our discussion at that time, I presented a brief table showing the most frequent requirements for maintenance and/or component replacement of Shippers Car Line fleet equipment as shown in Fig. 1. We recently reexamined the slide to determine if there had been any change in the frequency or sequence of the items noted. As a matter of interest, there had not been any change, and the slide, as shown on the screen, is accurate today. You will note the slide lists AAR in-billing—Shippers Car Line shop items, and also designates the Relative Cost Impact of a number of the more critical items.

AAR BILLING	SCL SHOP		
	16	AXLES	
5	3	BENT ITEMS	
1	2	BRAKE SHOES	(B)
3	7	BRASS	(E)
	10	CENTER PLATES	
6b	9	COUPLERS	(D)
8	13	DRAFT GEAR - POCKET	
	5	DRAFT GEAR CARRIER WEAR PLATES	
6a	8	KNUCKLES	(D)
4	4	LUBES	(F)
	11	SIDE BEARING WEAR PLATES	
	6	SPRING NEST SNUBBERS	
2	1	SPRINGS	(C)
	17	TRUCK BOLSTERS	
	12	TRUCK INTEGRAL SNUBBING	
	18	TRUCK SIDE FRAMES	
7	15	WHEELS	(A)
	14	YOKES	

Fig. 1. Maintenance items.

For instance, the most frequent AAR billin item is brake shoes. We have deliberately left the IDT and COT&S incidents off the chart in that these are, in the main, purely service situations not involving material. Second most frequent AAR billing item is springs; third, brass; etc., and for Shippers Car Line service-maintenance facilities, the most frequent item of replacement is springs; the second, brake shoes; the third, in our instance, bent items; the fourth, lubrication; the fifth, draft gear carrier wear plates, and so forth.

Off to the right we have listed the relative cost impact of the items noted. One can see that wheels is the most prominent. If you and your own railroad would examine your AAR billing cost and shop cost closely for each car, you would find that wheels cost approximately 30% of your total maintenance cost for your car. Second cost impact is brake shoes; the third, springs; etc. Again, we have ignored the IDT and COT&S costs in this listing.

Fig. 2 illustrates a breakdown of a simple truck and the running gear associated with, in this specific instance, the tank car. For the purpose of our discussion, we will be talking about and discussing in detail wheels, bearings, adapters, side frames, springs, snubbing, wedges, side bearings, truck bolsters, centerplates, draft gears, draft gear carriers, coupler carriers, couplers and knuckles. We'll get back to this slide again later in our discussion. In the Shippers Car Line fleet, we find that the incident rate and cost of service-maintenance or replacement of the above items are generally related to mileage, train speeds, heavier loading, track conditions, car size and classification yard impact handling.

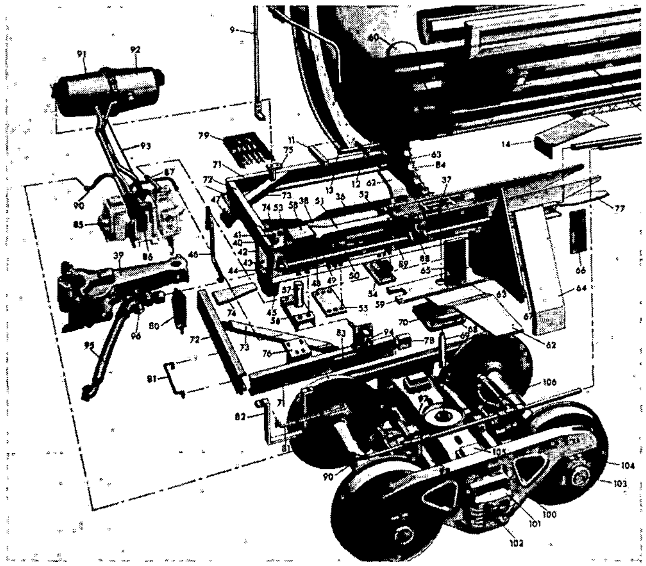

Fig. 2. Car components.

Dependent upon combinations of the above, Shippers Car Line shops its cars generally in cycles. This is illustrated by a typical car shown in Fig. 3 and maintenance costs are dependent upon the frequency of shopping and the frequency and level of the AAR in-billing. One can note the typical cycle as shown is on a five year basis. The heavy bars indicate the relative cost of each shopping; the two narrow lines indicate bad orders which cannot be accurately projected.

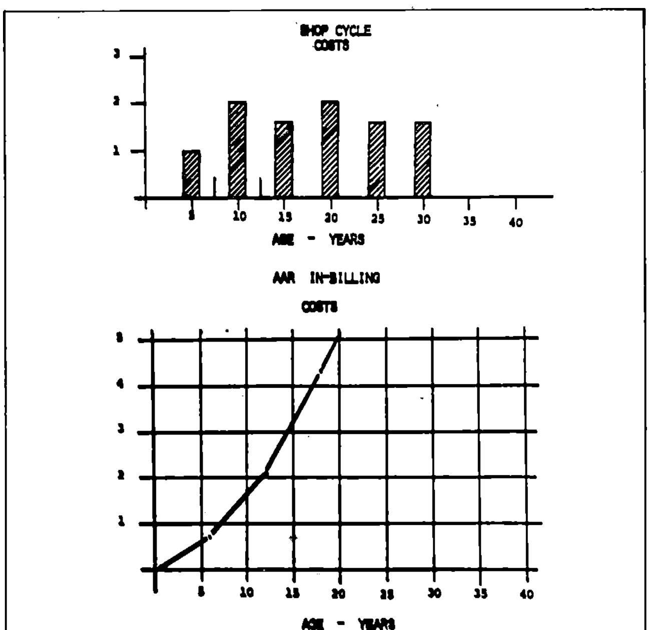

Fig. 3. Fleet maintenance.

In the lower half of the figure, the AAR costs are noted and one can readily observe that in the initial stages AAR costs are minimal. However, as a car ages, the AAR cost becomes significant and builds up as indicated by the steepness of the curve.

Fig. 4 shows car maintenance cost yardsticks. Here, we are merely attempting to identify specific items which affect costs such as capacity. A 100-ton car costs more to maintain than a 50- or 70-ton car. The type of car involved is definitely a cost factor. We have noted open hopper, covered hopper, tank, box, etc. to illustrate the point. Then, of course, the age of a car in years critically affects the cost picture. One of the more significant cost factors is the actual miles travelled per year. As we are aware, the average AAR mileage today hovers around 20,000 miles per year; however, there are cars traveling up to 200,000 miles per year. Recently, Shippers Car Line was asked to quote on a full maintenance lease for a unit train movement that would be running 350,000 miles per year loaded both ways. One cannot relate cost solely to miles but one must really relate cost to ton miles. We would illustrate that a 100-ton car actually represents a factor of 1.43 as related to cost when considering a 70-ton car. That is theoretically, a railroad can carry 43% more tonnage in the larger car.

CAPACITY (SIZE)	40	50	70	100	125	140	150	200	TON
TYPE	OH	CH	T	BOX	F	G			
AGE (YRS)	1	5	8	14	20	ETC			
MILES	20,000/YEAR			75,000/YEAR					
TON MILES	70	VS	100 TON	= 1.43	X FACTOR				
COMMODITY	IDEAL - NORMAL - CRITICAL								
	VEG OIL - NAPTHA - ACID								
	PLASTIC PLT.- GRAIN - MIXED FERTILIZERS								

Fig. 4. Car maintenance costs—yardsticks.

In estimating costs, Shippers Car Line considers the commodity in our overall cost picture. We have generally rated our fleet to be in either ideal, normal, or critical service with some typical tank and covered hopper car commodities noted.

To further qualify the background for the comments to be made, Fig. 5 shows a typical mileage audit report. As a private owner, we are fortunate in having all the mileage of our cars reported to us by each of you and we maintain an accurate mileage on each car in the fleet. The data, as noted in the figure, shows five-year specific loaded and empty mileage with a five-year total mileage for the car. Further, we have cummulative total mileage ranging back to 13 years and, in some cases, as high as 20 years.

CAR	YR	LOADED	EMPTY	TOTAL
61343	67	7111	6731	13842
	68	16270	12469	28739
	69	15212	10896	26108
	70	17472	10549	28021
	71	9977	8981	18958
TOTAL		66042	49626	115668
61344	67	12706	9114	21820
	68	14679	11892	26571
	69	20745	13871	34616
	70	14771	12242	27013
	71	14179	8900	23079
TOTAL		77080	56019	133099
61345	67	7111	4145	11256
	68	13520	11410	25030
	69	18989	13629	32618
	70	14643	10083	24726
	71	10184	7152	17336
TOTAL		64547	46419	110966
61346	67	10479	8360	18839
	68	7721	8119	15840
	69	13194	10797	23991
	70	17140	11590	28730
	71	14077	7397	21474
TOTAL		62611	46263	108874
61347	67	12032	8193	20225
	68	9646	9535	19181
	69	16500	14043	30543
	70	14603	11250	25853
	71	12677	8190	20867
TOTAL		67458	51211	118669
61348	67	10562	8739	19301
	68	14476	12738	27214
	69	18916	12452	31368
	70	13293	9620	22913
	71	12152	7957	20109
TOTAL		69399	51506	120905
61349	67	12282	8296	20578
	68	17189	15031	32220
	69	15545	11196	26741
	70	14993	12593	27586
	71	13537	9334	22871
TOTAL		73546	56450	129996
61350	67	8332	6464	14796
	68	14404	12723	27127
	69	17490	10601	28091
	70	18030	12974	31004
	71	14836	10454	25290
TOTAL		71028	53423	124451
61351	67	9635	9427	19062
	68	17541	13117	30708
	69	13542	9774	23316
	70	15131	14033	29164
	71	7223	6191	13414
TOTAL		63122	52151	116073
61352	67	15224	15977	31223
	68	13360	12250	25610
	69	15775	12026	27801
	70	15693	15155	30848
	71	12201	10051	22521
TOTAL		72656	65360	138016
61353	67	12407	2047	14454
	68	10229		10229
	69	12344		12344
	70	11043	353	11396
	71	11878	834	12712
TOTAL		57921	3234	61155
61354	67	25527	19965	45492
	68	18744	14003	32747
	69	9854	1622	11476
	70	14902	2432	16464
	71	10798	4002	14683
TOTAL		79425	42154	121079
61355	67	17494	19077	36571
	68	18948	14467	33415
	69	16440	4120	20558
	70	8813	1194	10007
	71	20704	6930	27599
TOTAL		82403	45736	128139
61356	67	15122	17500	32622
	68	24739	17736	42475
	69	16663	3565	24509
	70	10956	887	11843
	71	16425	2652	19477
TOTAL		86305	44121	130426
61357	67	13184	15701	28885
	68	24397	15226	39623
	69	16711	4212	20924
	70	10074	1110	11184
	71	15191	1296	16487
TOTAL		81557	38045	119602
61358	67	22000	22542	44542
	68	22331	15517	37848
	69	21727	4961	26688
	70	19168	5654	24822
	71	21552	8046	29598
TOTAL		106778	56520	163298
61359	67	23767	24930	48697
	68	17913	10462	28375
	69	21679	6044	27723
	70	16458	4765	21223
	71	11343	1916	13259
TOTAL		91220	48057	139277
61360	67	19152	21858	41010
	68	21199	17540	38739
	69	23546	4967	28513
	70	9779	3689	13468
	71	18160	5103	23263
TOTAL		91852	53177	145029
61361	67	19248	21217	40465
	68	18051	17319	35370
	69	19025	4201	23226
	70	21539	5001	26540
	71	16069	3594	19663
TOTAL		95872	51392	147264
61362	67	20592	18225	38817
	68	16145	14547	30692
	69	20471	6170	26641
	70	12559	1797	14356
	71	18637	3547	22184
TOTAL		88404	44286	132690
61363	67	18575	19720	38295
	68	21879	18322	40201
	69	11005	2078	13083
	70	17323	4109	21432
	71	9809	2692	12501
TOTAL		78651	46921	125572
61364	67	19397	18615	38012
	68	16361	13604	29965
	69	17634	4644	22278

Fig. 5.

Fig. 6 shows typical detailed cost of repair for a series of Shippers Car Line fleet cars. You can note that we break our cost down by Shippers Car Line shop, contract shop, and AAR billing. This particular sheet shows a six-year detailed billing and the cummulative total represents cost from 1961 to date.

ARCO-D COST OF REPAIRS FROM SEPTEMBER 01, 1974 TO NOVEMBER 30, 1974 DATE ISSUED DECEMBER 15, 1974 PAGE 555

CAR NUM		SCL SHOPS 69	70	71	72	73	74	CUMM	CONTRACT SHOPS 69	70	71	72	73	74	CUMM	RAILROADS 69	70	71	72	73	74	CUMM
				1878		1172	488	3538										55	177	72	69	364
				650				650										67	524	574	39	1259
						737		737								9-	28	278		20	3	581
						1106		1106								39	13	260	35		20	310
				1089				1335								29	15	158	20	76		54
		18		1606				1624								9		336	35	77-	111	414
							2008	2008								200	148	89	39-	11	6	682
																184	102	45	137	345	27	1223
						1880		2723									311	24	125	225	41	947
					1737	96		2143								10	245	137	402	141	121	1243
																79	273	58	257-	84	661	1126
		953			2225	2508		5726								173	287	587	125	50	37	1403
							5232	6520								12	290	272	43	252	196	1338
				2395				2739								59	216	26	6	297	90	802
						3735	1262	4997								371	22	35	251	38		884
		1071						1071								156	50	207	398	61	219	1299
	INACT	1171						1171								231-	314	22	535	100	26-	918
						3955	1091	5241								102	436	148	271	35	61	1194
							3232	3449								153	188	155	59	175		1150
							3818	4200								153	40	206	344	38	7	996
								1016								79	284	128	213	127	369	1275
																316	109	48	282	114	3	1349
						3667		3667								8	493	122	319	451	78	1509
		555	75				2122	3441								1151-	161	106	127	134	217	272
							3943	4186								511	35	113	50	19	66	995
						1962	3677	6259								302	174	173	282	368	30	1371
							4124	4329								123	147	284	356	225-	35	1265
				2480		1172		3799								184	76	134	71	88	140	703
		2634					2622	5609								183	47	88	98	47		537
					1616	2282	2770	8149								77	323	243	173	59	12	1025
						3488		3807								268	63	29	125	27	63	781
					1943		4441	6384								10	243	202	126	187	262	1203
						3833	2137	6205								89	319	49-	359	82	8-	1212
	INACT	193			507			1784							72	177	88	30	182	302	67	1073
					335			995								244	170	115	253	14	237	1496
																14	282	32	215	550	16	1356
		863		369				1252							177	92-	91	199	105	552	59	1529
		395						395							408	95	91	141	248	8-	139	001
						894		894								125	246	39	101	43	35	1033
															406	32	30	361	125	1416	40	2279
																143	484	93	999	326	204	2736
															355	82	421	51	253	344	82	1643
															327	264	416	453	439	103	163	2139
					1412			1956								74	277	58	63	305	42	1333
		882						882							373	44	130	44	215	87	13	939

CUMMULATIVE REPAIR COSTS INCLUDE COSTS FROM 1961 TO DATE.

Fig. 6.

Now let me be critical of each of you as railroad operating men. With a few rare exceptions, I know of no railroads that keep detailed maintenance costs of their fleet. This is a very critical situation in that each railroad has a complete billing section to keep and to bill other railroads for maintenance they do on that railroad's equipment. But the majority of roads treat the maintenance of their fleet as a multimillion dollar cost situation each year. For instance, we were talking recently to one railroad chief mechanical officer and he mentioned a $22,000,000 cost for his specific fleet of cars. Now, none of us can control costs when we talk of it in a lump sum of $22,000,000. Costs are controlled and estimated on a car by car basis, and a dollar by dollar basis, bringing into the picture detail components.

In the leasing business, maintenance costs are a critical part of the overall profit and loss for any of the leasing companies. If engineering misses the maintenance cost projection for a particular car in a lease situation, we have given a lessee, in effect, a free lease for a number of years. Shippers Car Line, as other leasing companies, leases cars from approximately one to as high as twelve to fifteen years. I have heard of some companies leasing cars up to 24 years. This is quite a feat.

Each leasing company guards their maintenance costs and practices very carefully, and I might add jealously, however, Fig. 7 shows the maintenance costs as Shippers Car Line normally approaches it. The figures actually used are not today's actuals and are several years old, but they can be useful in determining at least one approach to the problem.

	50 - 70	100	125
1 - 20,000	A	A_1	A_2
20,000 - 70,000	A+1¢/MI=B	A_1+1.2¢/MI=B_2	A_2+1.4¢/MI=B_2
70,000 - 200,000	B+1.8¢/MI	B_1+2.1¢/MI	B_2+ 2.3¢/MI

A, A_1, AND A_2 = BASE MAINTENANCE COSTS

Fig. 7. Maintenance costs—mileage—capacity.

Noted are three different types of cars, a 50-70-ton car, a 100-ton car and a 125-ton car. Maintenance costs are broken down as related to mileage ranges. In this specific instance, we selected 1 to 20,000 miles as base maintenance; this is, the A, the A1 and the A2 figures on the chart. The next mileage increment is 20,000 to 70,000 miles.

In this instance, we develop a B, a B1 and a B2 situation, which is actually the base maintenance A, plus, in the case of the 50-70-ton car one cent per mile additional cost over 20,000 miles, totaled together, you have a B maintenance cost.

Then, if one studies maintenance costs in detail, we would suggest that there is possibly a situation wherein the maintenance costs increase further, and for this illustration we have used a range of 70,000 to 200,000 miles per year. In this case, the B maintenance cost for a 50-70-ton car is added to a higher factor above 70,000 miles and, for illustration, 1.8 cents per mile is used.

The reason for the higher cost above a certain mileage is that major component replacement, such as side frame, bolster, etc. must be considered in the term of the lease, and dollars must be accumulated to ultimately purchase the major components.

I believe that is enough on the background or qualification for the discussion and we can now get to the specifics of conservation.

I don't think there is any need to convince each of you that there is a drastic need for conservation of material-energy, which includes both labor and power, and dollars, which are really our costs to operate the railroad.

Let us first emphasize the dollars which are primarily man power or labor costs. If one breaks down the AAR billing, it can readily be determined that labor represents about 40%, and material, 60% of the AAR billing dollar; however, the material cost represented at 60% contains about 66% labor costs. It so happens that particular labor is not generated by the railroads themselves in most cases. While we do not know the exact AAR billing total gross yearly transaction, we would judge it's in the neighborhood of about $350,000,000 for freight equipment, and the total rolling stock maintenance picture is somewhere in the order of $700,000,000 to $800,000,000.

When one talks of material, one has merely to review the Transportation Materials Management Form, Class I Railroad Material Survey Requirements for 1975 and 1976. I believe the preliminary draft is dated September 13, 1974, to give you an idea of the tremendous materials consumed by the railroad industry. In this report there are indications of 250,000 couplers, 350,000 knuckles, 200,000 side frames, over 100,000 bolsters, 1,600,000 wheels, and we could go on. Material conservation in this area is a must.

Now if we could return to Fig. 2. How can we achieve conservation of material-energy and dollars? And, of course, it must be recognized that this is certainly only one person's and one company's opinion, but it is a statement of how we can "farm better." For the purpose of the discussion we will restrict ourselves to the 100-ton truck and running gear. Specific items are listed here.

1. Wheels. We would suggest, and are fully aware, that the AAR is studying wheels and wheel wear, and specifically, the two wear wheel. But in our opinion, the time of the two wear wheel is at hand for a material add of about 5% steel—that is all the weight increase that is involved. One should expect with proper maintenance and proper interchange rule changes that a 60-80% increase in wheel miles (life) can be achieved. This, of course, assumes that the two wear wheel is removed at the proper time to allow remachining, and this also recognizes that the second wear or the second cut will not wear as long as, and will not run as many miles as, the first.

2. Axles. From our experience with axles, we can say that they are doing well and perhaps this is one of the best wearing and least susceptible items to conservation. An axle properly cared for will run the full life of the car.

3. Roller Bearings. In our opinion, roller bearings are doing well, and certainly are an improvement as related to hotboxes when compared to friction bearings. However, we are paying a price for the use of roller bearings in increased wear of wheels and, for that matter, increased wear of side frames, bolsters, centerplates, etc., on the truck.

4. Roller Bearing Adapters. These adapters were designed to wear and to prevent wearing of the side frame. However, certain things can be done to prolong the life of the roller bearing adapter. For instance, the shoulders can and should be hardened, and in some cases, depending upon the mileage the car will be running in a year, the crown can be hardened.

5. Side Frames. The integral snubber wear plates on the side frame should be the best alloy and hardened wear plates possible to buy. They should be attached by welding and bolting. If hardened crowned roller bearing adapters are used, of course wear plates in the roller bearing side frame area must be considered, and from our knowledge to date, attaching these wear plates in a permanent manner is still a problem within the industry, but the problem must and will ultimately be overcome.

6. Truck Springs. Shippers Car Line has adapted a 3-11/16 Spring Travel spring on all new equipment for our fleet. We use a full inner and outer nest primarily because our fleet contains tank and hopper cars which run at least one way fully loaded under the tonnage for which they were designed. Whether or not full inners and outers are required for a boxcar must certainly be evaluated by a railroad. In addition to using a 3-11/16 Spring Travel unit, we buy the best alloy shot peened and coated spring that is available on the market today. The alloy shot peened and coated spring has cut our spring replacement situation almost in half.

We would suggest in the spring area that it is a false economy to place one or two new springs into an already existing spring nest without first checking the springs to assure that they are the proper free height. That is, to assure that they have not already taken a permanent set such that the full loading of the car will be transferred to the new springs. We attempt in all cases to match carefully the spring nest grouping in any tear down and rebuild of a truck. We have found that any railroad that attempts to save us money by merely adding one new spring to a spring nest without checking the condition of the other springs in the grouping, is not doing us a favor nor in the end, any railroad a favor.

7. Truck Snubbing. The highest level integral snubbing force that can be obtained between the bolster and side frame should be used—that is, double spring nest and the larger spring grouping available through some bolster manufacturers, are all worth the added cost. The integral snubbing does much to contribute to the stability of the ride of a worn truck. And from our experience, once the integral snubbing is worn out, or someone tries to extend the life of the truck by not replacing the integral snubbing wear members—believing they are saving dollars, will find that it is extremely false economy when they compare centerplate and wheel wear.

8. Side Bearings. Our entire fleet of tank cars utilizes the old block that is cast iron block side bearing and we have found this to be the least maintenance cost and the longest life component in the side bearing area. Since this area involves several proprietary individual manufacturer arrangements, we will not discuss it further, but there are some that are very short-lived and do not do the job that they are supposed to.

9. Truck Stablization. To further the life of a 100-ton truck and to extend the life of the 100-ton wheel, constant contact stabilization between the truck bolster and the body bolster is becoming very obvious. Elastomeric constant contact side bearing systems are available and, in addition, other elastomeric systems causing an intimate contact between the body bolster and the truck bolster are also available. Each causes a degree of stabilization to the riding quality of the truck—in effect, it is dampening the truck free body mode as it moves over the rails.

Each truck manufacturer has a so-termed "super truck". All of these range upward and represent a cost add of about $1,000 to $2,500. It is very difficult to justify this type of cost add when analyzing, in depth, wheel wear and perhaps side frame, bolster and centerplate bowl and centerplate wear. However, one can readily justify the cost adds involved in several of the presently available constant contact side bearing or elastomeric connects between the body and truck bolster. We would suggest that each of you consider these carefully, not so much for the ride quality but purely from the wheel wear savings involved.

10. Centerplate Bowls. Some years ago, the AAR went to the manganese horizontal and vertical wear liners in the centerplate area. These are proving out to be very good service investments. We would suggest, however, that for the 100-ton truck, the 14″ centerplate was a mistake. I was a party to some of the decisions when the 14″ centerplate was determined as the standard for 100-ton cars and looking back at those days, the decision was possibly correct. However, today, with the condition of the track in this country, the 14″ centerplate is an "under designed entity" for 100-ton equipment. We would suggest that the AAR consider as a standard a 16″ centerplate with a 2″ deep pocket while still retaining the manganese horizontal and vertical wear liners. This 16″ centerplate will certainly extend the wear picture for the 100-ton centerplate area.

11. Separable Centerplates. Shippers Car Line uses separable centerplates and we use the 1¼″ thick flange unit. We would suggest that a 1¼″ thick flange, 16″ separable centerplate for 100-ton equipment is a direction in which we should ultimately go; and that the presently considered full machined center filler, center sill area, and centerplate surface is not a correct direction. Some people use the combination centerplate-center filler and, in some cases, centerplate-center filler rear stop arrangements. We would suggest that perhaps when wear occurs, these are too hard and costly to replace; however, certainly this is one case (where you pays your price and takes your choice). Insofar as wear with the present 14″ centerplate, the 100-ton car is showing about a 150,000 mile wear life under the most adverse conditions and about a 250,000 mile wear life under what perhaps can be termed normal, or even ideal, conditions.

12. Solid Bearing Cars. Now we would like to get to solid bearing-equipped existing cars. We would suggest for existing cars that have five or more years of life that the flat back solid bearing stabilization approach is the direction, rather than any of the stablizing inserts. However, if a car has less than five years of life remaining, we would suggest the stablized inserts—and there are several of these which perform very well, and a number which perform poorly.

Still in the area of the solid bearing, the sealed box, both lid and rear is a must, and Shippers Car Line uses a vulcanized lid seal arrangement. We are fully aware there are a number of snap-on types; however, from our experience, we have found that there are many rip tracks and classification yards in the country that seem to work on separable lid seals with a vengeance—hooking the lid open and tearing the lid seal off along with the opening action. Before the car leaves the yard, they have a separate crew which applies a new separable lid seal. This, I would suggest from a conservation standpoint, really doesn't make any sense and, from our standpoint and our money, makes no sense at all.

Continuing with solid bearings, there are lubricating oil additives that prevent the light rust and pitting that normally occurs when a car stands for a period of time. In discussing additives with members of the AAR Lubrication Subcommittee, we find that they have not approved a specific additive we use, in that it is the only one that works and an AAR committee cannot approve a proprietary identified single commodity. However, this has cut our light rusting and pitting, axle and wheel pair removal from about 80% in several critical areas to 20-25%, and just recently to as low as 10%.

One final word in the area of the lubrication oil and solid bearing boxes. Certainly the lid should be closed! We are continually receiving reports from our field engineers that lids are opened for inspection and remain open in many yards for a number of days before they are finally closed as the train consist leaves the yard. If it rains, we now have water in the box and the railroad has the exposure of a hotbox, or at the very least, a rusted or pitted journal. I do not know a single railroad that enjoys removing wheel pairs for light rusted or pitted journals.

13. Draft Areas. Moving away from the truck to the draft gear area, utilization of the highest grade available couplers and knuckles, and, for that matter, yokes, can be easily justified from the standpoint of initial cost versus maintenance cost. Shippers Car Line prefers the friction-elastomeric draft gear as compared to the all rubber or the all friction draft gears available. We have found that the all rubber draft gear has given us, and is giving us, severe key slot wear due to its continuous movement in a train consist. While it has just recently been adopted by the AAR, we have been using a double carrier in our draft gear area for many years, finding that this minor added new car cost expense lessens our maintenance and wear problems in the entire draft gear area.

14. Coupler Carrier Wear Plates. I think as a final note of specific items, the sacrificial coupler carrier wear plate is a must as related to allowing the coupler to wear. Today we have couplers without wear plates, wear plate inserts, and couplers with wear plates welded directly to the shank. Each type requires a different hardness coupler carrier wear plate to obtain optimum wear from the coupler carrier wear plate.

To turn a moment to conservation of cost and labor, let's look at the absolute need to pay close attention to the use of components in freight cars that wear or last the optimum length of time. Fig. 8 shows the ordinary labor rate progression in dollars per hour from the years 1965 through 1974. One can see that there was a base escalation in ten years of 275%. Today, we are looking at a $14.24 hour.

Fig. 9 shows the same type of situation, taking the past ten years as shown in Fig. 8, and extrapolating out at the same compounding for the next ten years. If the projection 1974–1985 is correct, that is, a 10% compounding does occur, each of us as mechanical people will be looking at $41.00 per hour ordinary labor rate in 1984 or 1985. This should be considered very carefully by you as management in the mechanical area, and by you in attempting to convince your division and corporate managements of the need for buying a "better mousetrap" or maintaining a "mousetrap" in a better manner–today–more than ever before.

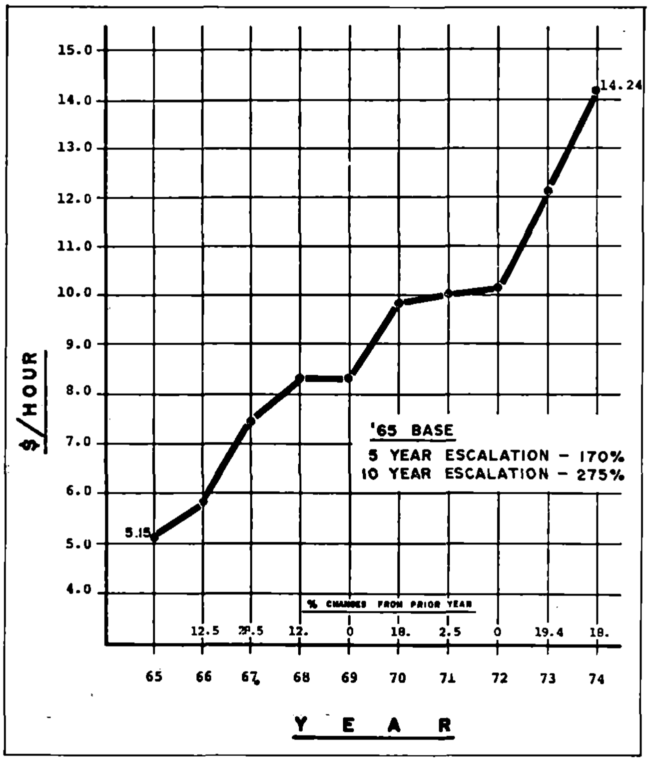

Fig. 8. AAR ordinary labor rate.

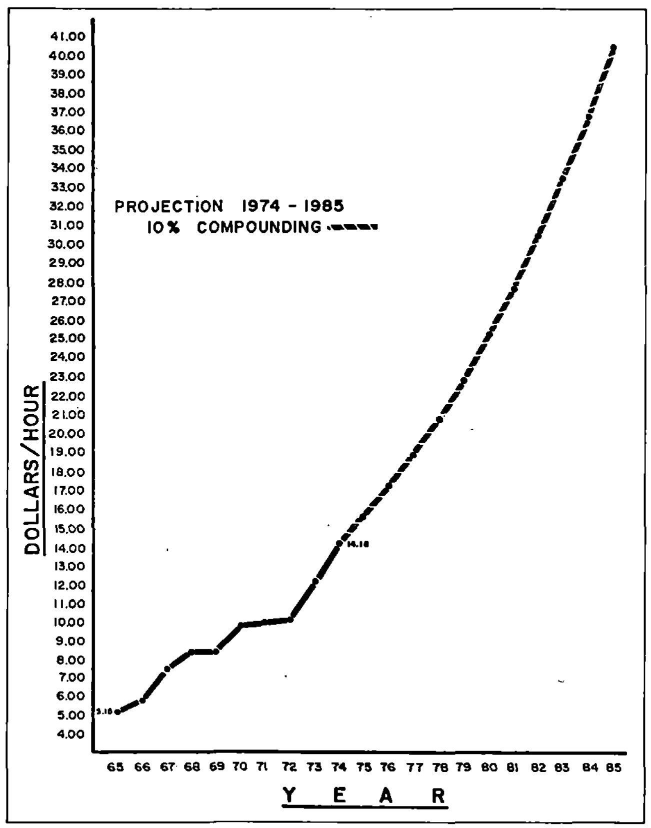

Fig. 9. AAR ordinary labor rate projection.

To all that has been said, and to emphasize some of the points, let's look at only two areas in detail–wheels and axles. As we suggested at one point in the discussion, the AAR billing for freight cars should be in the area of about $350,000,000 per year (quite a figure), and of this cost about 30% involves wheels.

We have looked at some 120,000 wheel removals involving our fleet cars. Fig. 10 shows the results of one year of this situation. You will note that 26,283 wheels were removed; however, 17,000 and some odd were for associated repairs, but wheels removed for true wheel conditions were 8,670. We shall consider this as a base and all of the percentage figures in brackets relate to the base 8,670 wheels. Before we go further, I might say that our fleet consists of approximately 50% 100-ton equipment and the remainder is 70-, 50-, and 40-ton equipment. Also keep in mind that we are talking about tank and covered hopper cars.

TOTAL REMOVED	26,283	
ASSOCIATED REPAIR	17,613	
WHEEL CONDITION	8,670 (BASE)	
THIN FLANGE	1,565 (18%)	
HIGH FLANGE	652 (7.5%)	
THIN RIM	1,064 (12.3%)	
TREAD SHELLED	497	(13.4%)
TREAD BUILT UP	664	
SLID FLAT	827	(17.7%)
OVERHEATED - STUCK OR DRAG BRAKE	669	
MATE WHEEL SCRAP	2,046 (23.6%)	

Fig. 10. Wheel study—1 year.

In looking at the data as presented, 18% of the wheels removed in that particular year were for thin flange, 7.5% for high flange, and 12.3% for thin rim. A very shocking figure is that 23% of the wheels removed were for mate wheel scrap. In a thin flange situation (18% of the total), the mate wheel is, in our experience, never thin flanged, and is in the majority of cases perfectly usable, and by AAR regulations and rules, remountable. In this particular study, it shows about an equal removal for thin flange and tread wear; however, when one studies about five years of our overall removals, this ratio does not hold, but the thin flange results in about a 1.3 to a 1.35 ratio to 1.0 over tread wear.

In 100-ton equipment, the ratio of thin flange removal to tread wear, which we define as high flange or thin rim, is 65% thin flange and 35% tread wear (1.85 to 1). This is very critical, especially in relation to mate wheel scrap. The present AAR billing cost for a one wear 36" wheel is $182.13, and from our experience, a minimum of 80% of the mate wheels on a thin flange removal axle pair is good and remountable.

The scrapping of 23% of the wheels removed in our existing railroad fleet or, for that matter in the entire railroad fleet, makes no sense from the standpoint of material conservation under any condition. So as not to weight the overall picture, we deliberately picked a year wherein our thin flange and our tread wear were approximately equal. I believe if you examine your own records you will find that the thin flange consistently exceeds the rim wear removal cost and the mate wheel situation, in such a case, increases drastically.

In one of the detailed items discussing possible simple solutions to truck problems, we mentioned lube oil additives to reinforce the requirement, and absolute need for better lubrication to prevent light rusting and pitting. We would illustrate this through Fig. 11. It is a single year axle removal study in our fleet. Total removed, as you can see, is around 13,116 axles; however, a number were removed for associated repairs, but 9,351 were removed due to the axle condition. This again is considered as a base. Note that 76.3% or 7,138 axles were removed for the journal rusted or pitted. This was light rusting or pitting and the railroads or ourselves had to recondition the journals for remounting. This is a very cumbersome, costly, and time-consuming task, and as I stated once before, no railroad enjoys removing lightly rusted or pitted axle pairs for rework in their shops. It is suggested that the use of an additive which can significantly reduce this percentage is needed, and should be an AAR requirement ultimately so that the 76% can be reduced, at the very minimum, in half, and wc believe the 50% reduction and more, is readily obtainable.

TOTAL REMOVED	13116
ASSOCIATED REPAIR	3765
AXLE CONDITION	9351 (BASE)
JOURNAL RUSTED OR PITTED	7138 (76.3%)
JOURNAL OVERHEATED	874 (9.4%)
JOURNAL RUSTED OR PITTED (SCRAP)	250 (2.6%)
JOURNAL CUT	605 (6.5%)

Fig. 11. Axle study—1 year.

As a final note and some general comments that one can make concerning things that are occurring today and are definitely affecting material use, energy use, and of course, dollars in cost, is that new wheels have a tendency to hunt less than worn wheels. This is becoming more evident as more and more tests are being accomplished by various railroads and by private owners. Recontoured wheels tend to hunt less than worn wheels. Additional dampening in the truck tends to lessen the tendency to hunt. Wheel hunting causes flange wear, diagonally opposite flange wear in any truck, and it might be said that a solid bearing truck tends to hunt less than a roller bearing truck. That is, the solid bearing truck wheel pair hunts, but it does not throw the entire truck into a hunting mode. In our experience, when comparing thin flange removals from solid bearing equipment versus roller bearing equipment, the solid bearing equipment has about 30% less thin flange incident.

Contouring units that can recontour a wheel tread while the truck and axle pairs remain on the car are available on the market. A number of railroads are doing this for their power equipment. We know of none who are doing it in depth for their railroad freight equipment. Shippers Car Line is presently looking at the dollar and cost justification for accomplishing a recontouring within our facilities as each fleet car is shopped. To date, we have not finished our study, but we are continuing to investigate this possibility.

If one studies 100-ton wheel life, it can be noted that the wheel removed for thin flange ranges in miles life from about 70,000 to 150,000-160,000 miles. If a wheel is removed for tread wear, the range is from about 140,000 up to 300,000 miles. Again I remind you that this is related to 100-ton equipment. In our experience, the average life of a 100-ton wheel, considering all causes, is about 160,000 miles. This compares with the average life of all wheels in our fleet of about 250,000 miles, remembering that the fleet ranges from 40-ton up through 200-ton.

Stated another way, if a wheel is removed for thin flange, it is only experiencing 50% of its available life, and insofar as material conservation we have thrown away 50% of the usable life of a 100-ton wheel when we allow truck hunting to develop thin flange conditions.

Another general comment that could be made is that normally the private owner (Shippers Car Line is no exception) practices periodic maintenance, that is—we call our cars into our shops periodically to maintain them. This is in opposition to the normal railroad practice of running a car in service for perhaps ten to 20 years and sometime during that time, perhaps at the 15th year, accomplish a complete rebuild of the car, depending upon the normal AAR running maintenance to maintain the equipment in the interim time.

We suggest when you consider periodic maintenance versus a 15-plus year rebuild that you examine your AAR billing for the maintenance, removal, and application of integral truck snubbing. In our fleet, we have little or no AAR billing in the truck snubbing area, yet if a truck integral snubbing wears to the point of ineffectiveness, truck hunting is an absolute result and thin flange is the costly result. Accompanying thin flange are severe adapter area wear and bolster, center bowl and centerplate wear.

The practice of replacing one-for-one broken springs without checking the spring grouping for regulation spring height is not unusual in the railroad rip track, and a one-for-one replacement in a "tired" spring grouping results in a sheer waste of money. We would suggest that perhaps each of you would want to examine your spring replacement cost in your AAR in-billing situtation and analyze whether or not you would care to periodically maintain your own spring groupings.

Also, periodic maintenance allows for centerplate service and maintenance. Cars built prior to 1966 do not have manganese horizontal and vertical wear liners and the wear occurring in 100-ton cars built in 1966 and prior is excessive when compared to the 70-ton truck. We have noted instances of centerplate flange contact to the truck bolster bowl rim at between 150,000 and 250,000 miles. If one cares to play with the geometry, in measurements the normal gap in this area is ½" to 5/8" so the centerplate horizontal surface and the truck bowl horizontal surface have worn 5/8". If you will investigate this, you will find that it is fact. Once the truck bolster bowl horizontal surface wears beyond about 1/4", no truck manufacturer will condone or support a remachining in this area. All will advise that the truck bolster is subject to be scrapped. We suggest that this is not a conservation of material, labor, or cost.

Now, there remains how to sell the purchase of a "better mousetrap" to management. For a number of years, we have fought with this problem within our own company. Engineering (each of you as mechanical engineers knows the problem) lives with it every day within your rip tracks and maintenance shops, and yet the majority of railroads today buy the least cost or, stated another way, the cheapest railroad car that can be purchased on the marketplace. Each builder, in turn, to be competitive, is forced to put together the minimum car for sale to the majority of railroads.

We might add that a number of railroads, and thank God for that number, are beginning to ask for and, in fact, demand modifications that will extend the car and component life and will conserve material, labor and cost downstream. I would suggest to you that the least first cost railroad car is perhaps the most expensive overall

AAR COST ANALYSIS GROUP – MECHANICAL DEPARTMENT

$$\frac{\text{FUTURE MAINTENANCE COST}}{(1+i)^n} = \text{PRESENT WORTH}$$

$100.00 IN THE 10TH YEAR AT 10%

$$\frac{100.00}{(1+0.1)^{10}} = \$38.55 \text{ NEW CAR}$$

$100.00 TODAY - $259.37 10TH YEAR

Fig. 12. Maintenance cost analysis approach.

cost railroad car you can place in your fleet.

Fig. 12 shows a very simple cost analysis method used by our engineering people in conjunction with our comptroller's group to convince our management to allow additional first cost for our fleet equipment. It is a very basic formula, and one of the first steps into a much more complex analysis, as to whether or not you can afford to expend one dollar more for the new car when compared to the maintenance costs over the service life of the car. However, take that first step and allow your analysts and cost control people to help you to finalize it with your management. The formula is one of the most basic in accounting and as noted on the top, future maintenance costs divided by one plus the interest factor to the year in which you will experience your maintenance cost equals a present worth, or $100.00 of maintenance expended in the tenth year factored at 10% interest per year equates to $38.55 that you could afford to spend on a new car today. The reverse of the situation is $100.00 expended today should save $259.37 in the tenth year.

I won't attempt to go further in this area because once you start factoring in before and after tax situations, inflationary trends and about five other factors, I am lost and I find that our comptroller's department is the mainstay and my ally in this area. But open the subject up with them and conserve both material-energy, which of course is labor and power, and cost, all of which in the end equate to profit and a profitable operation for your railroad.

Moderator Loftis: Thank you, Bill. Our next speaker will be Loren W. Smith, who I know you are all familiar with, as Loren has served as Conference Moderator for the prior ten Conferences sponsored by Dresser T.E.D.

The Freight Car Truck "Capability Gap"

Loren W. Smith
Manager-Research and Engineering (Retired)
Dresser Transportation Equipment Division
Dresser Industries, Inc.

Loren W. Smith recently retired after 17 years as Manager of Research and Engineering of the Dresser Transportation Equipment Division of Dresser Industries, Inc., at DePew, New York. He has also served as a consultant to the U.S. Government for activities of the National Academy of Sciences and the Air Force Research and Development Command.

Smith received a BS degree from Canissus College in 1935 and furthered his technical education at the University of Buffalo, New York University, University of New Mexico, University of California, and Massachusetts Institute of Technology. He has held research and engineering positions with Chevrolet Motor Company, Linde Air Products, American Radiator Corporation, Curtiss Wright Corporation, and Cornell Aeronautical Laboratory.

He is a member of ASM, AIME, ASME, and AFS and has been active in their national programs. Smith has been General Chairman and Moderator of the Dresser Engineering Conferences since their initiation.

After having conducted ten Engineering Conferences at DePew, it is apparent to Dresser T.E.D. that freight car truck performance is still one of the most pressing problems in our industry. With that obvious conclusion, many of you involved with truck service problems have already thought, "So, what else is new?" or perhaps more kindly, "What is being done about it now?" My talk at this stage in the program will serve as background to the question of what is being done about it. I will briefly review how we got to where we are in truck performance and point out factors in the truck service environment that have to be contended with, in order to get where the industry feels we ought to be.

Trucks and truck problems have been discussed at all ten sessions of the Conferences. From the extensive input from railroad and carbuilder speakers, together with our own observations and findings from tests and service feedback, we are completely convinced that there is a widening margin between service requirements and truck performance. We choose to call this margin the "truck capability gap."

The truck capability gap can be described as the difference between the performance being rendered by the freight trucks currently in operating service and the performance that reasonably should be expected to be rendered by them.

Fig. 1 is a graph which illustrates what we believe has happened in the development of this gap and will continue to do so unless a determined effort is made to correct the underlying causes for it. Performance required and performance provided are shown as linear curves. Obviously, these lines would not be so straight if all of the factors involved were shown, with indications of their influence and chronological sequence. The graph, therefore, shows only the general trend in which the two curves diverge to indicate an increasing gap between the requirements and the capability to meet them. This gap is indicated by the red area of the graph.

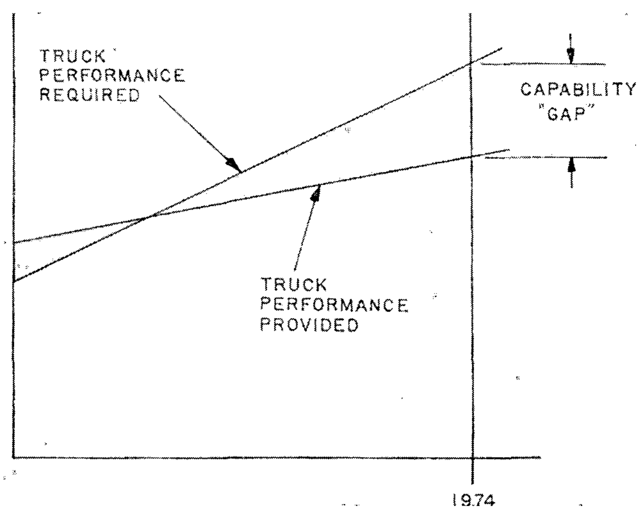

Fig. 1. Truck performance capability gap development.

How did this capability gap come about? First, consider the influence of the truck itself. Since most of the factors involved relate to the past, a few highlights of truck development history will serve to provide a relative orientation.

Most of us are aware that the basic three-piece truck has been with us almost since the infancy of the U.S. railroads. It has been refined over the years to provide remarkable service, both mechanically and economically. The simplicity of it is its greatest asset in that it means low first cost and relatively simple maintenance procedures. This simplicity was also considered to apply to the operating functions of the truck.

Fig. 2 shows a generalized design loading sketch for static conditions. The simplicity of the loading under static conditions is obvious, but we have come to realize that the loadings under dynamic conditions, in contrast, are extremely complex. This is an important part of the problem that faces truck designers. The high-level talent that has been brought to bear on this dynamics problem and the very sophisticated analyses that have been produced to gain an understanding of the mechanics involved attest to the magnitude of the task. During the tour of the Department of Transportation Test Facilities, you will get an idea of the effort that is required just to provide the opportunity for truck dynamics studies.

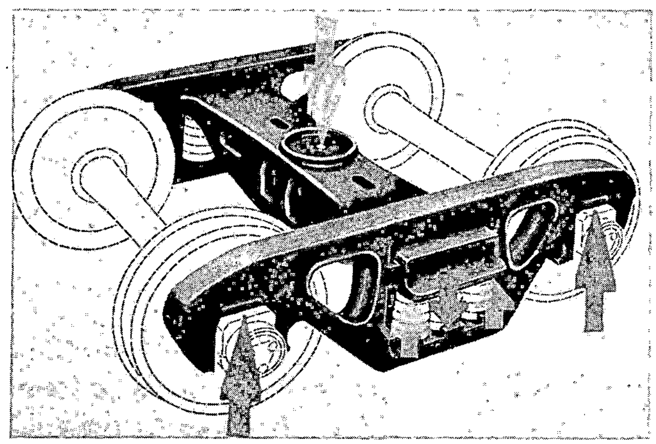

Fig. 2. Generalized design loading sketch for static load conditions.

Returning to the basics, Fig. 3 shows what may be considered the father of the four-wheel truck design. It is the "arch bar." A few of the excellent photographs of railway equipment taken by Matthew Brady during the Civil War show the arch-bar truck in universal use. This design of truck was in general use on railroads in the United States until the late 1920s, when it was "outlawed" for general service in favor of the cast-steel integral box design.

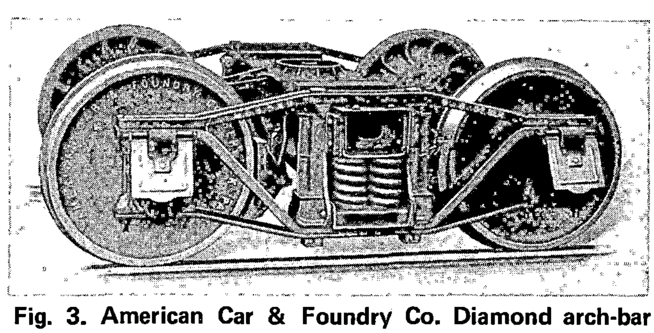

Fig. 3. American Car & Foundry Co. Diamond arch-bar truck—30, 40, or 50 tons capacity.

Although "outlawed," the arch-bar truck can still be found in work service. Fig. 4 is a photograph recently taken of an arch-bar truck after being rebuilt in a modern truck shop for "on-line" service. Some of you may recognize that this truck will go on a snowplow: it is unsprung.

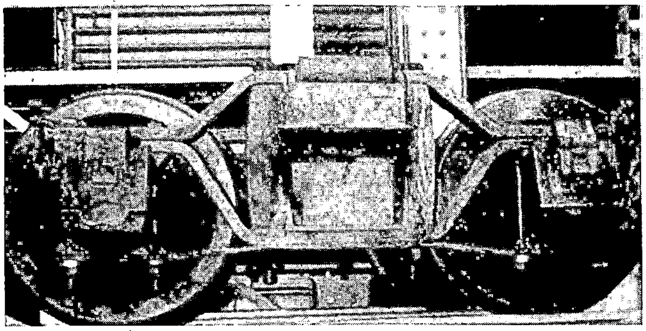

Fig. 4. Recently rebuilt arch-bar truck for "on-line" service, probably for a snowplow, since it is unsprung.

With the perfecting of the open hearth steel furnace in the late 1800s, resulting in uniform, high-quality, low-cost, cast steel to shape, the Andrews type cast-steel side frame (Fig. 5) came into use. This side frame, like the arch-bar design, used a separate journal box which was manufactured of malleable iron. The early designs of the Andrews side frames had various types of section members such as "I," "T," and "L" sections. The "U" section did not come into universal use until the World War I era.

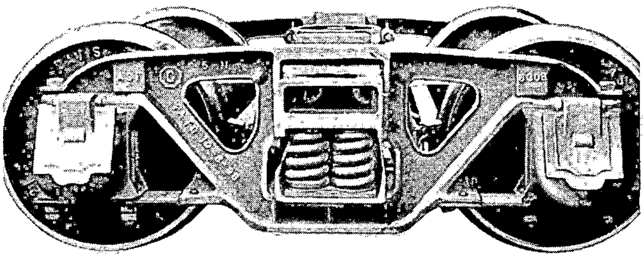

Fig. 5. American Steel Foundry's Andrews side frame truck.

The Vulcan truck, with its jaw-type side frame (Fig. 6), also came into use during the period of the Andrews side frame. This truck also used a malleable-iron journal box.

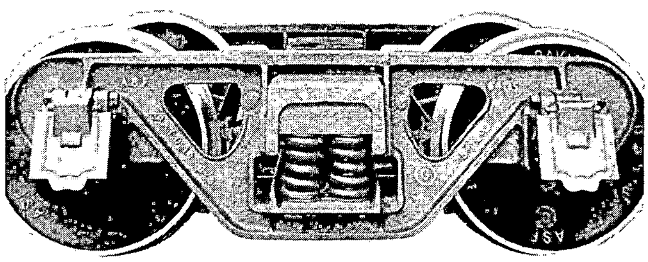

Fig. 6. American Steel Foundry's Vulcan truck.

Another interesting design truck which enjoyed considerable use at this time was the "fox" truck shown in Fig. 7. This truck differed from the usual four-wheel truck design in that the springing was at the journal boxes, and it was of riveted, pressed-steel construction. Its main difficulty was high maintenance.

Fig. 8 shows the Bettendorf integral journal box side-frame truck. It was introduced at the turn

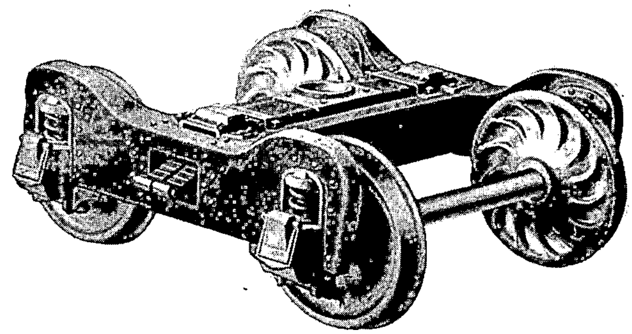

Fig. 7. Pressed Steel Car Co.'s Fox Pressed steel truck.

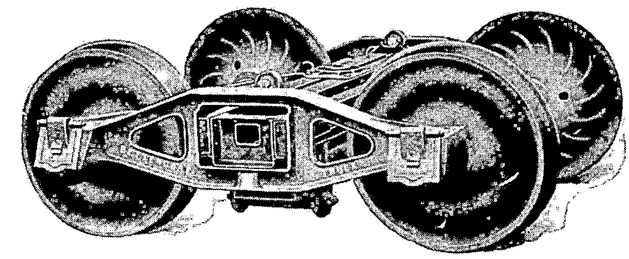

Fig. 8. Bettendorf Co. swing motion truck for 30-ton capacity car.

of the century and gradually outsold the Andrews and other trucks of separate journal box design. During the period just prior to and during World War I, the Bettendorf Co. had such a large volume of integral side-frame business that it was necessary for them to "farm out" a sizable portion of their production to other railway steel foundries such as Gould Coupler Corp., American Steel Foundries, and others.

During this period an interesting design came into limited use. This was the Taylor truck shown in Fig. 9. It was designed by the mechanical engineer of the Reading Railroad, so naturally the Reading was the main proponent of this truck. As can be seen, the bolster, springing, and the spring plank are enclosed in a circular side frame opening to provide ease of side-frame articulation.

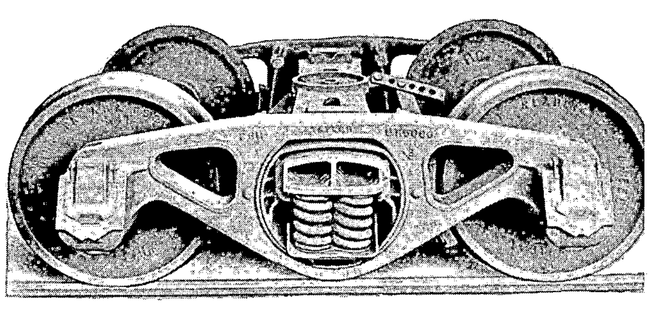

Fig. 9. Taylor flexible freight car truck, minimum height design.

At the beginning of the 1920s, with the expiration of the Bettendorf integral box patents, all the railway steel casting manufacturers developed integral journal box type side frames, and the "U" section design came into universal use. It was during this period that ASF and Symington built and perfected the side-frame fatigue testing machines as tools for proving side-frame designs. These machines are still used for certifying new side-frame designs for fatigue resistance, in accordance with standard AAR acceptance procedures.

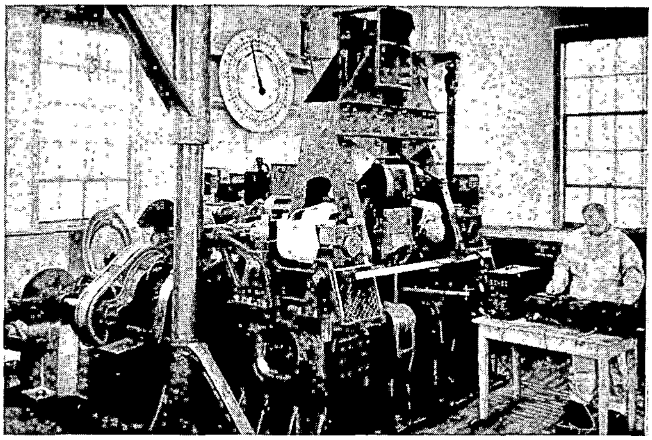

Fig. 10. Side frame fatigue testing machine at Dresser T.E.D.'s DePew, N.Y. plant.

Fig. 10 shows the Dresser side-frame fatigue testing machine at the DePew plant. Early fatigue tests conducted by Symington of all the various side-frame designs proved the superiority of the cast-steel, integral box, "U" section side frame. This machine applies a number of simultaneous loadings to a truck side frame. Service conditions are reproduced. Thus we see that truck designers have been concerned with dynamic loading of side frames for many years, on a go or no-go basis.

In the early 1930s, the major cast-steel side-frame manufacturers formed the four-wheel truck association, composed of ASF, Gould, Buckeye Steel Castings Co., Scullin Steel Co., the Bettendorf Co., Birdsboro Steel Foundry and Machine Co., Ohio Steel Foundry Co., and Pittsburgh Steel Foundry Corp. This association was responsible for the development of the double-truss, self-aligning, inverted tension member, spring-plankless truck. This truck enjoyed universal acceptance during the 1930s. While the "self-aligning" feature of this truck was deemed a necessity for good truck operation at that time, it was later found that a rigid, square truck was superior, and the self-aligning feature was discarded.

Snubbing designs were the main development in the thirties and forties. This development was due to the high damage claims, truck spring failures, and high rate of tank car derailments caused by the galloping action of the unsnubbed trucks. The success of snubbing led, after World War II, to the design of trucks with built-in snubbing systems. These were the forerunners of trucks now in general use, such as the Barber, ASF, and National types. These are friction snubbed trucks, with the snubbing being accomplished through the action of spring-loaded wedges at the ends of the bolster against the side-frame columns.

Over the past 30 years or more many improved designs of trucks have been proposed and built by knowledgeable railroad people. Many of these experimental trucks have gone the long, tedious, and expensive route of field testing by interested railroads. Remember! The primary motivation for truck manufacturers is to come up with a winner. Let me quickly show you a few of the diversified design approaches to trucks that turned out to be losers—losers in the sense that general acceptance by the railroads was not achieved. Some of these did reach commercial status but have since fallen by the wayside, or maybe I should say the "right of wayside."

Figures 11 to 25 show only a small sample of the total number of truck designs developed and evaluated over the years. During the past few years, in spite of the high cost of research and development coupled with an extensive test period required to establish even initial truck acceptance, the truck manufacturers have continued to put their latest concepts on the drawing boards and in some cases have developed experimental trucks for field testing. Indeed, the truck manufacturers are still reaching for the brass ring in the merry-go-round of truck development.

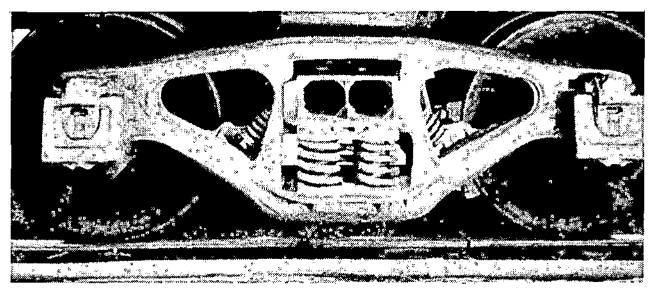

Fig. 11. Holland Co. RS-8 ride stabilizer unit truck.

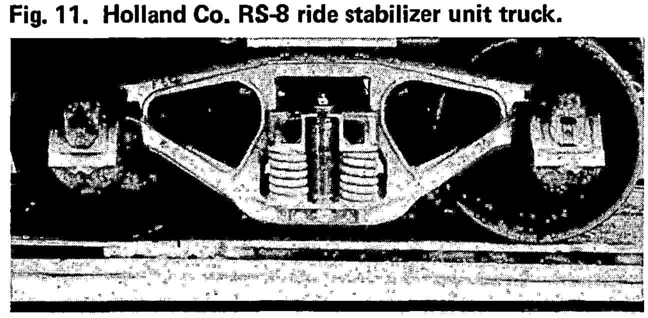

Fig. 12. Monroe Auto Equipment Co. shock absorber truck.

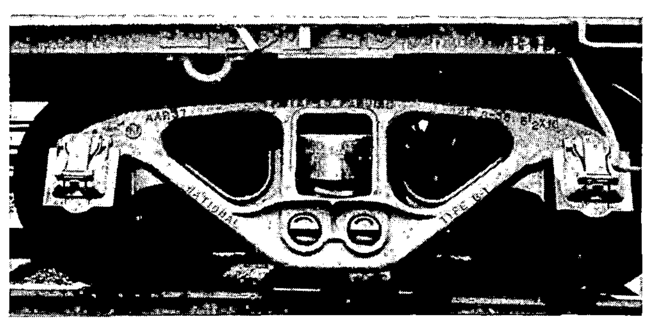

Fig. 13. National Truck Type B-1, stabilized.

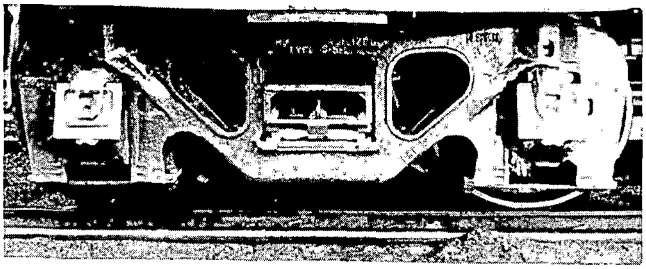

Fig. 14. Standard Car Truck Co. Barber Type S-5-L truck.

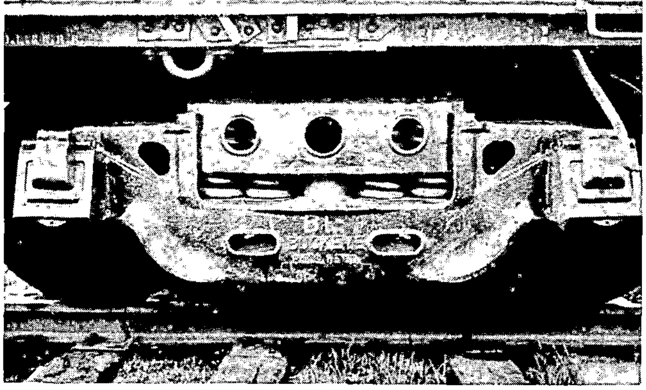

Fig. 15. Buckeye truck.

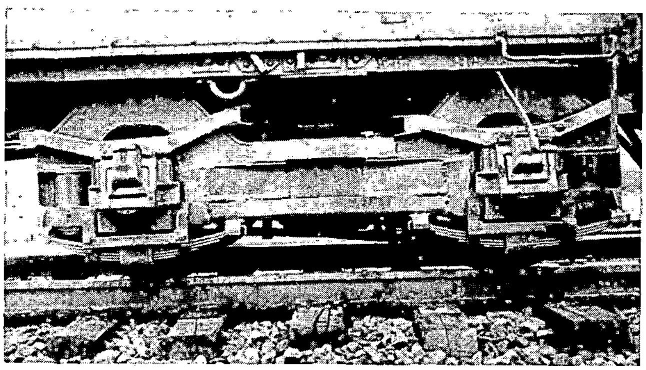

Fig. 16. Allied Railway Equipment Co. full-cushion truck.

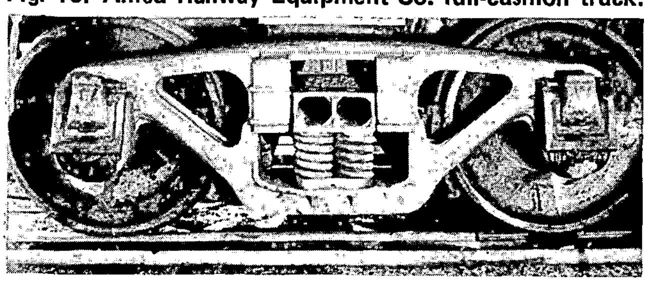

Fig. 17. Scullin Steel Co. L-V truck.

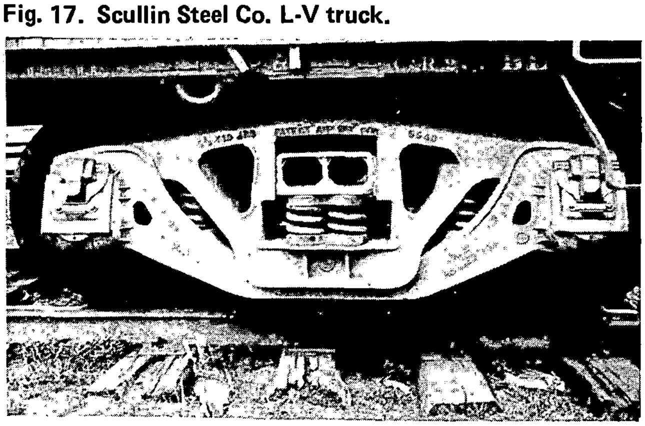

Fig. 18. Scullin Steel Co. truck with two-piece side frame design.

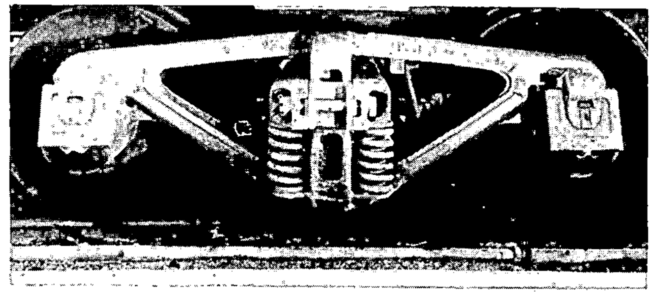

Fig. 19. Frost Railway Supply Co. Endsley truck.

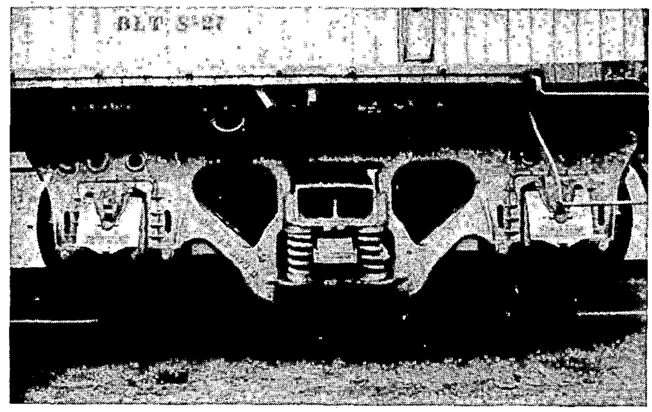

Fig. 20. Symington truck for 1939 AAR tests.

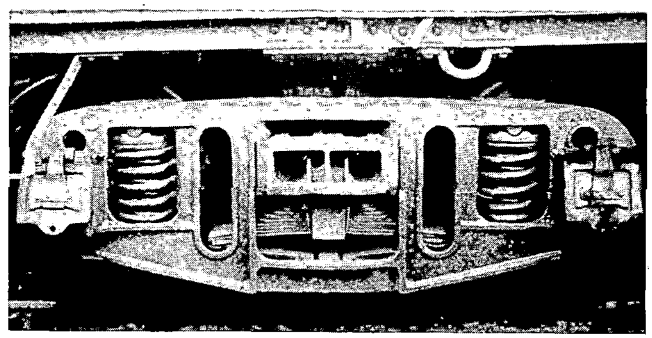

Fig. 21. PRR No. 1 truck.

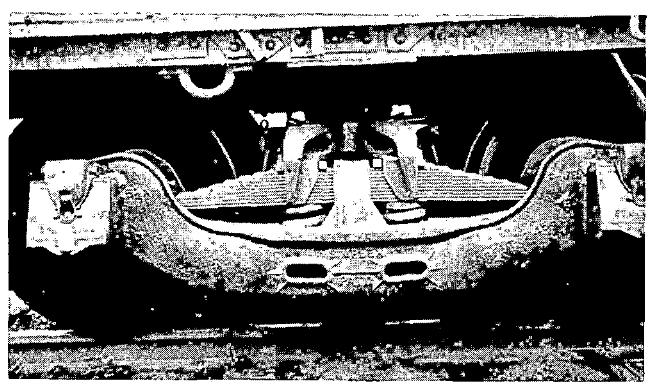

Fig. 22. Bettendorf Co. Simplex truck.

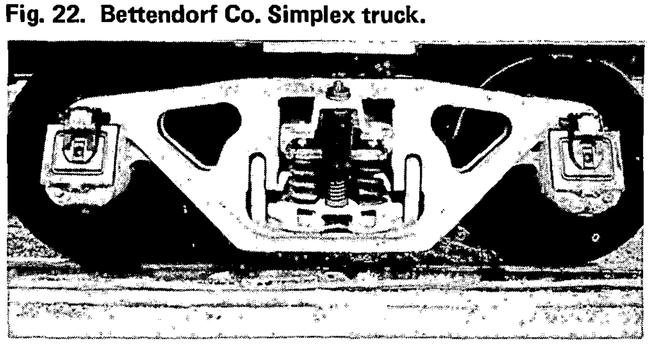

Fig. 23. Symington-Gould Corp. Chrysler FR-5D truck.

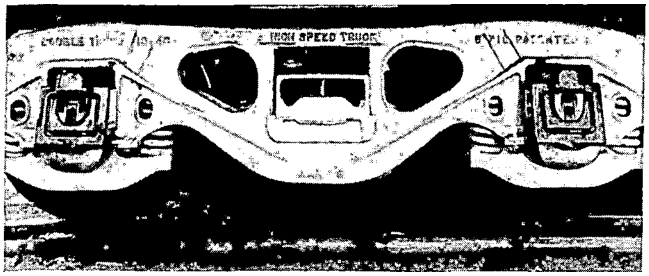

Fig. 24. Symington-Gould Corp. XL-50 truck.

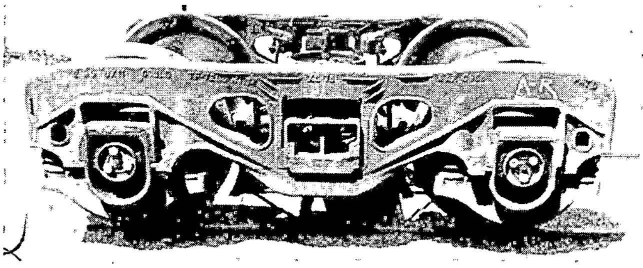

Fig. 25. Symington XL-70 truck.

Thus we see how the basic three-piece design has endured to the present day. While a constantly decreasing portion of the 1.7 million car applications is still providing acceptable performance, there is a constantly increasing number of car applications which are not doing so. The capability gap is widening. The reasons for unsatisfactory truck performance are many. They include the detail design of the truck itself, the car design, the track condition, and the operating conditions in general. To a greater or lesser degree, these factors combine to create the capability gap. Each truck designer has his own ideas as to which one has the greatest or least effect on total car performance.

Most designers will agree on one factor as a principal cause of truck suspension problems. This is, of course, the track condition. However, it is generally acknowledged that because of the tremendous task involved in overall track upgrading, the conditions must be accepted as is for a considerable time to come. Nevertheless, the track condition, which has deteriorated gradually over the past 20 or 30 years because of deferred maintenance, must be fairly high on the list of factors that have caused the capability gap, particularly when related to certain types of freight cars.

This leads us into car design as a causative factor. I doubt if there will be much argument against the contention that car design has contributed greatly to the capability gap. Cars that have a natural roll frequency which becomes synchronous with rail joint cross-level variations in the operating speed range have played a very significant role in creation of the gap.

Increased wheel loading and some revenue-inspired overloading also were not achieved without some increase in the capability gap. Longer cars negotiating the many minimum radius curves subject the truck to added strains and consequently increase the gap a further increment.

Operationally, many cars are being run at much higher speeds and have accumulated much greater mileage. The average rate of speed is continually increasing, as it certainly should. This factor is producing a justifiable increase in the capability gap in terms of mileage, but an unjustifiable increase in terms of wear rate of truck component parts because of the lack of proportion between mileage and wear.

There are many other factors that contribute to the gap in the operational and maintenance areas. These include:

1. Sticking brakes
2. Unreleased hand brakes
3. Broken side bearings
4. Damaged centerplates
5. Damaged body bolsters
6. Excessive wear of parts
7. Skid or shelled wheel treads
8. Uneven loading or load shifts
9. Severe train action
10. Excessive derailing or overturning forces from long train curve resistance and jackknifed couplers

I'm sure that most of you could add to the list of factors that contribute to the gap because of inadequate or deferred maintenance.

Up to now it may seem that I'm suggesting that the responsibility is on everything but the truck itself. To the contrary, we at Dresser T.E.D. believe that the truck does in fact play a major role in the capability gap.

You will recall that earlier in this presentation I mentioned the industry's experience with the self-aligning truck and how it was concluded that a trammed square truck was superior to the extent that the self-aligning feature was discarded. It is ironic that this same type of thinking was again applied in the introduction of a spring-plankless truck which was introduced just after World War II and was apparently successful. I believe that this initial success was due to the squaring action that was provided by the inbuilt friction wedge arrangement that was also adopted at about that time. As I recall, this type of truck provided satisfactory operation in service until the introduction of roller bearings, which eliminated the lateral play of the wheel sets at the journals.

While roller bearings have provided many real advantages, especially in hot box prevention with reduced maintenance, the elimination of wheel set lateral has proven to be a negative factor. Every truck designer knows the value of the introduction of controlled lateral freedom of the wheel and axle sets in the inhibition of hunting problems. The roller bearing manufacturers have made numerous attempts to introduce lateral freedom into their bearings but with no real success, to my knowledge.

The mechanics of hunting and its effect upon the truck, car, and track, not to mention the all-important lading, has been and still is the subject of many studies. I believe a great deal of progress has been made in the last decade in the development of knowledge of the hunting phenomenon and its causes. But this is a complex subject in itself, and I do not propose to dwell on it except to support the contention that truck hunting has indeed contributed greatly to the capability gap. It is well within the realm of possibility that there are other as yet undetermined factors that contribute to the gap.

In the past, there have been other capability gaps. The truck designers have always been able to find ways to eliminate them and keep the basic three-piece truck acceptable to the railroads, who perhaps have set the standard for truck design with that questionable evaluation cliché "Good enough is best." Many improvements in structural design, wear life, fatigue strength, maintainability, and standardization have been introduced, service approved, and AAR accepted over the past 20 years. More are presently in the mill. Many concerned truck manufacturers and AAR representatives are actively involved in relating these improvements in truck performance objectives to the procurement specifications, to assure all railroads the latest innovations at the least cost.

Why can't this problem-solving type of approach to truck development be continued as in the past to keep the performance-provided curve equal to or above the performance-required curve? Why are we in the red? A logical question, and the answer is that we appear to be reaching a point where the gamble of the cut-and-try method of new truck development is no longer acceptable due to the high costs involved and the increasing uncertainty of the outcome. Speaking, perhaps, for most truck designers, we are not at all certain as to the dimensions of the problem. So many changes have taken place, and each interacts with and affects the others to the extent that a renewed understanding of today's basic design parameters is now necessary.

Many of the design improvements made to the conventional current truck were made to correct observed problem effects and have not treated the underlying cause of the problem. Usually this is because we were not in possession of the necessary knowledge relating to the cause. With regard to the economic factors of truck design, we have been unable to determine the true economic value of a possible successful solution. For instance, Dresser T.E.D. has for years been endeavoring to gather economic justification for the XL truck, which has performed so well in many tests and service evaluations but has not been able to make the grade economically to the satisfaction of the railroads in general. We strongly believe the cost is in fact justifiable, based on various data we have developed.

In this frame of reference it is very possible that given the ability to measure the true cost of truck ownership, which takes into account all of the cost factors that detract from railroad earnings, there may be a truck design or a so-called premium truck on the drawing board or actually available that could provide the basic mechanical requirements necessary to close the capability gap at a lower actual cost of ownership than the current conventional truck. We will not know this until a real attack is made on the true nature of the current truck problems and on the total economics of truck ownership. The TDOP truck design optimization project being conducted by Southern Pacific under the sponsorship of the FRA, I am glad to say, has these objectives. We hope it will result in specifications and economic data that will enable the truck designers and concerned manufacturers to provide the hardware that will not only close the gap but provide a margin in the other direction to give the operating people assurance of optimum truck performance and economic ownership.

Moderator Loftis: Thank you, Loren. Our next speaker is Bob Byrne, of SP.

Freight Car Truck Design Optimization Project: Purpose, Organization, and Program

Robert Byrne
Manager-Research
Southern Pacific Transportation Company

Robert Byrne is Manager of Research for the Southern Pacific Transportation Company, San Francisco, California. A native of New Jersey, he received a BS degree in Chemical Engineering from Lehigh University in 1952 and an MS in Chemical Engineering from Northwestern University in 1959.

Byrne joined the Association of American Railroads, Chicago, as a chemical engineer on the research staff. He was later appointed Director of Mechanical Research and then Research Director of the association. His present position was assumed in 1972.

He is the author of several articles on railroad materials and components and a member of the American Society of Mechanical Engineers, Air Brake Association, and Newcomen Society. Byrne has been chairman of the AAR Committee on New Truck Designs for Freight Cars.

Introduction

On June 28, 1974, the Department of Transportation's Federal Railroad Administration awarded the Southern Pacific Transportation Company a contract to conduct a comprehensive study on freight car trucks. In announcing this contract award, J. W. Ingram, Federal Railroad Administrator, commented that projected increases in rail transportation demand, coupled with increased emphasis on improved safety, point toward the need for entirely new approaches in basic freight car truck design.

The Federal Railroad Administration/Southern Pacific Truck Design Optimization Project (TDOP) is an important step in finding modifications to existing trucks that will improve performance and lower overall costs. Furthermore, new generations of trucks will be evaluated for potential use in cars in special service. Southern Pacific, as prime contractor to the Federal Government, will provide for the development of technology required to establish technically sound and economically feasible specifications for new and improved trucks.

In conducting the TDOP, Southern Pacific will coordinate with the railroad and railway supply industries to achieve the most effective results. For example, collaboration with the ten-year Track/Train Dynamics program of the AAR, which is designed to furnish substantial technological input for developing new generations of equipment, is important.

Furthermore, the freight car truck manufacturing industry supplies essential components in support of new freight car construction (see Fig. 1). The TDOP encourages truck suppliers to use their productive and technical capacity to furnish improved truck hardware and to participate on design advances. Principally, this encouragement will be accomplished through development of truck performance specifications, economies of truck ownership, and project participation through Southern Pacific acting as prime contractor.

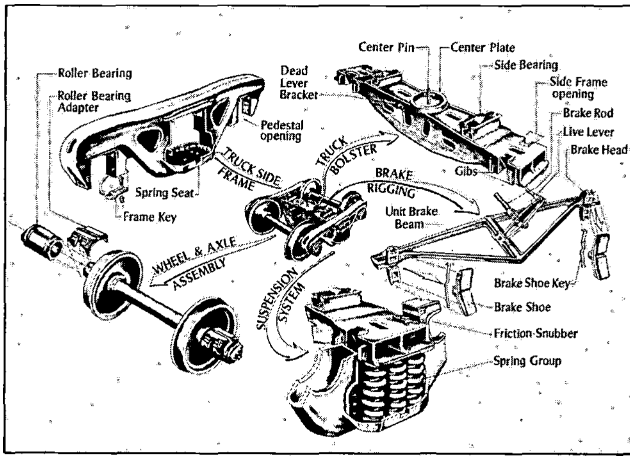

Fig. 1. Freight car truck—components and nomenclature.

Program Objectives

The TDOP is intended to (1) evaluate performance characteristics of existing railroad freight car trucks, (2) determine through cost-benefit analysis the feasibility of improving truck performance by mechanical modification of existing type trucks or technical introduction of new truck designs that respect carbody/suspension system interfaces or are otherwise compatible with existing freight train systems, (3) provide performance and testing specifications for use in the development of freight car suspension systems, and (4) study concepts of integrated carbody support systems and advanced designs in anticipation of future railroad requirements.

Achievement of program goals is anticipated to result in an overall cost savings in railroad operating expenses under conditions of rising traffic and more critical service demands.

Program Phasing

The TDOP will be performed in three phases covering a period of over four years (see Fig. 2). Phasing is planned to provide a systematic approach to the needs of railroads, recognizing short-term requirements in the early phases and longer-term development concepts in the last phase.

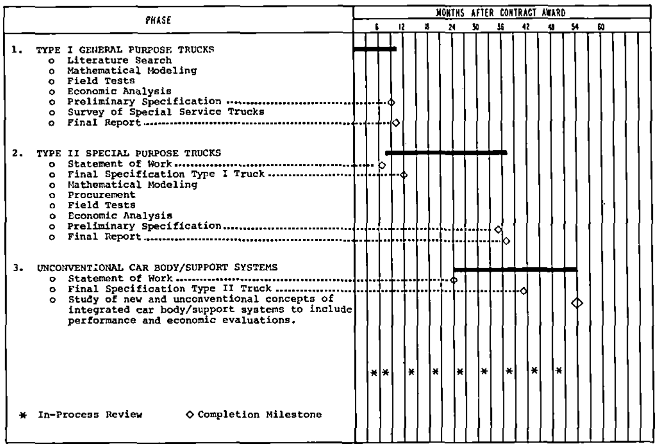

Fig. 2. Freight car truck development–overall project schedule.

Phase I, covering a period of ten months, includes work necessary to arrive at preliminary performance specifications for Type I general-purpose trucks. This phase will also include a survey and appraisal of Type II special-purpose trucks currently under development.

Phase II, projected as a 27-month effort following Phase I, will result in refined Type I truck performance specifications and preliminary performance specifications for Type II trucks. Research will be initiated in Phase II into advanced (unconventional) carbody/support systems.

Finally, Phase III will produce refined Type II performance specifications and will complete the research on advanced carbody/support systems.

Scheduling

The three phases of the TDOP are arranged to proceed sequentially, starting with Phase I, dealing primarily with general-purpose trucks; followed by Phase II, essentially covering special-purpose trucks; followed by Phase III on integrated carbody systems.

The scheduling of tasks for Phase I establishes a logical and rational development of input requirements necessary for creating preliminary truck performance specifications for general-purpose trucks. The schedule includes presentation of progress reports, project orientation briefing, in-process reviews, and a final report. Plans are to give extensive distribution to developments in the project providing railroads, railway suppliers, and others with interests in the project with current information.

In the early months of Phase I (see Fig. 3), preparations will be made for acquiring the data necessary to validate mathematical models of trucks, generate performance specifications, and establish economic criteria. This planning effort will include a review of the literature and background material to be published for general distribution. Department of Transportation track geometry cars will be utilized to select and provide preliminary characterization of tracks on which tests will be conducted. This early planning will include the work of acquiring and assembling a data collection system having the characteristics necessary to provide defined outputs from truck testing. On-board digitization of test data and recording on high-speed tape will be accomplished. Postprocessing of digitized information will be conducted immediately following each day's tests. Data tapes will be stored in such a way that the information can be accessible on a national basis for investigators who may later have need to refer to the test data being generated in this project.

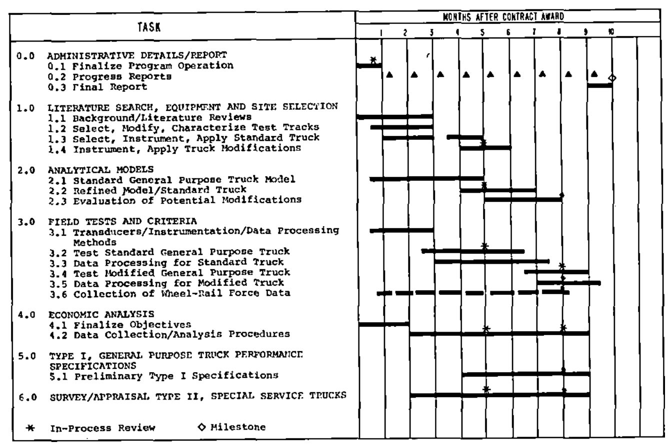

Fig. 3. Freight car development–schedule of tasks for Phase I, general purpose trucks.

Analytical model representations of freight car trucks will be accomplished in early phases of the project. These preliminary representations will be used to finalize the selection and placement of measuring transducers and in finally guiding the specific details in testing.

Truck testing will proceed in the latter months of the project, following completion of the groundwork needed to furnish valid test results. Testing will be accomplished over three sections of railroad having characteristics that (1) will provide forcing frequencies leading to establishment of resonance conditions, (2) will allow high-speed operation where self-induced truck action occurs, and (3) will furnish a variety of curves for evaluating negotiability characteristics of freight car trucks.

The technical aspects of truck evaluation are somewhat advanced as they are related to an economic understanding of truck ownership costs. Consequently, planning for the economic task and creation of data collection and analytical procedures will receive major emphasis in Phase I. Assembling, evaluating, and creating economic standards will be pursued in later phases of the project.

Project Organization and Structure

Southern Pacific Transportation Company is the prime contractor in the TDOP. The project will be executed by the Technical Research and Development Group of Southern Pacific under direction of the Vice President-Engineering and Research (see Fig. 4). A Principal Project Supervisor will administer the project. Four project supervisors will be responsible for the activities of:

1. Analysis
2. Testing
3. Engineering, assembly, and application
4. Economics

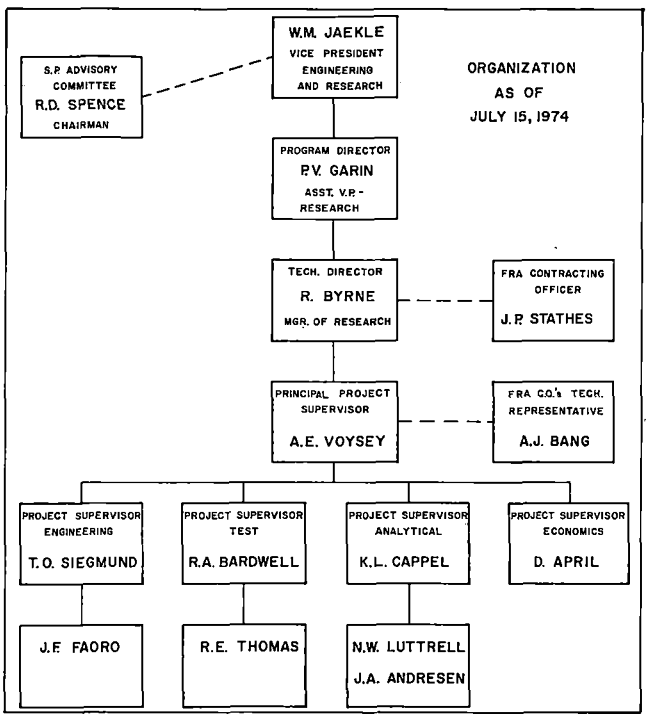

Fig. 4. FRA/SP truck design optimization project.

A Southern Pacific Advisory Committee, chaired by the Vice President-Operations and consisting of representatives from various operating departments, will counsel the project team and lend guidance to progress of the work.

Information exchange and technical reviews will be accomplished through industry coordination, utilizing consulting arrangements for employing, in particular, the interests of railroads and railroad suppliers.

Project Groups. The Principal Project Supervisor will administer and conduct technical and economic aspects of the program, including scheduling and allocation of personnel and resources. His responsibility includes integration of technical details developed by the four project supervisors and subcontractor personnel. Presentations, reports and in-process reviews are arranged within this responsibility.

The activity of the Engineering, Assembly, and Application group involves procurement of freight car trucks, their assembly, and application to test vehicles. Truck components will be measured and calibrations performed as required. Components for use with test trucks and cars will be designed and fabricated.

All measurements and data developed in the performance of work will consider metrication and be in conformance with the provisions contained in Metric Practice Guide, ASTM Designation: E 380-72.

This activity includes, as well, the development of primary areas for use in general performance specifications. These will be modified and detailed as data from the testing activity are evaluated with respect to initial specification ideas.

Engineering analyses of modified trucks and of new truck concepts are an important function in the Engineering activity. These analyses will be conducted in close cooperation with designers and potential suppliers of trucks preliminary to consideration for testing and field evaluation.

The Analysis activity, coordinating with all other aspects of the program, involves instrumentation requirements for field and simulation testing programs. Data reduction and data analysis methods will be derived for general application in the TDOP and for future reference in subsequent research into suspension systems. Thus, data handling methods and hardware recording and processing selection are constrained by the long-term needs of railroads and by the requirement to provide an integrated functioning system. A principal responsibility of the Analysis group is to develop and validate mathematical models simulating truck performance which can be used for predictive analyses of design modifications. Models are contemplated in both frequency and time domain to provide a comprehensive understanding of the dynamics at interfaces of components within a truck system. Completed mathematical models are intended for the use of designers in assessing the potential value of design modifications, with expected extension to truck designs of completely different characters.

The Test function in the project covers procurement of instrumentation, installation, and checkout in Southern Pacific's instrument car, and scheduling and conducting field and laboratory tests. Transportation planning involving assignment of test trains, train crews, and schedules is coordinated within the Test activity.

Field testing of freight car trucks will be conducted on Southern Pacific's tracks in the San Francisco Bay area. Initially, the Federal Railroad

Administration furnished their track geometry measurement cars to assist in the selection of tracks for testing at high speeds, moderate speeds, and over curves and grades. Three test locations will be selected to represent a spectrum of track conditions on which trucks are to be studied (see Figs. 5, 6, 7, 8, 9, 10). Tests are planned in the Rail Dynamics Laboratory at FRA's Pueblo Test Center (see Figs. 11, 12, 13).

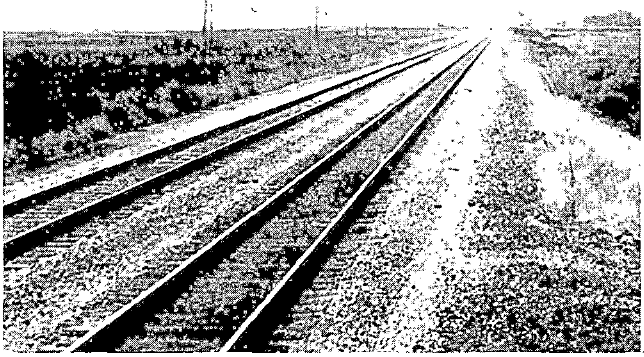

Fig. 5. Illustration of test site—freight car truck development—test track section, high speed running, main line west, Suisun, Ca., MP-43.3.

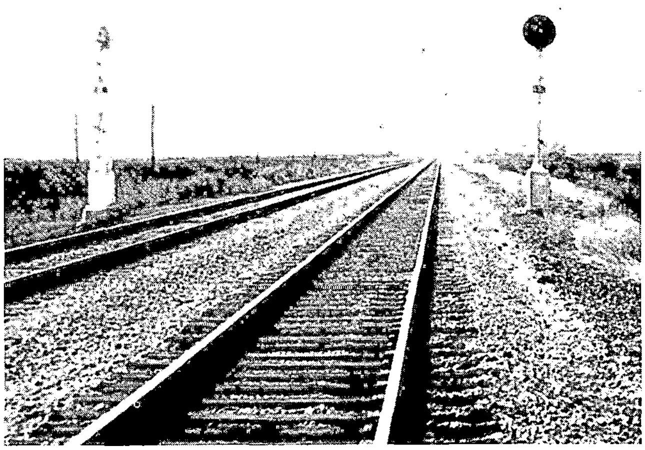

Fig. 6. Illustration of test site—freight car truck development—test track section, high speed running, main line west, Suisun, Ca., MP-43.3.

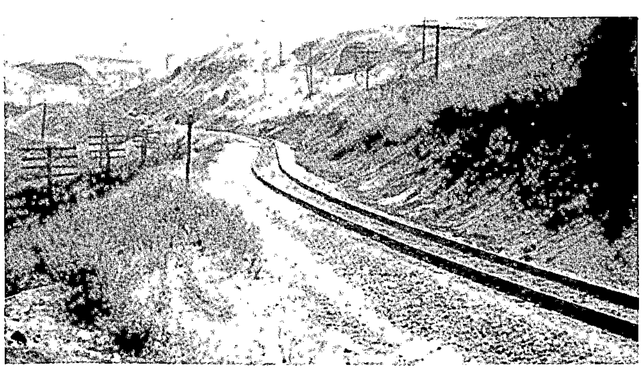

Fig. 7. Illustration of test site—freight car truck development—test track section, curve negotiation, 1% grade, Altamont, Ca., MP-56.

Fig. 8. Illustration of test site—freight car truck development—test track section, curve negotiation, 1% grade, Altamont-Ulmar, Ca., MP-53.

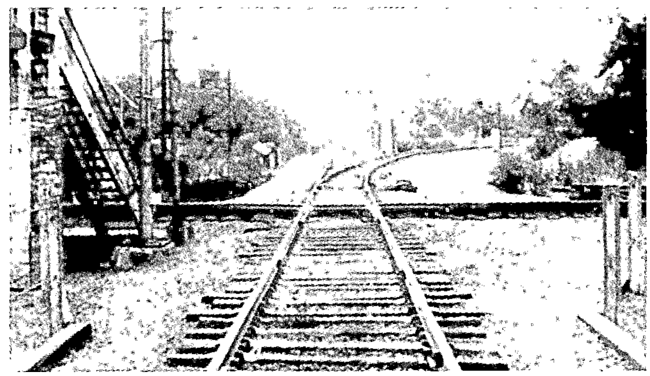

Fig. 9. Illustration of test site—freight car truck development—test track section, vertical/lateral vibration, WP crossing, Snoboy, Ca., MP-29.7.

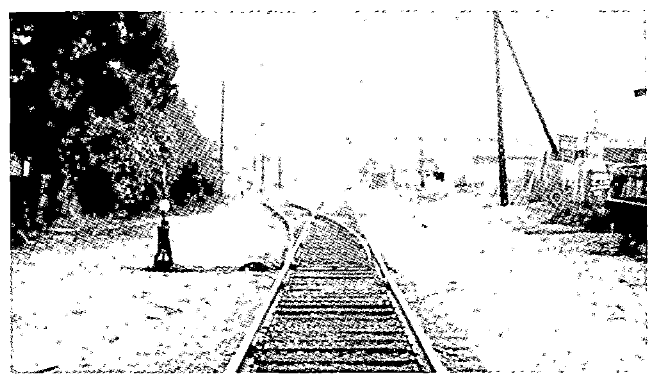

Fig. 10. Illustration of test site—freight car truck development—test track section, vertical/lateral vibration, Irvington, Ca., MP-32.

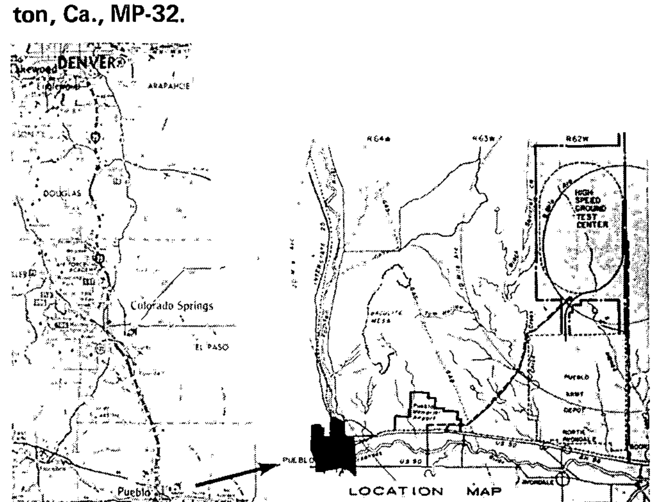

Fig. 11. High Speed Ground Test Center location map.

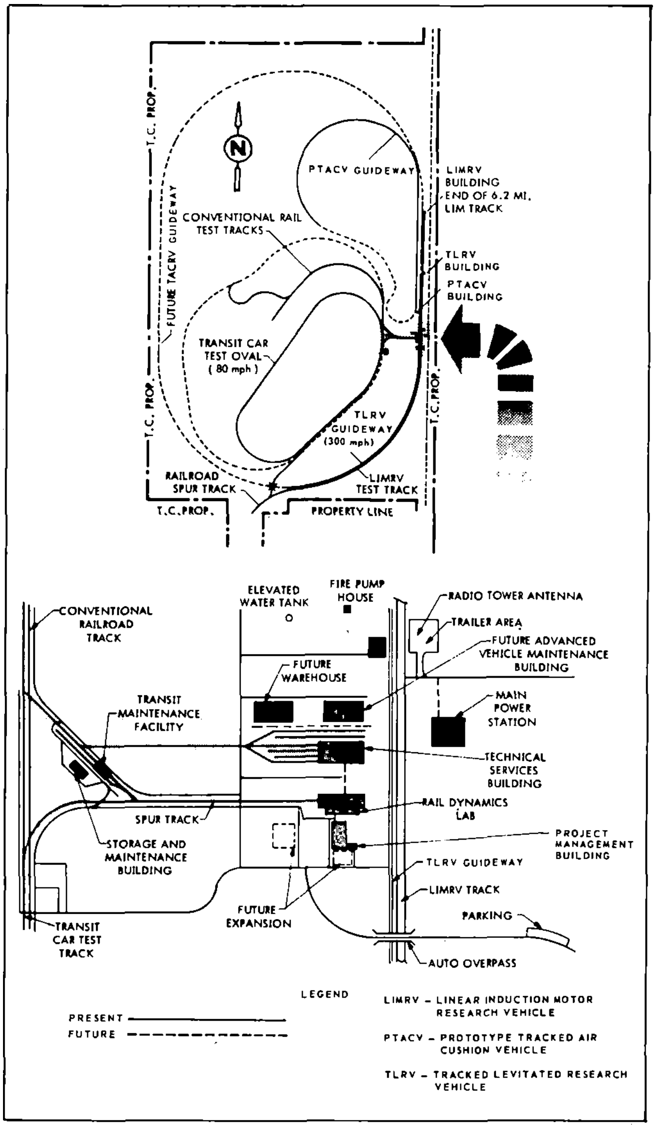

Fig. 12. High Speed Ground Test Center overall layout.

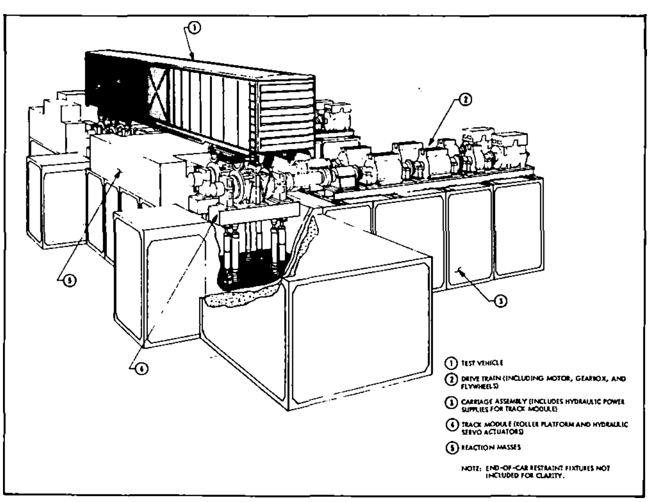

Fig. 13. Cut-away view of rail dynamics simulator with typical test vehicle installed.

A further responsibility of the Test group is to define testing requirements to be included in truck performance specifications as they ultimately evolve.

Economic activity in the project is to support the selection of future truck types for railroad freight cars. Only limited data are available at the present time to equate the economics of truck ownership with technical performance. A cost data base requires development to use with cost models that will be evaluated in the initial phase of the economic work.

Eventually, the Economic function will be broadened to achieve a data base of industrywide costs. This will include costs relating to lading damage, truck maintenance, car utilization, safety, and financial investments. The ultimate acceptance and use of improved truck hardware will be influenced by economic choices.

Outline of Tasks in Phase I

Since the Phase I effort is specifically covered by the contract award, a general description of tasks is included below:

Task 1.0: Literature Search, Equipment, and Site Selection

Subtask 1.1: Background/Literature Review

A thorough search of railroad and related technical literature fields will be conducted, including domestic and foreign material pertaining to freight car truck designs and development. A comprehensive bibliography of the findings will be prepared for subsequent publication. Significant monographs will be included in the bibliography. The bibliography will contain references so that source of material is readily identified. An overview of contemporary freight car truck development will be presented in introductory material.

Subtask 1.2: Select, Modify, Characterize Test Tracks

Based upon data obtained from FRA track measurement cars, field testing sites will be selected that typify operating conditions likely to be encountered by cars in national revenue service. In selecting test sites, the principal consideration will be conditions most likely to produce inputs that excite freight car trucks to respond with vibration modes or patterns that will characterize their performance limits. The test sites will be used in repetitive test runs, with cars having initially unmodified and later modified contemporary trucks. As required, the track structure will be maintained to produce the desired excitation and ensure a representative performance spectrum.

Subtask 1.3: Select, Instrument, and Apply Standard Trucks

Contemporary general-purpose trucks in each of two common load ratings, 70- and 100-ton class, are scheduled for testing and evaluating performance. These trucks are the three-piece, friction-snubbed type widely used on domestic railroads. Contemporary trucks are considered suitable for low-cost incremental improvements through the replacement or variation of components or by simple mechanical modifications capable of being performed in conventional railroad maintenance shops. Trucks will be instrumented to provide for the measurement of dynamic responses necessary to define performance quantitatively. Instrumentation will further provide the capability for correlation of truck performance data with track geometry data measured by FRA's track geometry cars. Instrumented trucks will be used with 70- and 100-ton capacity freight cars, including a representation of various car lengths in common usage.

Subtask 1.4: Application of Truck Modification

In the course of Phase I, "breadboard" modifications will be designed, fabricated, and installed to determine the effects of these features on general performance. Modifications are chosen as a result of earlier freight car truck studies conducted for Southern Pacific, using a dynamic test machine. "Off-the-shelf" components and devices will be used to determine potential improvements possible with existing type truck. No proprietary design efforts are intended.

To the extent possible, the analytical modeling performed in other tasks will be employed to guide the use of specific modifications. In addition, a certain amount of predictive analysis may be used with the expectation that verified models will assist truck designers in their approach to developing practical commercial hardware for improving trucks.

Task 2.0: Analytical Models

Mathematical model development is for the purpose of analyzing the dynamic action and force paths of contemporary trucks and for the further purpose of furnishing an additional design tool to freight car truck designers and equipment builders.

Subtask 2.1: Standard Truck Models

Mathematical models depicting the performance of contemporary trucks will be created using existing models to the extent possible. Models created for the project are intended to be compatible for use in assisting in validating the performance of the Rail Dynamics Simulator at the High Speed Ground Test Center (HSGTC). The models will be developed to characterize the actual performance of contemporary trucks. As described previously, these models should be suitable for use in evaluating proposed engineering design changes in existing Type I trucks, using predictive analysis techniques. Provision will be made for extending the mathematical modeling effort in connection with Type II truck studies in Phase II. The systems analysis, programming, and operating procedures used in developing models will be documented to permit wide application and use of the models by truck and freight car designers in their individual engineering development activities.

Subtask 2.2: Refined Model for Standard Truck

Further development and refining of the models created in the prior task will be accomplished by comparisons with data obtained in actual field tests. These data will be used further to verify model predictability potential through computer simulation. A high level of correlation between simulation and actual performance will be sought in the mathematical models prior to commencing evaluation of potential contemporary truck modifications.

Subtask 2.3: Evaluations

Computer simulation and predictive analysis techniques will be used to evaluate potential mechanical modifications to contemporary trucks or new designs that appear to offer improved performance. Modifications or new designs predicted to offer greatest promise for improved performance will be verified through testing. Test results will be used for further verification and to establish a confidence level for the models.

Task 3.0: Field Tests and Criteria

Subtask 3.1: Transducers/Instrumentation/Data Processing

Force, vibration, and displacement data will be collected and processed permitting the characterization of the dynamic performance of unmodified, modified, and new freight car truck designs. This effort will include the preparation of a Data Collection and Processing Plan describing the instrumentation, recording, and processing methods employed in collecting performance data, as well as the analytical procedure that is followed in comparing test results with mathematical models.

Measuring equipment will consist of standard types of transducers applied to test trucks and cars in such a manner that test objectives are achieved. These objectives include, but are not limited to, the preparation of graphical displays showing statistical histograms, power spectral densities, transmissibility, and frequency/amplitude plots to assist in analyzing fundamental vibration characteristics. Additional data displays will be used for studies of force transmission paths traced from the rail surface to the freight carbody.

Arrangements are made to capture all data on digital tape on board the Southern Pacific instrument car. Appropriate internal calibrations and controls are included in software packages to assure that valid and verified data are recorded on the magnetic tape and that analog inputs are faithfully reproduced.

Data processing will be accomplished on Southern Pacific's IBM 370-168 computers located in San Francisco. Using planned security procedures, data tapes will be transferred following each day's test runs to San Francisco for overnight processing. This fast turnaround on data gives nearly real time information on the character of dynamic events and further allows subsequent tests to be immediately adjusted, as needed to emphasize the more important aspects of truck performance.

Subtask 3.2: Test Standard Truck

Field testing of unmodified contemporary trucks at the selected test sites will be carried out. Prior to testing, a detailed test plan will be prepared which delineates the test objectives, schedule, procedures to be followed, and the responsibilities of test participants.

A mechanical refrigerator car, 70-ton capacity, will be the principal car used in testing. In addition, a 70-ton low-deck flat car will be used to study the low-level truck and provide performance data on a long, torsionally flexible vehicle. In addition, a 100-ton car with a short, light body and a 100-ton boxcar will be evaluated. Different types of conventional friction snubbing will be studied at each capacity level.

Subtask 3.3: Data Processing for Standard Truck

Data collected from field tests will be processed on Southern Pacific computer equipment in San Francisco, as previously described. This processing will provide for validating analytical models, for the establishment of preliminary criteria, and for analysis of the performance of various truck designs and configurations. The software product developed in this task is intended to be used for evaluating proposed mechanical modifications to contemporary trucks through computer simulation, as a guide in making "breadboard" hardware for subsequent field testing.

Subtask 3.4: Test Modified or New-Design Truck(s)

Testing procedures used in an earlier task will be employed to evaluate truck modification. Overall performance characteristics will again be determined by operation over high-speed track, moderate-speed track and through curves and over grades. An adequate performing truck will be expected to have good control of frequency induced vibration, be stable to self-excitation, and yet minimize track forces on curves.

Subtask 3.5: Data Processing for Modified Truck

Data processing includes a quantitative comparison of the performance between unmodified trucks and each modification introduced to trucks for evaluation of concept. As multiple modifications are employed, combined effects will be compared to the influence of each single modification. Cumulative effects of several modifications employed collectively will be appraised, to look for optimizing performance over the wide variety of operating conditions employed in testing.

Subtask 3.6: Collection of Data Describing Wheel-Rail Interface Forces (Lateral and Vertical)

The FRA plans to collect data on instrumented freight car trucks owned by them for the purpose of establishing a data base on vertical and lateral forces applied to the track structure. The TDOP is a convenient structure for operating this government equipment and for accumulating data for them over test tracks selected for the principal purposes of the project. Southern Pacific will not supply technical staff personnel for the special equipment involved in this task. Furthermore, data collection, processing, and analysis occurring from the operation of these special trucks will be handled independently by FRA.

Task 4.0: Economic Analysis

Subtask 4.1: Definition of Cost Factors/ Objectives

The comprehensive evaluation of truck economics will originate with development of methodology for conducting the study. Among the factors to be considered in truck economics are initial investment cost, maintenance cost, failure rate, economic life, effect on car utilization, damage to lading attributable to truck performance characteristics, damage to track, cost of capital, and other investment alternatives. The results of this effort will be compiled into an Economic Analysis Plan delineating the data collection and analytical procedure to be followed in establishing economic factors for later use in determining the cost effectiveness of various truck designs. Particularly, consideration will be given to assessing the life-cycle cost implications of the performance specifications, and truck configurations and designs that may result from this research project.

Subtask 4.2: Data Collection/Analysis

A data collection and analysis program designed to meet the objectives of the Economic task will be created. In establishing the economic data base, inputs will be sought from as many sources as possible representing a national experience, drawing upon other railroads, the AAR, suppliers, and others, with appropriate weighting for regional and operational differences to the extent possible. Preference will be given to those sources that offer a controlled or semicontrolled environment where historical data are desired. Statistical reliability and validity are to be considered dominant over sample size in determining input sources.

Task 5.0: Type I Truck Performance and Testing Specifications

Subtask 5.1: Preliminary Performance and Testing Specifications, General-Purpose Truck

Preliminary performance and testing specifications will be prepared for Type I general-purpose trucks. A specification format will be arranged so that Type I truck hardware can be designed, procured, and applied using customary railroad industry practices. AAR requirements for interchange service and safety regulations will be used as required in developing standards.

The preliminary performance and test specifications are to be prepared with supporting documentation so as to permit wide dissemination for review, comments, and recommendations from the railroad community. This is a prerequisite to the preparation of final performance and testing specifications to be considered for acceptance and use by the railroad industry.

Task 6.0: Survey and Appraisal of Type II Trucks

Many variations of freight car truck design are appearing in domestic and foreign markets. Several different design concepts are included, as design is often based on the requirements existing in a particular service or geographical region. In the course of Phase I, a survey will be conducted to investigate existing trucks and truck designs which might come within the definition of Type II trucks. Furthermore, there will be a preliminary assessment of the desirability of including potential Type II candidates in the test and evaluation effort of Phase II of the project. Technical feasibility, availability, and cost factors relating to these trucks will be evaluated as a basis for recommending the extent to which such trucks might be employed in Phase II studies.

Administrative Arrangements

Southern Pacific Transportation Company, as prime contractor for the FRA in the TDOP, encourages and seeks industrywide participation. Through cost reimbursement-type arrangements, subcontracting for support is within the responsibility of SPT as prime contractor. Subcontracting with railroads, railroad equipment suppliers, AAR, and the Railway Progress Institute, and liaison with the international railway community, will be handled with the concurrence of the FRA. Technical research assistance is sought to ensure the thorough exploration of near-term, well-defined operational payoffs. Invitations for proposals may be employed to engage industry expertise in looking at innovative truck designs and modifications. This type of proposal activity is expected to start near the end of Phase I work. Sole-source proposals are welcome, with consideration to be given for integration in the project as appropriate.

Consultants will be engaged to furnish specialized technical or economic assistance, review project developments, offer recommendations, and otherwise furnish the technical expertise necessary to ensure the achievement of realistic and objective results from the research project. A similar approach employing consultants will be used for obtaining industry input and review during the course of the project.

DOT's High Speed Ground Test Center, in particular the Rail Dynamics Laboratory and the FRA train dynamics track, will be utilized, at appropriate times, for freight car truck and equipment testing.

Summary

The TDOP of Southern Pacific and the FRA presents a significant approach for developing railroad transportation equipment technology by using expertise and facilities existing on the railroads and in its related railway supply industry. Through the FRA's cooperation with railroads in such ventures, equipment improvements can be achieved. Otherwise these improvements would require a considerably longer time to develop and greater expenditures of industry funds. The TDOP is planned to establish technical and economic standards as a basis for developing freight car truck designs with improved performance characteristics.

Moderator Loftis: Thank you, Bob. Our next speaker is Mr. H. Scheffel, of South African Railways.

Modified Three-Piece Truck Reduces Hunting and Improves Curving

H. Scheffel
Chief Mechanical Engineer
South African Railways

H. Scheffel is Chief Mechanical Engineer in Charge of Development of Rolling Stock for South African Railways, Pretoria, South Africa. Born in Germany, he was educated at the Technical University at Darmstadt, from which he was graduated as a mechanical engineer in 1953.

In 1955 Scheffel immigrated to South Africa under contract to the South African Railways (S.A.R.), and he has worked for that railroad ever since. Initially he was in the Production Section, and since 1966 he has been engaged in truck design and riding-quality tests. The Development of Rolling Stock Section which Scheffel heads is equipped with a scientific instrument coach for train operation tests and a test laboratory for impact tests.

Summary

An analysis of dynamic truck oscillations based on the linearized creep theory shows that hunting can be controlled by the provision of elastic links which connect the diagonally opposed axleboxes of the two wheelsets of a truck. The yaw constraint of the wheelsets in relation to the truck frame can then be kept to a minimum, and full advantage can be taken of the ability of wheelsets having conical or profiled wheel treads to align themselves radially on curved track.

The resulting high hunting stability and good curving ensure that the tread profile conicity does not change significantly in service due to wheel wear, and thus hunting stability will be maintained for long service periods.

South African Railways has incorporated such a diagonal wheelset suspension in a three-piece truck of standard dimensions. Encouraging test results have been recorded on empty and loaded gondola-type ore cars using such trucks. Although relatively sharp curves are prevalent on the track on which tests were conducted, flange wear is virtually eliminated.

Introduction

For some time investigations into the hunting stability of railroad cars have been based on the creep theory. If this theory is applied in linearized form to a single wheelset mounted in a roller rig and elastically constrained to ground, we obtain the critical hunting speed of the wheelset, approximately, from the equation: [1]*

$$2V_c^2 \frac{\gamma}{lr_o} = \frac{2k_T}{M} + \frac{2kb^2}{Ml^2} \qquad (1)^\dagger$$

Roller rig (Fig. 1) test results are in reasonable agreement with this equation but show, at the same time, that for rail and wheel profiles of practical interest to railroads, the motions of a wheelset are influenced considerably by nonlinearities [2]. However, we can accept the above equation as adequate for a practical evaluation of the hunting phenomena. From Equation 1, we see that the stability of a wheelset suspended to ground can be increased by increasing the stiffness of the elastic constraints k_T and k and/or by decreasing the wheeltread conicity γ. The above approximation remains valid as long as the sum of the elastic constraints are small compared to the creep constraint. Expressed mathematically, this condition reads:

$$2k_T + 2k\frac{b^2}{l^2} \ll \frac{(2f)^2}{V^2 M} \qquad (2)$$

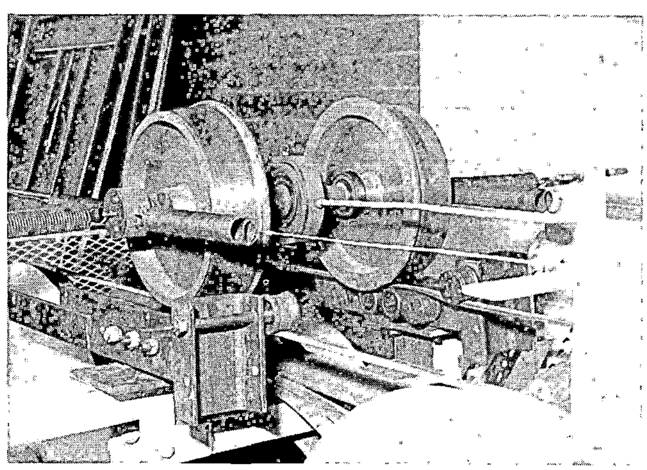

Fig. 1. Model of wheelset in roller rig.

In a railroad car the wheelsets cannot be constrained to ground. They can, however, be flexibly mounted to the truck frame or carbody. However, we find that such suspension to a

* Note: Reference numbers in brackets refer to the references given at the end of the article.

† Note: Equation numbers are given in parentheses. For notations used in equations, see the section at the end of the article.

movable mass (in place of ground) considerably reduces the effectiveness of the constraint from a hunting stability point of view. In fact, a system consisting of a single wheelset elastically constrained to a mass is unstable at all speeds, that is, the effectiveness of the lateral and longitudinal constraints, k_T and k, is lost completely in this case. Therefore, to obtain effective elastic constraint, at least two wheelsets have to be suspended to a mass.

If a system consisting of two wheelsets and a mass is investigated, it is found that wheelset stability increases, particularly with an increase in the yaw constraint k, although to a lesser degree than indicated by Equation 1. We might, therefore, say that in a truck, the wheelsets obtain stability by being suspended to each other in yaw via the truck frame. As is obvious, such yaw constraint impairs the curving ability of the wheelsets as they are prevented from attaining radial alignment on curved track. Conventional truck designs, therefore, rely for curving entirely on the action of the wheel flanges. While such a mode of curving is unsatisfactory in itself because of considerable wear to rails and wheels, it also frequently causes a rapid breakdown of the hunting stability of the car for reasons that will be outlined later on.

Diagonal Wheelset Suspension

If we now return to the wheelset mounted in a roller rig, we see that hunting stability can be obtained equally well by arranging the springs in a diagonal manner (see Fig. 2). In this case, Equation 1 reads as follows:

$$2V_c^2 \frac{\gamma}{lr_o} = \frac{2k_D}{M} \cos^2\alpha \left(1 + \frac{a^2}{l^2}\right) \qquad (3)$$

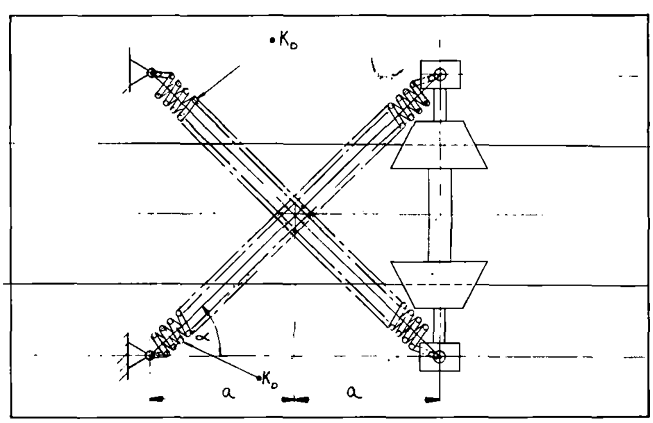

Fig. 2. Wheelset diagonally suspended to ground.

If we apply such a diagonal suspension between two wheelsets mounted in a truck we find that the arrangement results in an improvement of the effectiveness of the wheelset suspension constraints. Thus the hunting stability is increased, and adequate hunting stability can be obtained without resorting to high yaw constraints of the wheelset relative to the truck frame (see Fig. 3).

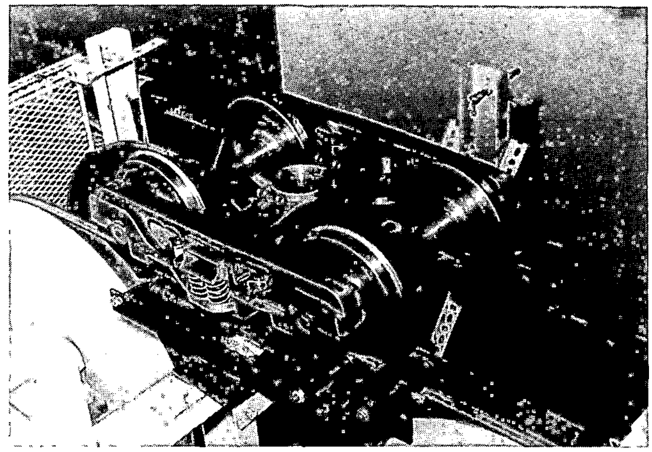
Fig. 3. Model of three-piece truck fitted with diagonal wheelset suspension mounted on roller rig.

It can be shown that a wheelset having conical or profiled wheel treads will execute a pure rolling motion on curved track if unconstrained in yaw [3], provided a certain wheel tread conicity and flange to rail clearance prevails [4].

Concurrently it is evident that the diagonal suspension does not interfere with the curving ability of the wheelset, as it can be made to be virtually unconstrained when the two wheelsets of the truck have attained a radial position on curved track. However, it is not practicable to mount wheelsets in the side frames of the truck in such a manner that they are completely unconstrained longitudinally and in yaw. In any case, an analysis of the curving ability of diagonally suspended wheelsets shows that some yaw constraint is desirable for optimum steering ability of such an arrangement [5]. This optimum is reached when the diagonal suspension is virtually unconstrained while the truck negotiates a curve. To ensure this the longitudinal constraint between wheelset and each side frame should be:

$$k = 2G_R \frac{l^2}{b^2} \qquad (4)$$

As wheel flange and rail wear increase with axle load, k is selected to ensure optimum curving for the fully loaded wagon. For example, for a 25-ton axle load, the optimum longitudinal constraint between wheelset and each side frame is k = 3,900 lb./in. for a wheel tread conicity of 0,1 and 7,800 lb./in. for a conicity of 0,15. In practice we have found good curving can be maintained for longitudinal constraints up to about twice these values. Computer analysis of a complete car for standard gauge (4′8½″) shows that the ultimate hunting stability of such cars can be well in excess of 150 mph.

Test Results

As can be seen from the graphs and photos in the figures, tests conducted on the SAR (3′6″

gauge) with ore wagons (Fig. 4) using such a truck arrangement (Figs. 5, 6 and 7) have provided encouraging results. The longitudinal constraint on these trucks is 2,000 lb./in., i.e., considerably less than the values mentioned above, and the wheel treads have a conicity of 0,2. Nevertheless, good hunting stability has been recorded up to speeds of 75 mph, which is the maximum obtainable with available locomotives (see Figs. 8 and 9). The improvement in flange wear has been very noticeable (see Figs. 10–13). While such reduced wheel wear is a very desirable achievement in itself, it is also of considerable importance to the maintenance of hunting stability for long periods of service.

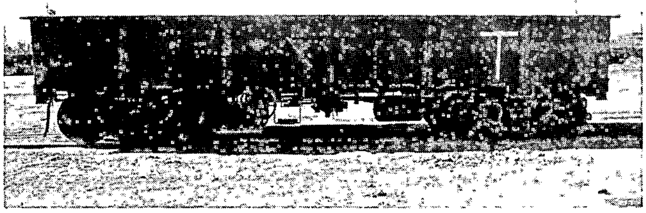

Fig. 4. Ore wagon. Weight of wagon: 33,000 lbs. (tare). Weight of loaded wagon: 164,000 lbs.

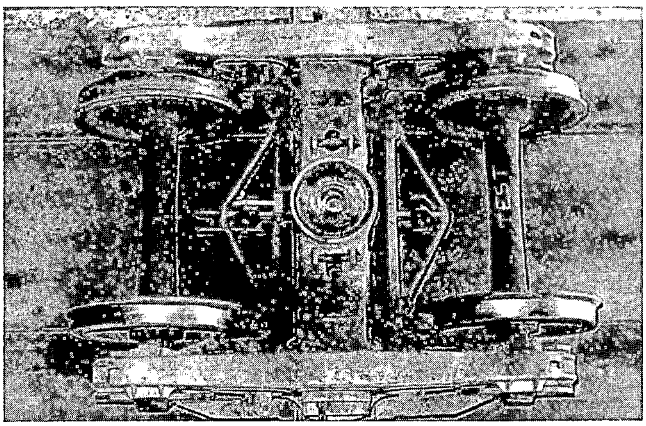

Fig. 5. Modified three-piece truck fitted with diagonal wheelset suspension—plan view.

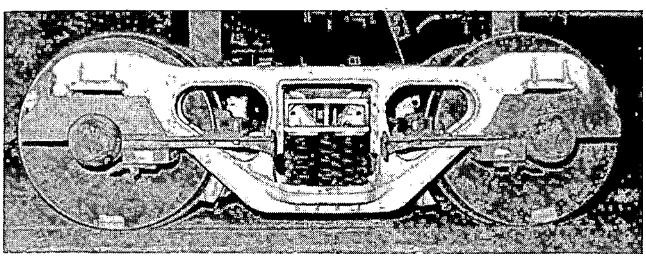

Fig. 6. Modified three-piece truck fitted with diagonal wheelset suspension—side view.

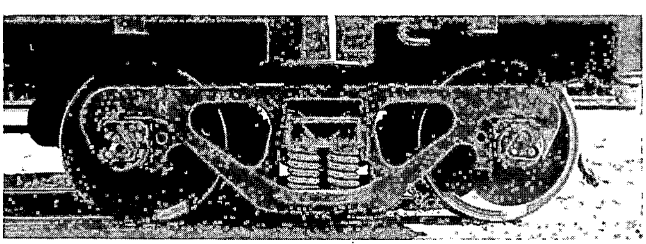

Fig. 7. Standard S.A.R. three-piece roller bearing type truck fitted to ore wagon.

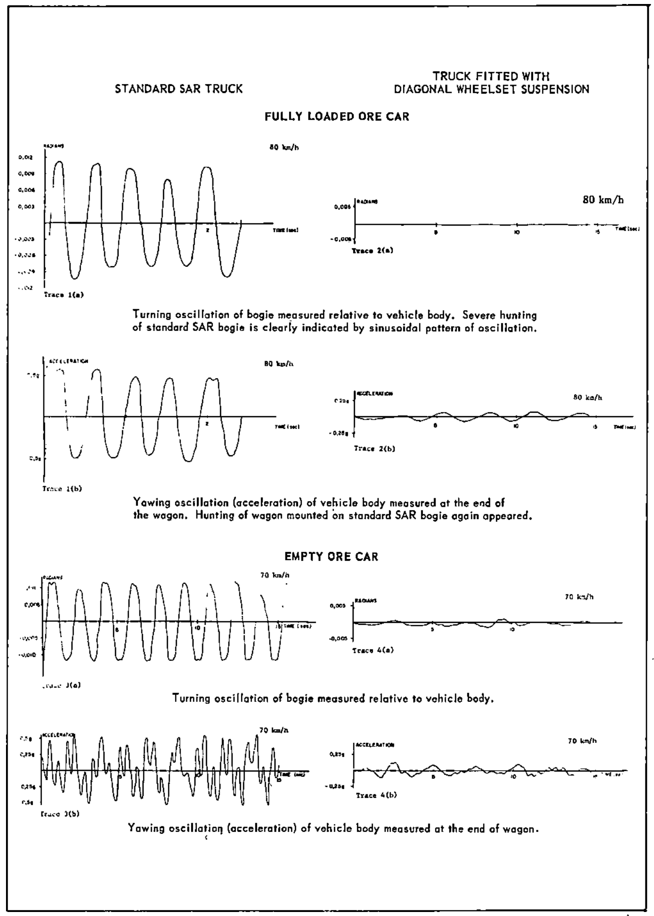

Fig. 8. Comparison between the standard S.A.R. bogie and a bogie equipped with the diagonal wheelset suspension clearly shows the improved riding qualities obtained on loaded as well as empty wagons.

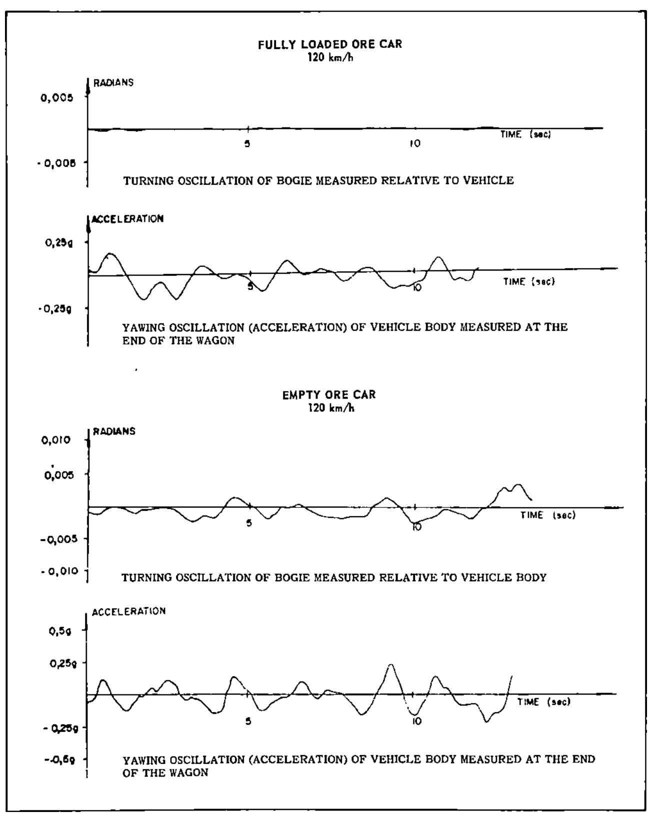

Fig. 9. Bogie equipped with diagonal wheelset suspension.

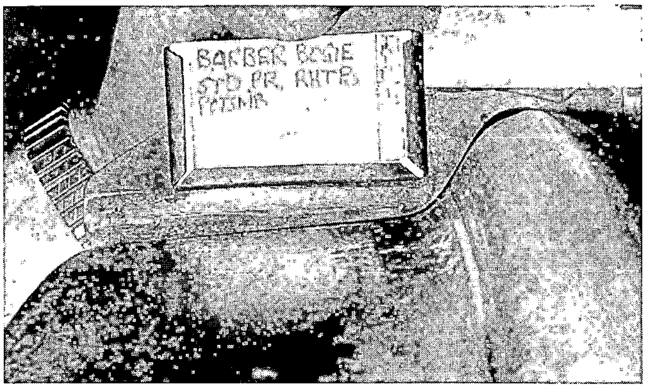

Fig. 10. Condition of wheel tread of wheel fitted to standard truck at start of flange wear test series.

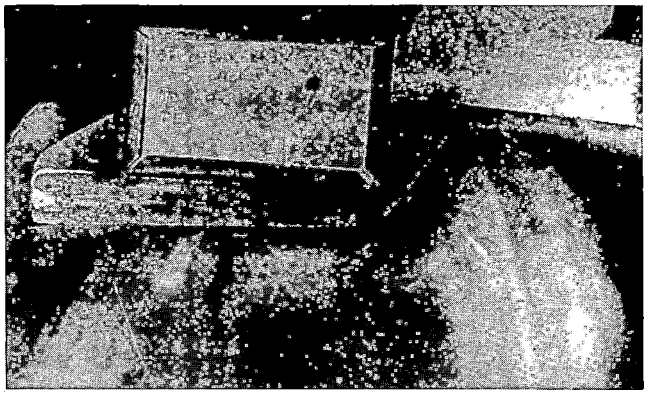

Fig. 11. Condition of wheel tread of wheel fitted to standard truck after a total distance of 20,000 km.

Fig. 12. Condition of wheel tread of wheel fitted to experimental truck (diagonal wheelset suspension system) at start of flange wear test series.

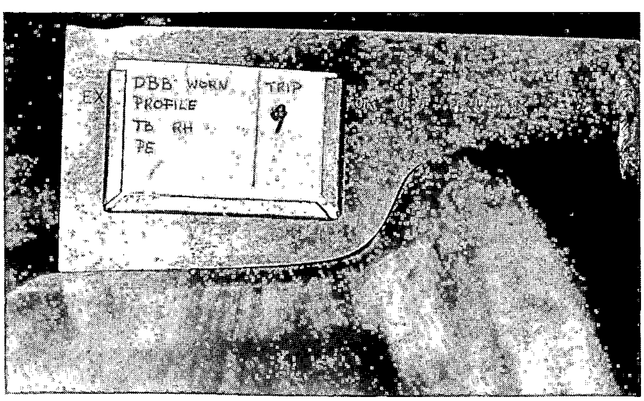

Fig. 13. Condition of wheel tread of wheel fitted to experimental truck (diagonal wheelset suspension system) after a total distance of 20,000 km.

Body Hunting

It is well known that in addition to wheelset hunting, which (as was shown above) is a function of wheel tread conicity, other hunting instabilities occur which are caused by the inertia forces resulting from carbody or truck frame motions. Such forces cause severe hunting motions whenever the natural frequency of the mass concerned coincides with the kinemetic frequency of the wheelsets. From a practical point of view these instabilities are far more undesirable than the wheelset instabilities, as they are frequently experienced well inside the operating speed range of the vehicle. These instabilities can be controlled by suspension damping, but it has been found that such damping tends to get out of tune if there is an appreciable change in wheel tread conicity.

It is well known that in a normal truck, the treads of standard wheels having a conicity of 0,05 when new will rapidly wear hollow. Such hollow worn wheels have a conicity of 0,1 to 0,2, depending on the degree of hollow wear, and it is usually found that a car is far more prone to hunting oscillations when the wheel treads are worn hollow. Apart from hunting motions themselves, wheel tread wear is caused by the slipping motion of the wheels on curved track. Thus reduction of such slippage will ensure a constant wheel tread conicity for long service periods. This is, as we know, a prerequisite for hunting-free operation.

Design Details

Compared to other self-steering truck designs, the cross-anchor truck is simple in design. It was pointed out before that the arrangement is designed to ensure that the anchors are virtually unconstrained on curved track, steering being effected entirely by the conicity of the wheel tread. The anchors and pin joints are, therefore, not subjected to high loads and are of relatively light construction. The low yaw constraint between wheelset and side frames is obtained by mounting the side frames on rubber sandwiches of low shear stiffness. These sandwiches are fitted in axlebox adapters. With the exception of these adapters and the cross anchors connecting the adapters on diagonally opposite axleboxes, the design features of the standard stabilized three-piece truck have been retained.

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2. Law, E. H., and Brand, R.S. Analysis of the nonlinear dynamics of a railway vehicle wheelset. *Journal of Dynamic System, Measurement, and Control, Trans. ASME,* Series G, Vol. 95, No. 1 (March 1973), p. 28.

3. Newland, D.E. Steering a flexible railway truck on curved track. *Trans. ASME,* August 1969, pp. 908-918.

4. Scheffel, H. A new design approach for railway vehicle suspensions. To be published in *Rail International* (October, 1974), pp. 638-651.

5. Scheffel, H. The hunting stability and curving ability of railway vehicles. *Rail International* (February 1974), pp. 154-176.

Notations

- $2b$ Distance between longitudinal spring constaints of wheelset
- f Longitudinal and lateral creep coefficient
- G_R Lateral gravitational suspension stiffness
- k Stiffness of longitudinal spring constraint
- k_D Stiffness of diagonal spring constraint
- k_T Stiffness of transverse (lateral) spring constraint
- $2l$ Distance between wheel/rail contact
- M Mass of wheelset
- r_o Wheel radius, wheelset in central position
- V Constant forward speed of vehicle
- γ Effective conicity of wheel tread.

Moderator Loftis: Thank you for a most informative presentation. At this time, I would like Stan Fillion to again lead the discussion period.

Discussion Leader Fillion: We will have to admit that we have had quite a survey of trucks today. This includes the fine papers just presented by Loren Smith, Bill Ruprecht and Mr. Scheffel. Do you have any questions for these gentlemen?

Delegate Comment: What would the effects of resilient side bearings have been on the rigid truck when the mass of the carbody and perhaps the lading would enter into the damping of the truck motions? What would you anticipate the antihunting characteristics to be?

Speaker Response: Well, we haven't tested that so I would not want to give a definite answer to this arrangement, but I would personally think that such an arrangement would never be better than the unit type frame of the type that we have tested. In other words, from such arrangements you could possibly expect an increase of some 10-15% in hunting stability. However, there is one very important point. We must distinguish between what we normally refer to as body hunting and wheelset hunting. In fact, most hunting instabilities that are being experienced by railroads at present speeds are in fact body hunting instabilities. Frequently these instabilities become apparent only when wheel tread wear has occurred. In other words, you put the truck into service with new wheels and you find it perfectly stable, but after it has been running for some time you find it is unstable. Such body instabilities can be suppressed by resilient side bearings and, under certain circumstances, a considerable improvement in riding quality can be obtained. However, with further wheel tread wear the damping effect of the extension pads could become inadequate and body hunting will recur.

But any body (or secondary) hunting instability can be controlled quite easily without the use of resilient side bearings. I refer to this as the "tuning" of the suspension system. It can be shown mathematically that the wheel tread conicity and all damping and suspension elements you have in the truck must be dynamically tuned to suppress such instabilities; and the tuning is going to be lost with tread wear that is a change in conicity. This is why we place such importance on the curving ability of the wheel as well. Good curving ability is not only required to reduce flange wear, but the curving ability gives you the added advantage that there is not going to be much slipping on curved track. Consequently your wheel tread will not change its conicity for many, many miles of running, and if the wheel tread conicity does not change, the tuning is going to be retained. You are not going to run into any of these secondary hunting instabilities that are rather more bothersome than the so-called wheelset instabilities, which normally only occur at speeds at which we are, at the moment, not operating freight trains at anyhow.

Delegate Comment: I am wondering if you would have said runs counter to some test results we have had—it may or may not. We did operate a rigid truck up to better than 80 mph, which would be far more than a 10 or 15% increase in critical speed compared to a conventional three-piece truck. I guess my question is, does that somehow run counter to your experience?

Speaker Response: No, I am sure it does not. It would help if you could give me the full characteristics of the vehicle you have been experimenting with. Most people look at a particular car in which they happened to experience trouble and then by trial and error try to get rid of the particular hunting instability, without at that stage bothering too much or analyzing too much whether it is in fact wheelset-hunting instability or body-hunting instability. As I said, if the problem was a body-hunting instability (which you can suppress), then the improvement you get can in fact be anything. Remember that the body-hunting instability depends very much on the car you are operating with as well. You can have a truck that is perfectly stable under one car, and you put it under a different type of car and find all of a sudden it is no longer stable. This is because of the destabilizing influences of carbody oscillations.

Delegate Comment: How much actual lateral displacement is there between those axles when they adjust for curving?

Speaker Response: The lateral displacement between the side frame and the adapter for the rubber sandwiches is of the order of half an inch. The longitudal displacement is of the same order. For curving you require longitudal displacement between the axle and the side frame mainly, but we allow about half an inch displacement in both directions.

Delegate Response: Have you ever run standard solid friction-bearing trucks in an ore car, and what was your experience with them?

Speaker Response: You mean what we call plain bearings. Yes, we have these bearings on many of our trucks. The older type of three-piece trucks is of course a plain bearing truck, and we have done many comparative riding quality tests. I cannot go with the statement Mr. Smith made this morning that that arrangement has a higher hunting stability than the one that has roller bearings. In our experience it is just as poor or slightly poorer than the one with roller bearings.

Delegate Comment: How would the wheel flange wear compare?

Speaker Response: The wheel flange wear is of the same order. The same applies to roller bearings having lateral float. We have tested such bearings on freight cars and locomotives and the claims that they would reduce flange wear could not be substantiated under our track conditions: the wear was of the same order as for normal bearings. Before we tried the rigid frame trucks and before we developed the cross anchor truck, we tried everything that we had ever come across in the literature to improve the flange wear and the hunting, and nothing gave us any real improvement.

Delegate Comment: What are the axle mounts and wheel diameters that have been designed for this truck?

Speaker Response: Loaded cars have an all-up height of 164,000 lbs. The wheel diameter is 2′10″ or 34 inches. The wheelset weighs about a ton to 1.2 tons. A truck for 30 ton axle load using 36″ diameter wheels has also been designed.

SESSION II
TRACK/TRAIN DYNAMICS

Moderator Loftis: Before proceeding with Doctor Harris' presentation, I should like to pay tribute to him for the progress he and his department are making in the development of facts about railroads through his policy of cooperative research. Recognizing the need for assistance from all involved in transportation by rail, he has forged a link between industry, railroads, and Government to tackle the most vexing problems facing this industry today. Doctor William J. Harris, Vice President-Research and Test, Association of American Railroads.

KEYNOTE ADDRESS

Cooperative Research in the Railroad Industry

Dr. William J. Harris, Jr.
Vice President-Research and Test Department
Association of American Railroads

Dr. William J. Harris, Jr., is Vice President of the Research and Test Department of the Association of American Railroads, Washington, D.C. He received both BS and MS degrees in Engineering from Purdue University in 1940 and the degree of Doctor of Science in Metallurgy from the Massachusetts Institute of Technology in 1948.

Harris filled staff positions in various agencies before being appointed Assistant Executive Secretary, Planning, of the Division of Engineering of the National Academy of Sciences-National Research Council in 1957. Later he became Assistant Director of the Columbus Laboratories and Head of the Washington Office for the Battelle Memorial Institute. He joined the AAR in 1970.

Harris is the author of about 40 technical papers and co-editor of *Perspectives in Materials Research.* He has been an active member of the professional community, serving as president or chairman of a number of associations, boards, and advisory committees.

It is a great pleasure for me to be here with you this afternoon. I have had the unique opportunity this morning to witness and perhaps to participate in a *Today Show* filming of activities at the Pueblo Test Center. If I carry on at some length this afternoon, it will be because I was required to deal with the entire Track/Train Dynamics program in one minute and 31 seconds, including time for questions addressed to me. Well, for those of you who know Dr. Harris, you know that's some frustration. Please accept my apologies if I repeat remarks made by earlier speakers; I was not here because of other duty.

The railroad industry, with more than 125 years of activity, surely has accumulated a vast reservoir of empirical investigation into how to make this industry run. However, our technological advantage in comparison with other modes of ground transportation has been so great that it is not surprising to find research not vigorously supported once the principal technological issues were resolved in the latter part of the 19th century. However, as soon as the interstate system was completed, the nature of the competition to our industry changed so radically that we had to adopt competitive responses including heavier cars, longer trains, and more intensive operations which we hoped would stay well within the range of our previous experience and understanding.

That has not proved to be the case. The problems that have arisen include track deterioration and dynamic instability, infrequently leading to derailments. They arose, in part, because we extrapolated practice beyond our range of experience. It is for that reason that we now are required to reinvigorate research so as to establish a sounder technological base. To be efficient these programs must draw on the tremendous range of experience in the railroad and supply industries and must utilize the great resources of the government as well as those of the universities and the research institutes.

I don't know what it is like to work in an industry that is denied the opportunity to pursue cooperative programs. We have much to lose in research if attempts to create a more competitive structure within the industry by deregulation destroy the legal basis on which we now can conduct cooperative programs. Many industries cannot deal with these matters as we can. We are privileged by a certain degree of immunity from antitrust prosecution, and we are utilizing that freedom in the national interest through research on safety and transporation effectiveness.

We have several examples of effective cooperative programs. All of you who have been reading the press coverage of our recent reports are familiar with them—the RPI-AAR tank car program; the RPI-AAR coupler safety program; the RPI-AAR truck safety program: a cooperative wheel program with Trailer Train; and a cooperative rail program with the AISI and AREA. Almost all of those cooperative programs also involve deep FRA participation, sometimes in terms of money flowing into these programs and generally in terms of a cooperative planning venture such that our work and the FRA's work are designed to be complementary. The international government/independent program on Track/Train Dynamics is the most satisfying of these ventures because it allows us to bring into sharp focus the critical dynamic interaction between components, cars, trains, and the track structure. From this program all elements of our industry, from operations through mechanical and engineering, can derive more precise insights as to the nature of the loads, the nature of the stresses, the nature of the dynamic forces.

We are approaching the end of Phase I of the Track/Train Dynamics program. It was a gleam in our eyes in 1970, translated into a contract for planning studies with the Southern Pacific in 1971, and became a full-blown program in 1972. As in any program, if we had really known what we were trying to do, we might not have had the courage to start it. But I am glad we did, because I think we have made very real progress on both an empirical and a more scientific and analytical basis.

Officially, Phase I will end December 31, 1974. Ed Lind has been Project Director and has performed with great effectiveness in that role, as you all know. Ed will stay with us until June 30, 1975 to wrap up Phase I and ensure that the loose ends are tidy. Phase II is in the planning stages now. Dave Sutliff from ACF Industries was nominated by RPI to be the Project Director for Phase II. He is on the board now on a full-time basis, working with Keith Hawthorne, one of my associates in the Research and Test Department, who will serve as Deputy Director of this program, and with Greg Martin, who is also a Deputy Director. They are preparing a plan for submittal to our Steering Committee in mid-November of this year and for more public announcement later. Phase II planning is underway and will be officially initiated on January 1, 1975.

A major symposium covering all facets of progress to date on Track/Train Dynamics will be held in Chicago, on December 4, 5, and 6, 1974. You are all welcome—Ed Lind will be happy to give you additional information about the program. I hope many of you have a chance to attend.

In research, once you begin to get some momentum in a program, it is possible to draw in support and enthusiasm for it. But the ultimate concern of research managers is the justification of the commitments made to programs.

What is the payoff? How can it be measured? This we intend to cover in part in the December symposium, but let me share just a few thoughts with you on that subject today.

We have been exceedingly fortunate in Track/Train Dynamics to have a group of governmental personnel and cooperating railroad and supply representatives who have taken back to their companies the lessons they have learned in Track/Train Dynamics. We see being put into railroad handbooks of train handling practice those guidelines generated by the program. We already have taken some of the analytical models that we have developed in the course of this program and, at the request of individual railroads, have determined the degree of stability of individual cars. We are working for the Mechanical Division of the AAR on a number of problems. For example, what are the consequences of changing brake piston travel on stopping distance? There is some possibility of relief in that area. We are being asked by another railroad to use these dynamic analytical models for the purpose of derailment investigation analysis. We now have more than 65 specific questions addressed to us by the Mechanical and Engineers Divisions of the AAR, which can be answered by these analytical tools in a manner not previously possible.

The notion of a cooperative program has been fully accepted. I don't think there is a chance that we can enter into any programs in the future unless everybody is working with us and looking over our shoulders. That's the way it really has to be. The more speculative, conceivably the more innovative, programs must be carried out by individual groups, individual companies, and the government. Therefore, there is no way in which the kind of program that we are now responsible for at AAR can be the entire industry program. It is one important facet of the total industry approach to R&D, but absent commitments by individual railroads, individual supply companies, and the universities, through support from the Federal Government as well as by in-house effort of the Federal Government we cannot have a rounded and balanced research effort. Such a proud-based program is essential for the railroad industry to be able to perform the functions it must perform.

This industry will be expected to take on more responsibility for movement of the goods and people in this country because of the fact that we are a low-energy consumer, and we are a relatively low polluter per ton mile. That will place continuing and enormous demands on us. Our capital expenditures generally involve long-lived equipment and track. We cannot afford to make mistakes in design.

We cannot afford the luxury (given the cost of money today) of making intuitive judgments when an explicit analysis can give more precise insight into the exact solutions to problems and the direction to be taken—construction and operations.

I believe that we have made much progress. We are always delighted to have a chance to share these thoughts and concepts with you, and we are looking forward to the chance to continue to participate in these kinds of Conferences.

Moderator Loftis: Thank you, Bill. Our next speaker is John German, of Missouri Pacific.

A Maintenance Officer's View on the Effects of Freight Car Dynamics

John G. German
Assistant Vice President-Engineering
Missouri Pacific System

John G. German is Assistant Vice President-Engineering for the Missouri Pacific System, St. Louis, Missouri. A third-generation railroader, he received a BS degree in Mechanical Engineering from Case Institute of Technology in 1943.

He began his continuous railroad service as an assistant to the Master Mechanic of the Great Northern at Spokane, Washington. After becoming Superintendent of Motive Power for that road, he left in 1961 to become Chief Mechanical Officer of the Missouri Pacific. In his present position since 1967 he has had charge of the maintenance of way and equipment for all MP family lines.

German is a member of the American Society of Mechanical Engineers, American Railway Engineering Association, and various railroad groups. He has been very active in the Association of American Railroads since 1962 and is presently Chairman of the Mechanical Division General Committee and Co-chairman of the Track/Train Dynamics Train Handling Review Committee.

The species of freight cars which are common to the North American continent operates in an environment that is not experienced elsewhere. In addition to facing extremes in temperature, humidity, and natural weathering, they are exposed to the largest dynamic inputs of train handling and track reaction that are known. Buff forces in excess of 500,000 pounds and draft forces in excess of 400,000 pounds are not uncommon. With the type of couplers and draft gears in use, it is not unusual for a long North American freight train to develop over 100 feet of free slack. With a 2,500,000-lb. locomotive consist on the head end, it is understandable that the shock forces can be tremendous.

As a railroad officer responsible for maintenance of both equipment and track, I have long had a keen interest in the interrelationship of the two. Unfortunately, until Track/Train Dynamics came to the attention of our present-day railroaders, there was little general interest in this interrelationship, except as related to the unknown cause of a specific train accident. Yet I see millions of dollars being spent annually by the railroads because such little attention is being paid to the everyday interface between equipment and track. Too many mechanical and civil engineers lose sight of the fact that any action between equipment and track will cause an equal and opposite reaction. There has not been enough cooperative discussion between the equipment engineer and track engineer in regard to this simple law of physics. The problem is further compounded in some instances by freight rate structures which do not recognize the resulting maintenance problems. The equipment man has blamed bad tracking characteristics of long cars on inadequate track structure, and up to a point he was correct. Yet his equipment was improperly designed to live with today's track, and it accentuated the deficiencies in current track structure design.

Unfortunately, the resulting extraordinary maintenance costs could not be pinpointed in ICC accounts to assist the rate maker in realizing the burden being established. It is through seminars such as this and the previous Dresser Conferences that men from all phases of railroading can get together to share experiences and discuss truly common problems of serious import.

I often wonder which came first in this case—the "chicken" or the "egg." Did the equipment force deterioration of the track, or did track structure deficiency create a deterioration of the equipment? I know of a 28-mi. industrial branch which was constructed some seven or eight years ago. It is a beautiful piece of railroad, but it has been practically unused since the date it was built. In spite of the sun, wind, and rain, this track structure remains today as strong and perfect as the date it was built. Identical track structures rebuilt at that same time to the same standards are already showing the effects of pumping mud in the joint areas, grade crossings, and switches and require annual surfacing to keep them in a fairly smooth condition to handle some 35,000,000 tons annually. It takes the dynamic action of the freight car to accent the deficiencies of the track structure!

Subsequent to World War II, with the aid of dieselization, American railroads were able to operate longer and heavier trains and thus overcome the high cost of the operating crew agreements then in effect. By 1957, dieselization was for all practical purposes complete. During this same period the railroads were replacing their car fleets which had been depleted by the effects of the depression and the war with equipment which had greater capacity. By mid-1955 it was becoming evident that freight car equipment was deficient in design. It was unable to cope with the greater forces resulting from heavier trains and more powerful locomotives, as evidenced by highly stressed areas in the vicinity of the draft gear, yokes, body bolster, side sill to doorway area, and top chords. All-steel cars were needing general repairs every eight or nine years. Certain railroads, and eventually carbuilders, began to take action to strengthen freight cars in these critical areas. Unfortunately it was very costly and time-consuming to stress coat the cars to determine where the high stress levels existed, and the mathematical analyses were too complicated and clumsy for manual computation. Little was known about amplitude and frequencies of vibration or the G-level of vertical and longitudinal forces. Consequently, by cut-and-try methods of changing the types and sizes of the material, the mechanical engineers slowly evolved "beefed-up" cars which, to a degree, withstood the ordinary wear and tear of modern-day freight train service. This effect sometimes was compounded by creation of heavier tare weight and lessening of payload, which affects profits. Some cars gained considerably more torsional resistance, but in so doing, it was not unusual to chase the concentrated forces from one critical area to another. It seemed as though cars delivered up through the mid-1960's were always needing some type of retrofit to offset our lack of knowledge of what really was going on within the freight car structure.

During the 1950s and 1960s our general repair shops were cluttered with cars with broken top chords, warped and split side sheets, and broken door posts, side sills, body bolsters, and draft sills. Too often these cars had been to the shops two or three times for "fixes" which failed or chased the concentrated stress from one critical area to the next. But we are beginning to see improvement in these areas. Cars 12 to 15 years old which are now coming into the shops for general repairs seldom need repairs to the top chord, doorway, and draft sill areas, and we are seeing fewer cars coming in for repairs to the body bolster area.

Since times between shopping were lengthened by better design of these trouble areas, we should have received some respite and the shop load should have lessened. But that has not been the case!

In the first place, modern cars are larger and more sophisticated and require more work per car. Also, the lading restraint devices have been a constant source of maintenance problems. This is due to underdesign caused by lack of knowledge of the forces and vibrations in existence, plus a tendency to use only the minimum amount of restraint. Progress in reducing maintenance is slowly being made. It is obvious that impact tests alone are not the proper basis for design criteria. Train-handling forces and the input from track structure dictate not only maximum forces to be restrained but also fatigue limits.

Secondly, it appears that wear and tear is developing in other critical elements of the freight car as a result of present-day freight car dynamics. For example, new covered hopper cars are suffering from an inordinate amount of wheel wear in their first six months of life, and then the rate of wheel wear declines to what is normally accepted. In my opinion, this is due to the stiffness of the truck assemblies and the rigidity of the carbody, plus the fact that the frictional snubbing shoes are not properly seated within the truck side. Boxcars, particularly 50-footers with roller bearings and some 100-ton covered hopper cars, are showing an extreme amount of centerplate wear on both the carbody and truck. These are cars which are prone to severe truck hunting while traveling empty or lightly loaded at speeds in excess of 60 miles per hour. It appears the running gear needs to be reevaluated. In certain types of cars, particularly open-top hopper cars that are flood loaded, there are entirely too many broken body and truck bolsters, which are apparently the result of rock and roll and the premature collapse of certain rock and roll stabilizing devices.

Fatigue cracking in body bolsters and truck center castings as well as roof sheets of covered hoppers is still too common.

With longer cars and more rigid carbodies, the maintenance officer is sorely pressed to develop a universal set of side bearing clearances for all types and lengths of cars. This is a problem which hopefully Phase II of T/TD and the Pueblo Test Center can resolve in the not too distant future. Obviously our present single standard is inadequate. Hopefully we can find a tie-in to torsional rigidity.

Unit train service, due to its inherent high mileage, seems to bring out the worst in a freight car. Fatigue and corrosive fatigue failures are sharply pointed out in 10–12 years of service. Roller bearing backing rings loosen from axles flexing under flood-loaded cars. It appears that 10–12 years in unit train service is more than equivalent to 40 years in normal service. I don't think we should design all cars to last 40 years in unit train service; however, it is obvious that special-service cars should justify a better car design. It just doesn't seem practical to downgrade specialized unit train cars to general service to get 40 years of total life.

It is obvious that despite all the fine work that has been performed to date by the AAR technical committees, including the Car Construction Committee, as exemplified by their development and updating of the Car Construction Manual, and the serious efforts of supply firms and carbuilders, there is a vast gray area in the design of freight cars to meet the demands of North American railroads. Better car design is a must!

With the development of better car design it is only logical to expect that we can quickly develop better protection of lading from both longitudinal and vertical shocks.

Fortunately, the 10-year joint cooperative venture by the AAR, the RPI, the FRA, and the TDA on Track/Train Dynamics has brought about more awareness of the dynamics to which freight cars are now subjected. With just slightly over two years of work in Phase I, we are already obtaining results which, with proper implementation, will permit better train handling and train make-up practices to reduce the force levels to which the freight car is subjected. With modern-day instrumentation and the use of computers to digest the huge volume of data recorded by such instrumentation, we are now in a position for the first time in the history of our industry to obtain truly valid figures on the levels, amplitudes, and frequencies of forces that are existent in the modern freight train.

The three-year Phase II program of T/TD now getting underway will take a systems approach to setting up interim guidelines on performance specifications for track, wheels, trucks, draft gear and couplers, carbody, and brakes to operate within the present environment. From recent breakthroughs in mathematical analyses for modeling, we now have available some exciting new concepts of finite analysis which can be handled by the computer to quickly develop designs to eliminate overstressing of key areas on the freight car. True, it takes costly computer time, but car repairs are much more costly. Never before have the car designers and the railway maintenance officers had so many sophisticated tools with which to develop performance specifications for components and to solve the problems that are plaguing the car repair shops and fragmenting the chief mechanical officers' budgets.

But all of this development and design work is very costly. Therefore, we railroaders are impatiently awaiting the full-scale development of the Pueblo Test Center to validate mathematical models and design changes. It is extremely unfortunate that this test center was originally set up under the guise of a high-speed ground transportation center, when the nation's strength and future were so closely allied to having a strong, viable, heavy-duty freight train system. Entirely too much time and money have been diverted to test programs involving passenger transportation at futuristic speeds that are obviously far beyond the physical and economic reality of today's railroads. Progress on improving present-day equipment and track structures, which would better serve the nation's economic needs, has been extremely slow. We are just now beginning to see test loops, testing facilities, and activities that will be of material aid to the freight-hauling railroads, the heart of our national transportation system. I therefore plead with the Department of Transportation that efforts in these areas be even more concentrated and accelerated, to the end that national growth will continue to be stimulated through strengthening the railroad's ability to cope with its engineering problems.

The track engineer has a big stake in the effects of freight car dynamics. Most everyone is now familiar with the problem of rock and roll and ways to remedy it—longer truck centers, efficient dampening arrangements, fix the d— track, etc. But in recent years another problem has arisen: i.e., the effect of lateral input from the car into even the best of track. Railroads which handle large volumes of traffic at high speeds are experiencing tie plate cutting on the field side, with resultant wide gauge on tangent track. This is an extreme situation that is probably developed from high-speed truck hunting. Most roads seem to be developing alignment irregularities which also stem from high lateral forces resulting from the combination of car reaction and compressive welded rail forces. Also, unit trains are beginning to take their toll in battered rail and roadbed. Passage of hundreds of like cars daily, all with the same frequency of reaction, are leaving pronounced imprints in rail, tie, and ballast wear. Thus, for equivalent traffic levels, the roadmaster is now forced to align and surface the track much more often. True, better tamping methods, laser beams, and ballast compactors alleviate somewhat the repetitive work required, but we need to reduce the main force vectors to improve track maintenance.

Until more capital money is available for track easements, I believe that there must be a reduction in the growing use of cars which do not properly fit the geometry of today's track. Better accounting by the railroads will prove that such cars are still ahead of their time. I further predict that increased traffic and continually rising costs for rolling stock and fixed plants will force the use of shorter trains. Again, we will all benefit by reduced forces and longer-lived equipment. But our latest T/TD information and design formulas will still be valid and necessary for reduced maintenance and improved operation.

As a maintenance officer for both equipment and track, I feel that we are now entering into the Golden Age of freight car development. We can now determine the forces that are present in today's operating environment. We can soon set up system studies to work out problems and establish sound performance specifications for component parts. We can then alleviate undue unit forces on the car, lading, and track and thus ultimately reduce maintenance costs.

For years the maintenance officer, both equipment and track, had to tolerate his lot in life and do the best he could to combat rising costs with the crude tools and empirical formulas at hand. It was a losing battle in the face of increased traffic and bigger motive power, cars, and trains. Finally, through cooperative efforts of railroads, suppliers, and Government, we are beginning to get a handle on the intricacies and scope of the maintenance problems. I am impatiently looking forward to the use of the new knowledge and tools to develop freight cars that will truly perform a useful life for 40 years and will only require two general repairs during their lifetime. All of us must do everything possible to bring this work to a successful conclusion so that the expense of maintaining equipment and track can be reduced and safety greatly enhanced.

Moderator Loftis: Thank you, John. Our next speaker is Ed Lind, of the AAR.

Anticipated Usage of Track/Train Dynamics Program Results by the Railroad Industry

Edward F. Lind
Project Director-Research Program on Track/Train Dynamics
Association of American Railroads

Since July 1972, Edward F. Lind has been the Director of the International Government-Industry Research Program on Track/Train Dynamics. He is a Registered Professional Engineer in California and Missouri and a member of the American Society of Civil and Mechanical Engineers.

Lind was graduated from Washington University in 1960 with a BS degree in Civil Engineering and received advanced degrees in Computer Science and Industrial Management. He has also been graduated from Stanford University's Transportation Management program. He has worked in various capacities for many companies, including the Army Corps of Engineers, IBM, Caterpillar, Missouri Pacific Railroad Company, and Southern Pacific Transportation Company.

To comment on John German's earlier remarks, after spending about four weeks at the FRA facilities in Pueblo, I have found the FRA has a definite realization that our efforts in the area of track/train dynamics are more relevant than a lot of their work currently being done in the area of advanced concepts for passenger vehicles.

Today, I think this point was vividly emphasized by Dr. Harris in our conversation with NBC. They had no idea that 97% of all revenue accrues to U.S. railroads through our freight operations, and therefore we stressed the point that the FRA should concentrate on developing improved technologies—for freight service. I feel that this might have a real impact on future work to be done at Pueblo.

I will first show a movie entitled "Improve Reliability & Safety of Operations," which depicts the complexities of the Track/Train Dynamics program and shows what we have been able to accomplish to date. Then I will update this film with a slide presentation, to demonstrate our current activities and work that is projected to be completed in the near future.

EDITOR'S NOTE: Movie was shown at this point in Mr. Lind's presentation.

To begin my slide presentation, I will define once again the three phases of the Track/Train Dynamics program as outlined in our original proposal and discuss the objectives of Phase I. Then I will update you on some of the following activities, not described in great detail in the movie:

1. Implementation of our interim guidelines.
2. The analysis of our enginemen sensitivity data.
3. Design and test engineering aid devices.
4. Development of our mathematical models.
5. Completion of our field tests to validate our mathematical models.
6. Parametric and accident investigation studies utilizing these mathematical models.

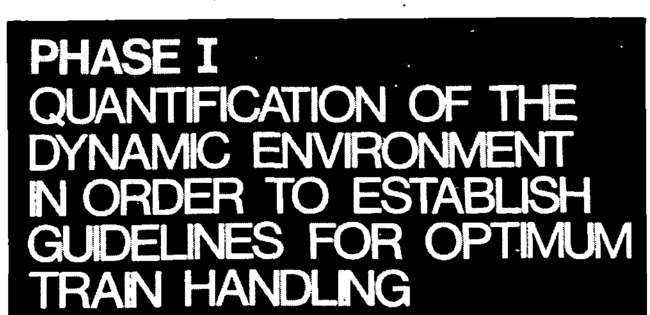


Fig. 1.

PHASE II
ESTABLISMENT OF PERFORMANCE SPECIFICATIONS FOR THE DESIGN OF TRACK, ROLLING STOCK AND COMPONENTS

Fig. 2.

The first three phases of the program are as follows: Phase I is an investigation of our operating environment in order to quantify these dynamic relationships. Phase II is a three-year effort which deals primarily with developing performance specifications for the design of components and systems. Phase III is a five-year effort which deals with the utilization of advanced technologies in order that major improvements in our track/train system can be achieved within an economic framework.

OBJECTIVES
Provide the Most Economical Solutions to the Problem by the Following Means:

Fig. 3.

The objectives of Phase I are:

1. The quantitative evaluation of the dynamic environment using experimental and analytical tools/techniques.
2. Application of this knowledge to develop improved train handling techniques and train make-up policies.
3. Modify existing systems to improve performance of system components in an economic manner.

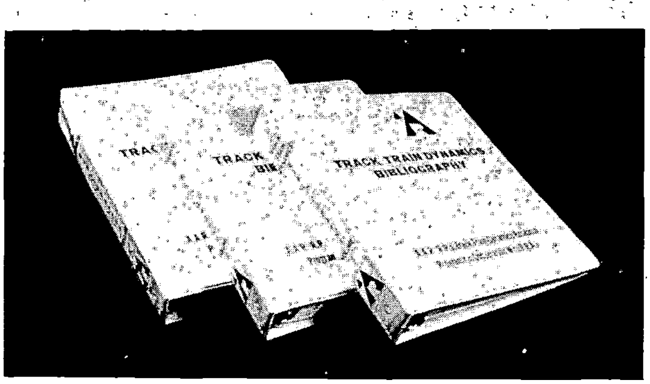


Fig. 4.

T/TD personnel prepared a comprehensive bibliography of subjects in the area of Track/Train Dynamics. Approximately 2,000 publication abstracts have been extensively revised to insure their proper format and to include the proper key word references. The thesaurus and key word index sections, containing the appropriate key words and their cross references, is included in the final bibliographic document.

The published bibliography consists of three volumes, each with a three-hole loose-leaf format to facilitate the later addition of more reference material, which will be issued as annual supplements.

The "Organization of Contents" sheet shown here outlines the organization and contents of the new bibliographic document.

TRACK/TRAIN DYNAMICS BIBLIOGRAPHY
AAR-RPI Track/Train Dynamics Research Program
(in cooperation with FRA)

ORGANIZATION OF CONTENTS

Title Page

Preface

Contents

Instructions for Use		(separator tab)
Thesaurus	(section)	(separator tab)
Key Word Index	(section)	(separator tab)
Bibliographic Documentation	(section)	(separator tab)

Ten numerical separator tabs, marked as follows:

Tab Marking:	Contents of Subsection:
1 – 1000	**American Society of Mechanical Engineers. Also includes the following joint organizations: American Society of Mechanical Engineers–American Society of Civil Engineers, and the American Society of Mechanical Engineers–Institute of Electrical & Electronics Engineers**
1001 – 2000	Railroads (American and foreign), institutes, individuals and miscellaneous
2001 – 3000	**Quarterly Reports,** Japanese National Railways, Technical Research Institute
3001 – 4000	**Railway Gazette** (England)
4001 – 5000	**Office for Research and Experiments,** International Union of Railways (Europe)
5001 – 6000	**Bulletin of the International Railway Congress Association**
6001 – 7000	**Association of American Railroads** Research and Test Department Reports
7001 – 8000	**Proceedings of the American Railway Engineering Association**
8001 – 9000	Published reports by the **Office of High Speed Ground Transportation, Rail Technology Division of the Federal Railroad Administration, Department of Transportation**
9001 – 10000	(Future use)

I might add that this work is being continually updated and will be released through the FRA's Railroad Information Service publications. This bibliography has been extremely beneficial to the

T/TD program because it has enabled us to understand more deeply what research work done in the United States, Europe, and Japan is directly applicable to the accomplishment of our objectives in order that duplication of these efforts may be avoided at all possible cost.

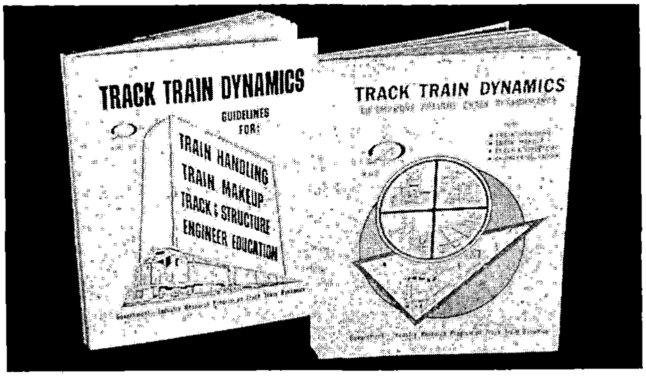


Fig. 5.

Certainly the next activity is one of our major accomplishments. In the next series of slides, I will be describing the Interim Guidelines Manual as well as our implementation activities with railroad personnel. Contained in this manual are some 300 recommendations in the following four major sections:

1. Train handling.
2. Train make-up.
3. Track and structure considerations.
4. Engineering education.

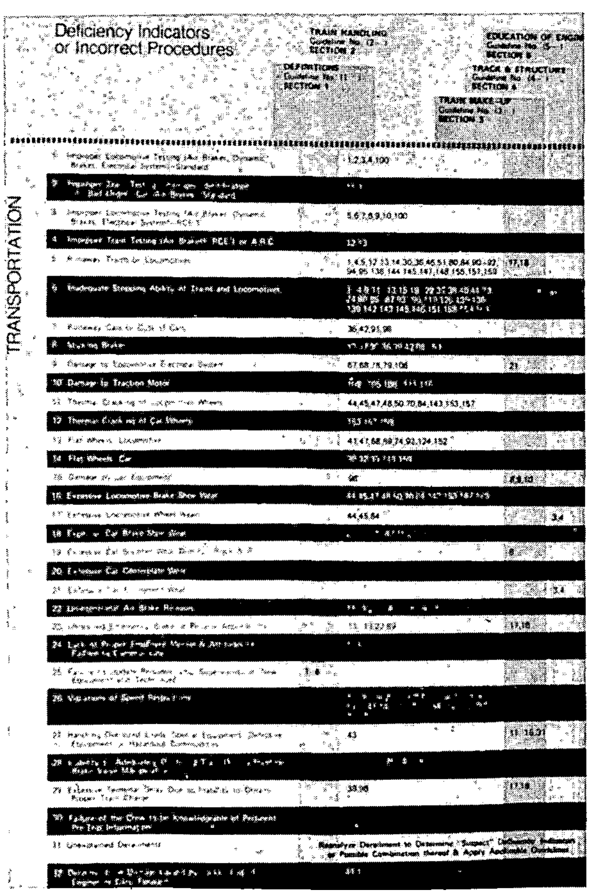


Fig. 6.

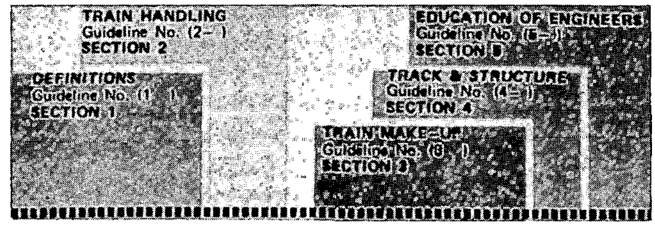


Fig. 7.

We also incorporated into the manual a section dealing with deficiency indicators which, when applied to specific problems, will give railroads and the industry directions on what can be done to solve or reduce the severity of their problems by using our guidelines.

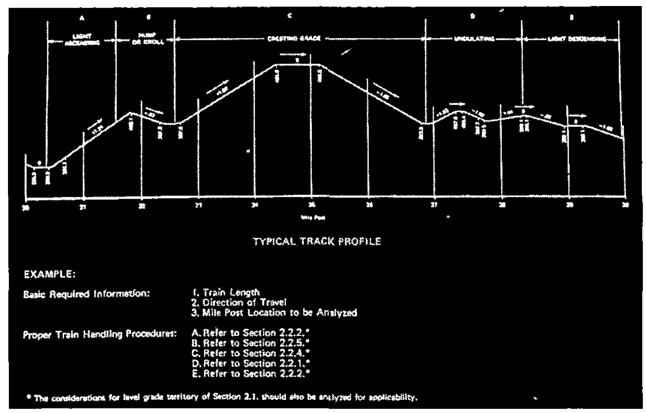


Fig. 8.

This is a copy of a diagram from the Interim Guideline Manual. It is used to demonstrate how certain train handling guidelines could be applied

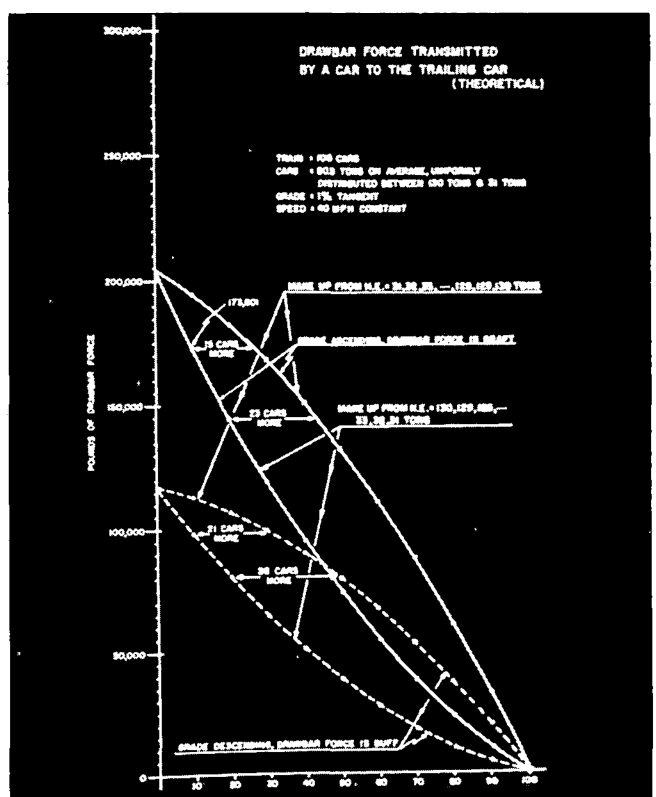


Fig. 9.

to that section of track to improve operations. We have applied these same guidelines to specific railroads, analyzing their territories in order that they could modify their operating rules to improve their own over-the-road operations.

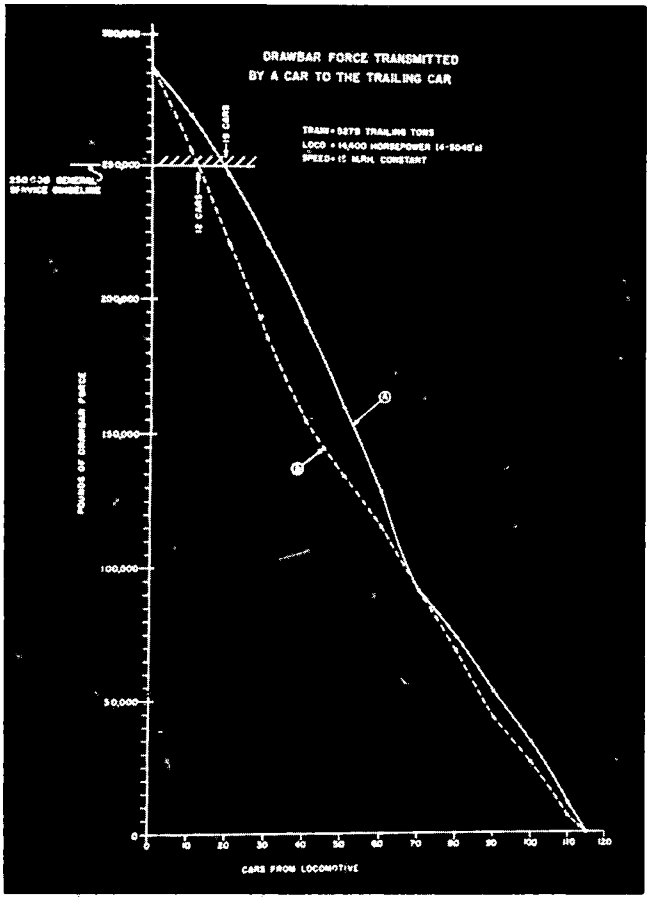


Fig. 10.

We have also looked at train make-up and how a car's position within the train, depending on its distributed mass, relates to the quasi-static and dynamic longitudal force environment. Theoretical train make-up versus hypothetical train make-up theories contained in the book have been compared to investigate comparative situations.

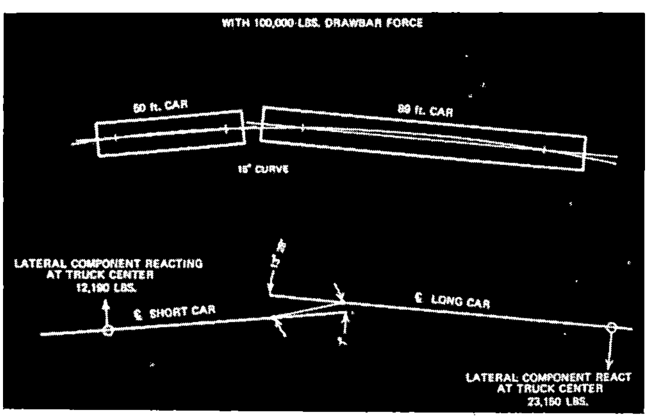


Fig. 11.

The adverse dynamic effect of long-car coupled to short-car trains have been analyzed in high buff and draft situations within the train, and specific guidelines have been generated on the handling of these cars.

Derailment Condition	Unrestrained Rail May Overturn	Flange May Climb Worn Rail	Wheel May Lift Disengaging Flange
Critical L/V Ratio	0.64*	0.75	0.82
Critical Lateral Force	21,440 lbs.	25,125 lbs.	27,470 lbs.
Degree of Curvature	When Draw-bar Forces Exceeds:	When Draw-bar Forces Exceed:	When Draw-bar Forces Exceed:
4°	300,000 lbs.	300,000 lbs.	300,000 lbs.
6°	205,000 "	240,000 "	262,000 "
8°	154,000 "	180,000 "	197,000 "
10°	123,000 "	144,000 "	158,000 "
12°	163,000 "	122,000 "	132,000 "
14°	88,000 "	103,000 "	113,000 "
16°	77,000 "	91,000 "	99,000 "

*Based upon the overturning characteristics of a rail and neglecting the torsional resistance produced by a heavier car both preceding and trailing the light car.

Fig. 12.

L/V ratios and lateral forces as they relate to curve negotiation, rail overturn, and wheel climb have been studied, and values for each of these conditions are listed.

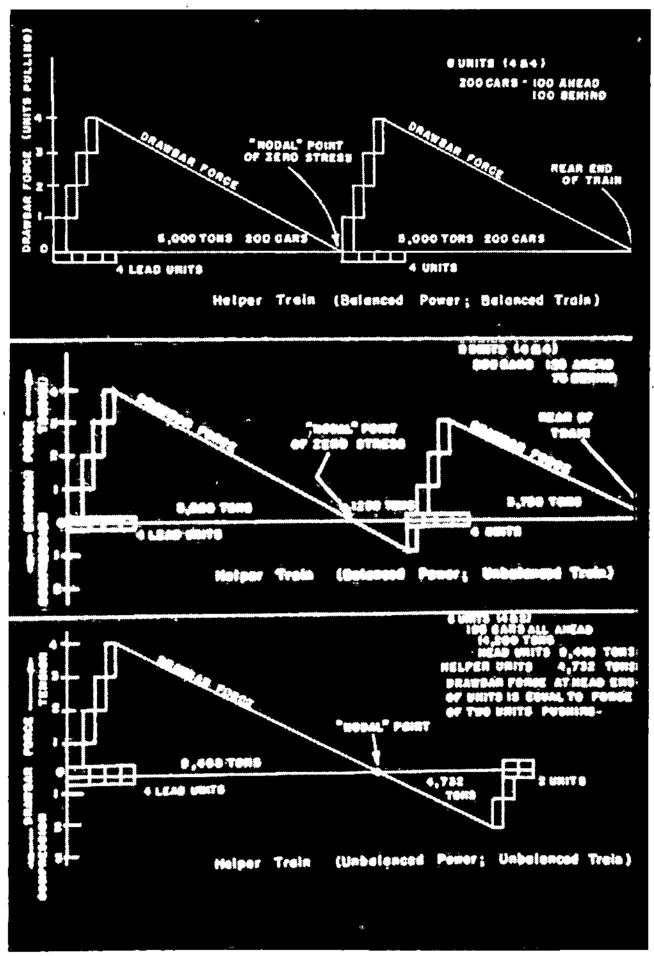


Fig. 13.

We have examined various distributions of power in trains and have done a modal analysis to best determine in certain situations where remote control units should be located.

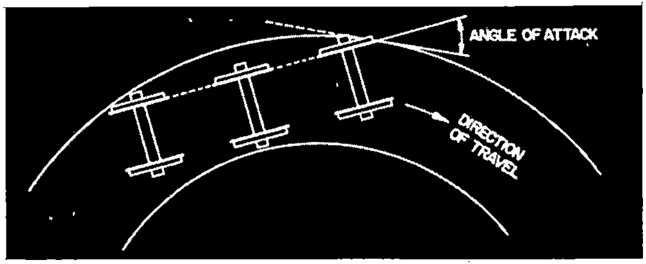


Fig. 14. Rigid truck.

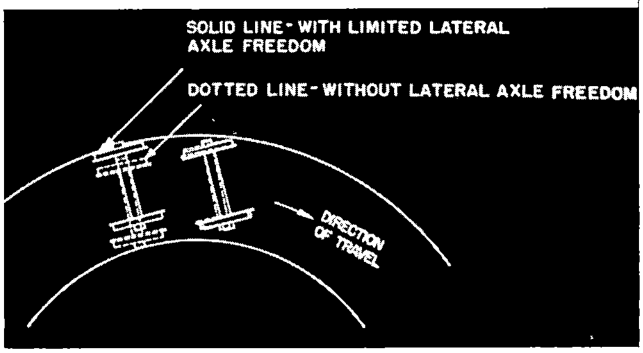


Fig. 15. Standard freight car truck.

The rigid truck as well as the two-piece standard freight car truck was studied and specific information was developed on their characteristics.

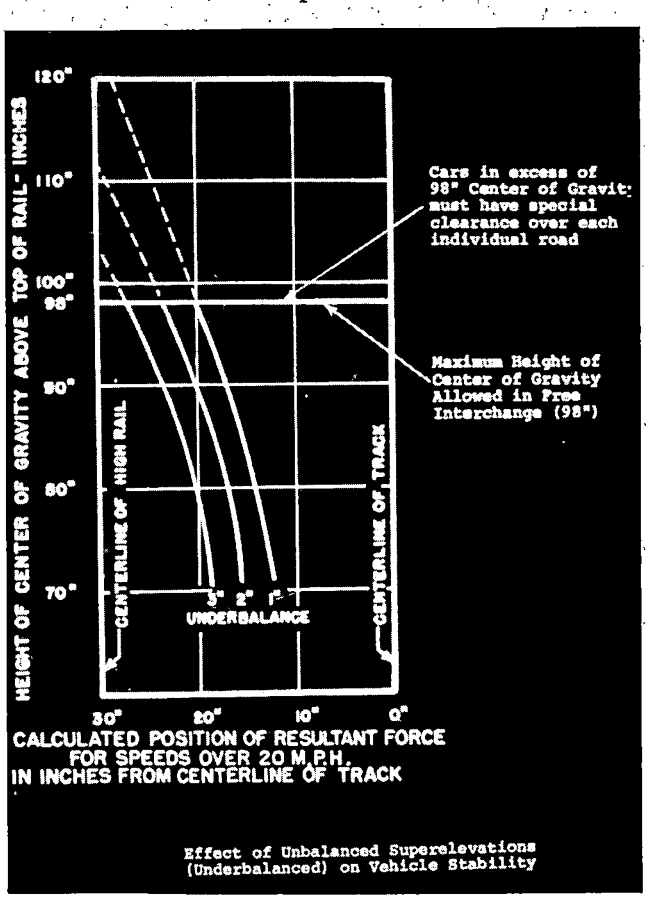


Fig. 16.

We have looked at various superelevation standards, e.g., the underbalance as well as the overbalance condition. We were able to determine the effects of the center of gravity in a loaded and unloaded condition and rate of change of superelevation in transition spirals on the instabilities of vehicles.

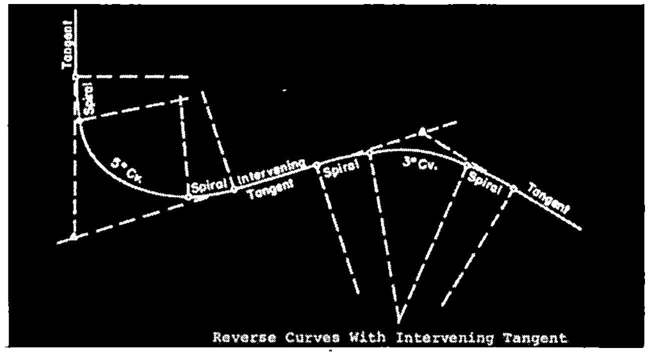


Fig. 17.

The alignment characteristics of track as related to intervening tangents, car length, and speed were discussed in great detail.

Fig. 18.

In the area of enginemen sensitivity, we have conducted approximately three months of testing on various roads including the Illinois-Central-Gulf, the San Francisco, Southern Pacific, Union Pacific, and Burlington Northern. We have actually operated these tests with many engineers over the same districts repeatedly to determine how various engineers react in the same situations.

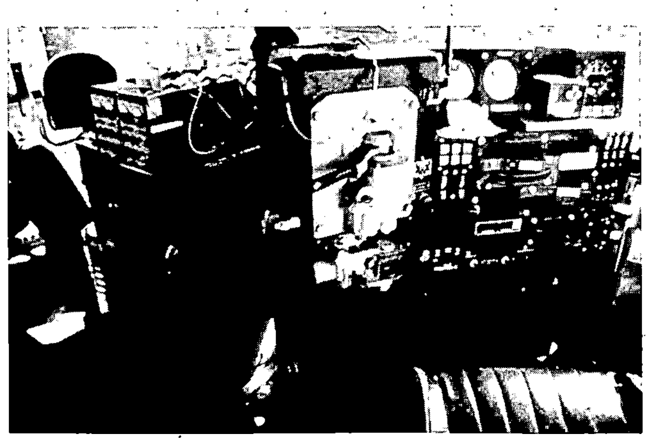


Fig. 19.

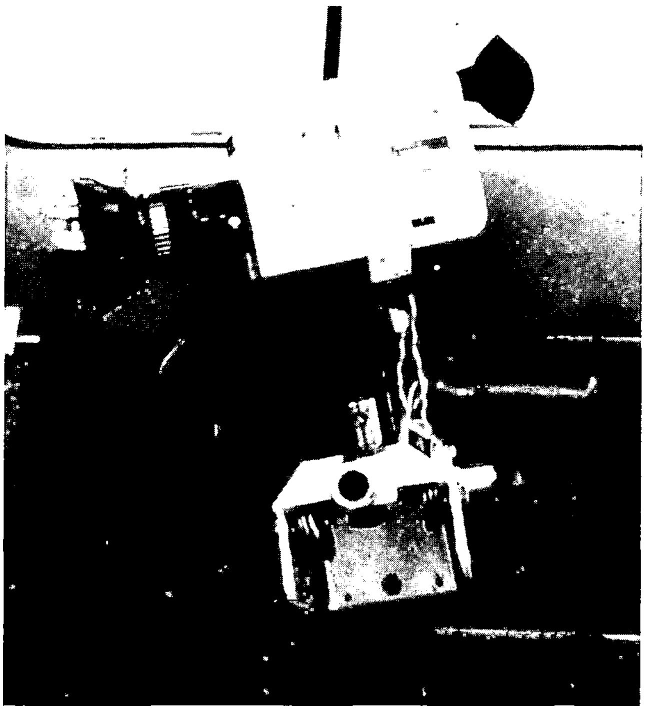


Fig. 20.

The complete control stand was instrumented, as well as synchronized video cameras used to record the engineer's actions.

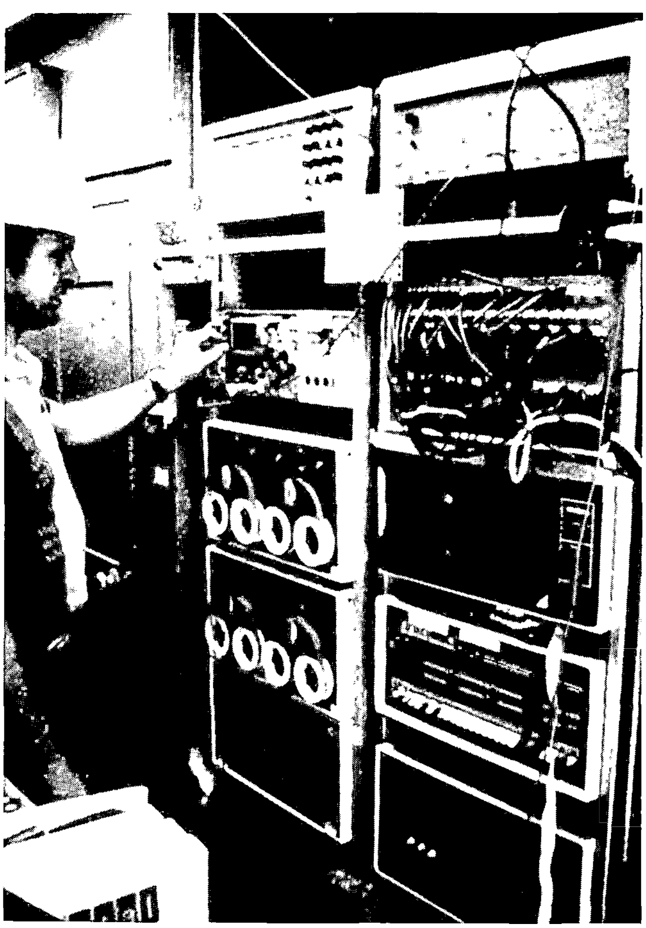


Fig. 21. Research car.

Data was collected on a research car, and certain analyses of the data have been completed, e.g., we have been able to correlate the control responses of a specific locomotive engineer vs. drawbar force, vehicle acceleration, etc. A trend analysis on engineer's performance has been completed and will be made available to the industry in the very near future.

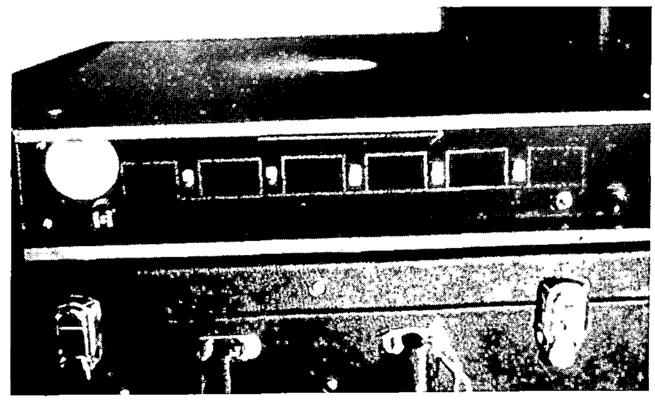


Fig. 22. Slack buff indicator.

We have also been able to develop specific engineering aid devices to be located in the locomotive cab. These devices include:

1. Power Force Indicator. This device indicates to the locomotive engineer what forces are being generated at the rear unit of his power consist. Electro-Motive Division was responsible for developing this device and Pulse Electronics is now fabricating 20 of these units which will be placed in the field for approximately six months for further evaluation. If these tests are successful, there is a good chance that this type of instrument will be installed on every locomotive purchased by some railroads.

2. Slack Buff Indicator. This device indicates the slack conditions at five points in a train. Using accelerometers, we can also display force levels occurring at those same points. The engineer views this device on his control stand, which enables him to observe what portions of his train are in draft as well as buff. This demonstrates to an engineer how the train is reacting to his control inputs.

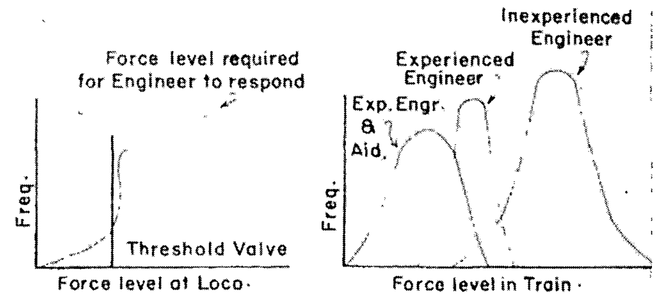


Fig. 23.

In our analysis we have been able to determine what threshold values a locomotive engineer is able to respond to in certain situations.

We have evaluated many engineers operating trains over the same territory to determine how an experienced engineer will handle his train as compared to an inexperienced engineer, and their associated learning curves. We are also very interested in learning how this same experienced engineer will handle his train over a difficult terrain using these engineering aids.

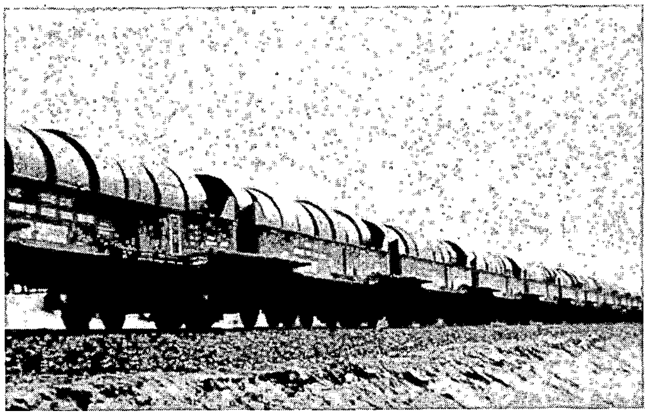


Fig. 24. SP steel coil train.

This is the SP steel-coil train test which was described quite vividly in the movie. In these tests we recorded such signals as:

1. Relative and absolute car velocities.
2. Lateral and longitudinal coupler forces.
3. Coupler angularity, etc.

We also monitored brake pipe and brake cylinder pressures on the cars as well as the locomotives. These data have now been analyzed, and there is sufficient correlation with several longitudinal models to say that they have been validated. Our "Train Performance Calculator" has been validated for some 50 cases. The Southern Railway has used the TPC to evaluate their operations on heavy mountainous grades. Purdue University has been given a great deal of information from these tests for use in their work to further develop the Detail Simplified Train Action model.

Fig. 25. Instrumentation.

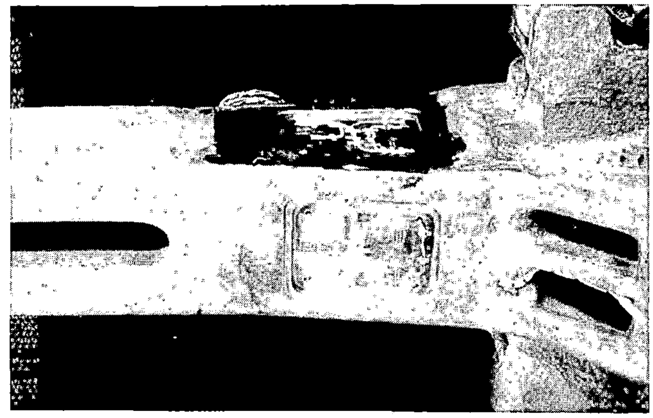


Fig. 26. Strain gauge coupler.

These are just some additional shots of the various components that were instrumented. I might say that Miner & EMD did instrument these couplers for our program.

Fig. 27. GE research car.

This is the inside photo of the GE 100, which was used in our high-speed locomotive tests. GE has been able to validate their locomotive model successfully for many conditions. A parametric study was developed for using the model to investigate locomotive performance.

Southern Railway conducted a whole series of tests using various types of draft gears (friction, rubber friction, sliding sill, and end-of-car cushioning). These characteristics were incorporated into our longitudinal models. This information can now be utilized to evaluate mixed train operations having many different types of draft gears.

Fig. 28. Wide gauge tests.

This is a series of tests we have just completed for investigating wide gauge on the UP Railroad at Pocatello, Idaho. Trains were operated at speeds up to 112 mph using all types of equipment including the new AMTRAK locomotives. We monitored 600 freight trains during this six-week test, which was manned on a 24-hour basis. These data are currently being analyzed by Battelle Research Institute. During these tests, we discovered that vehicle characteristics or signatures could be identified as the cars passed over the instrumented track. Our findings on truck hunting characteristics will be released to the industry at a later date. The instrumentation designed for these tests has performed very successfully. We have investigated the possibility of taking a minimum configuration of this instrumentation package.

Fig. 29. Trailer.

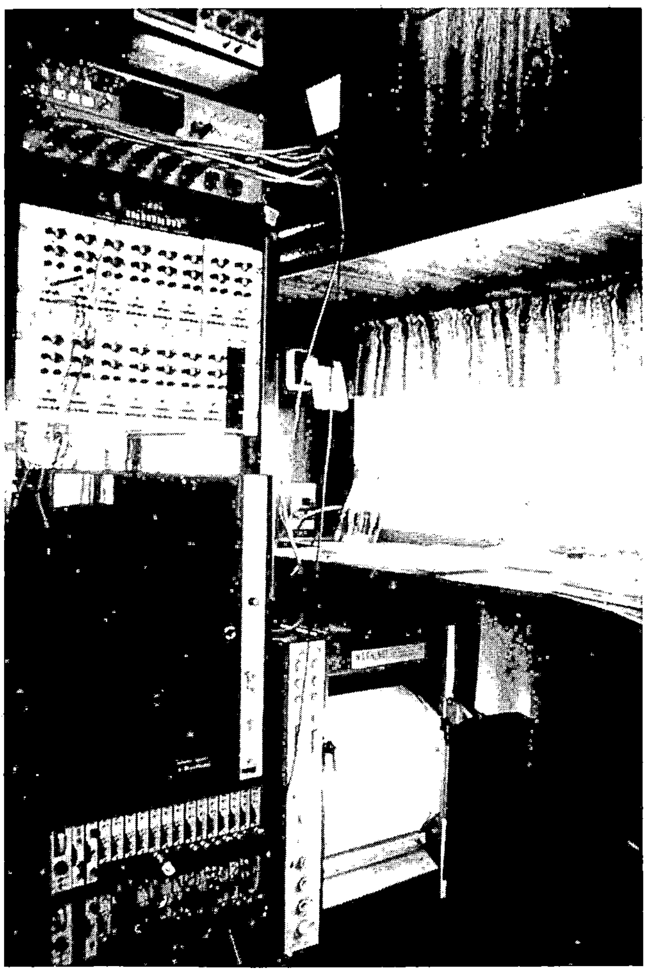


Fig. 30. Data collection equipment.

It will be located at hot box stations on various railroads to dispatch mechanical personnel to maintain problem equipment.

This is the trailer where our data collection equipment was housed.

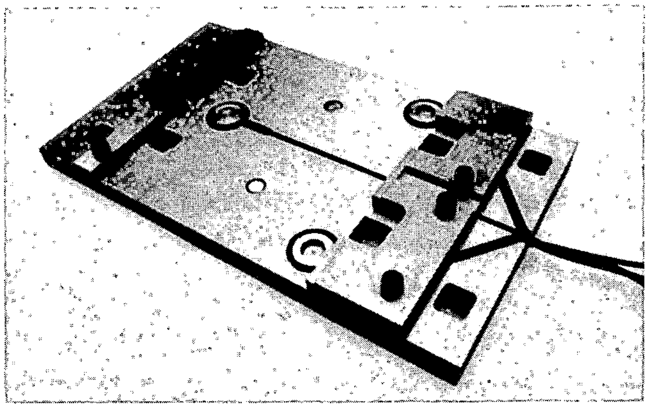


Fig. 31. Instrumented tie plate.

This is one of the instrumented tie plates that was located under the track.

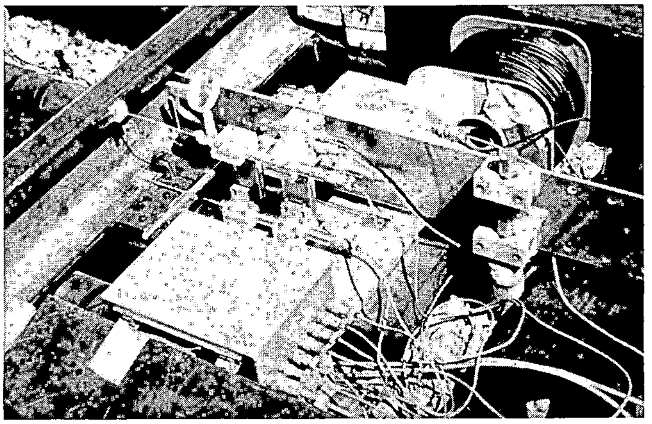


Fig. 32. Track instrumentation.

This shows a setup where we were collecting the following information:

1. Relative and absolute rail displacements.
2. Rotation of the rail.
3. Lateral/vertical rail forces.
4. Distribution of the vertical forces within the rail sections.

Standard track sections were varied using different tie plates and spiking patterns to determine what section offered the most resistance to gauge-widening.

We had mechanical forces located at Pocatello and Napa. When a problem with a specific car was identified, we dispatched the mechanical forces to inspect the vehicle. Some astonishing things were discovered about trucks, e.g., broken springs, missing springs and cracked side frames and bolsters. While this was experimental, we did develop a great deal of confidence in the system. These results will be used to validate the wide-gauge portion of our lateral stability model.

Fig. 33. Test train.

This is a series of tests that you will see tomorrow at the Test Center. Ten Sante Fe locomotives are being used in these L/V and lateral train stability tests. We have been conducting these tests for approximately three weeks and are within approximately four days of completing these tests. We have personnel from Freightmaster, Reaction Instruments, ENSCO, FRA, and of course AAR working on these tests.

To give you an idea of the magnitude of these tests, we are measuring and recording 88 channels of information. Each channel is being sampled at the rate of 200 times a second, so we are collecting 17,600 pieces of data a second. It took us approximately six months to develop this instrumentation required to measure all the various forces and displacements. This instrumentation package measures:

1. Relative vertical and lateral displacements of each wheel with respect to the rail.
2. The angel attack of each wheel with respect to the centerline of the track as well as the carbody.
3. Relative angular difference between the two adjacent axles on the same truck.
4. Lateral and vertical forces on each wheel.
5. The lateral and vertical forces on the side frames.
6. Roll and yaw characteristics of the vehicle.
7. Coupler forces.
8. Angularity of the couplers, etc.

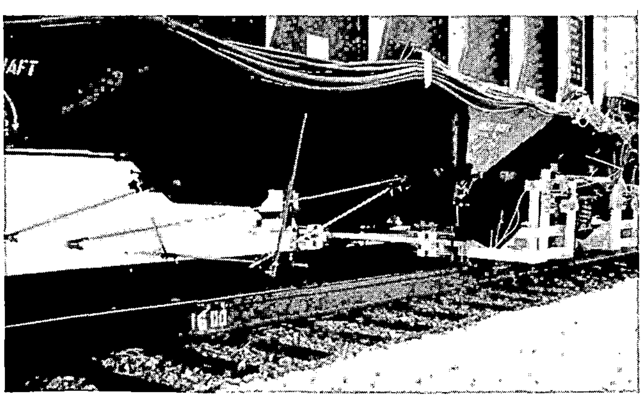


Fig. 34. Instrumented frames.

This is just another series of shots showing the vehicles that were instrumented.

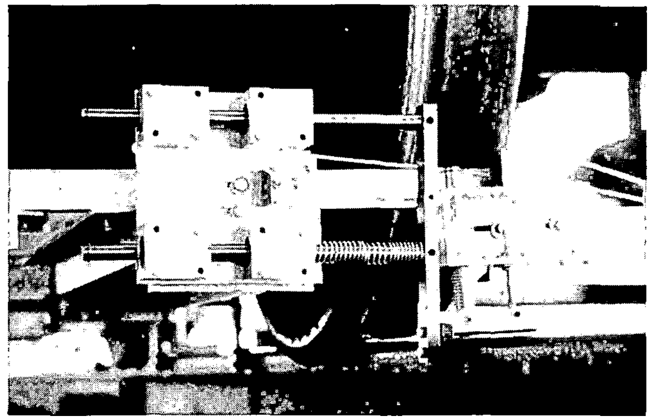


Fig. 35. Track feelers.

These are the feelers on the track to measure lateral and vertical displacement of the wheel with respect to the rail. What is quite amazing about this instrumentation is its durability. The customary thing in the past has been to take accelerometer data and double integrate the signals to obtain displacements. There are some real problems associated with using that technique, and that is the reason for developing this device.

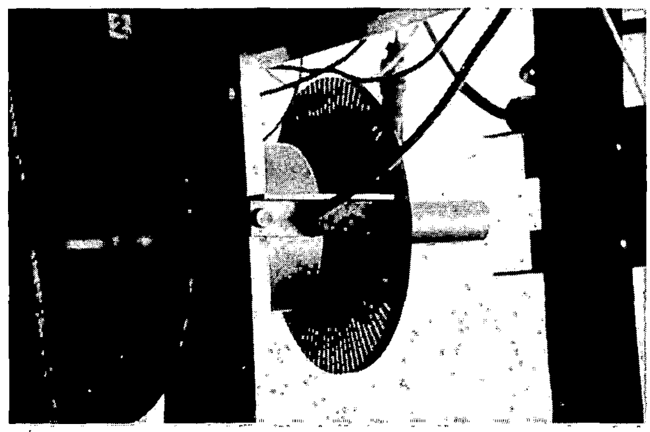


Fig. 36. Measures velocity.

This is an "Optic Shaft End Coater" used to measure absolute velocities of certain cars. This data will be used to validate our curve negotiation model, lateral train stability model, and L/V model.

We are also cooperating in a series of tests with the FRA/NASA to evaluate truck performance. Our first major activity in this area was an effort with American Steel Foundries to develop the characteristics of each individual component of their 70-ton ride-control truck. In the FRA/NASA project a complete truck assembly is being excited to measure various displacements and accelerations. This work has been completed at Martin Marietta, and the results of these laboratory tests have been extremely encouraging. The next step in this research activity is to excite a carbody in a similar manner to find out its modes and natural frequencies. Then we will place both the truck and the carbody on a shaker table to determine how they interact or couple together. Finally, early next year, we will be conducting a series of tests with NASA, Martin Marietta, and Clemson University to validate their nonlinear truck models. It is amazing that in this series of tests we were able to collect the data in real time on a digital magnetic tape, and within several hours have this information plotted.

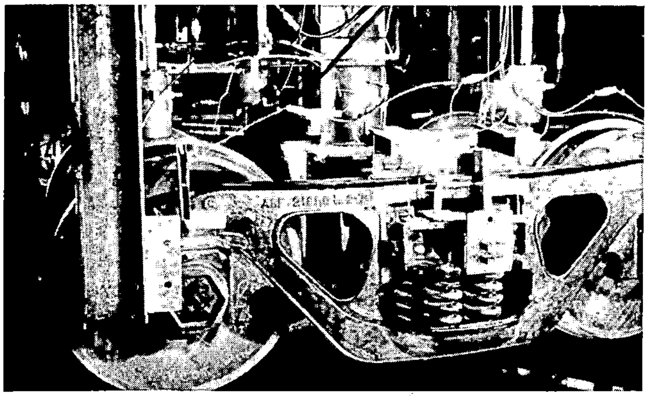


Fig. 37. Test fixtures.

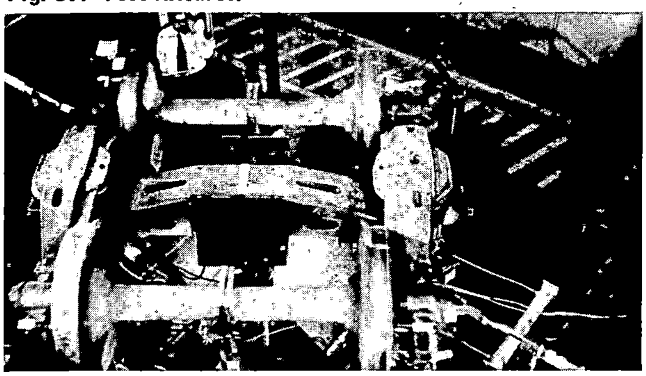


Fig. 38. Test fixtures.

This is the test fixture and some of the test setups.

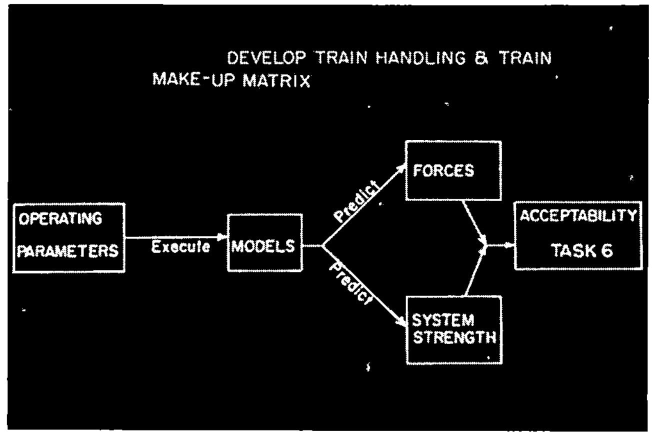


Fig. 39. Parameter investigation.

In utilization of this model, we will investigate some 4,000 different combinations or cases of operating parameters. From those results our Interim Guidelines will be updated. I might add that the implementation of the interim guidelines has gone very smoothly. Many of the railroads have already rewritten their operating rules based on these findings, and other railroads are in the process of doing so. We have had good feedback from the railroads on the effectiveness of these guidelines. As you can see this program is not an academic exercise, but research applied to our industry in a very meaningful way.

I certainly appreciate this opportunity to review all the various ongoing activities of our program. The only other thing I feel compelled to add is that without your great support this program would not have been a success story.

Moderator Loftis: Thank you, Ed. Our next speaker will be John Punwani, of the AAR.

The Estimation of Potential Benefits from Improved Operation with Advanced Coupling Systems

S. K. (John) Punwani
Senior Research Engineer-Research and Test Department
Association of American Railroads

S. K. Punwani is a Senior Research Engineer with the Research and Test Department of the Association of American Railroads at the Technical Center in Chicago. He was born in Karachi, Pakistan, and moved to Bombay in 1948 after the Partition of India. He received a BS degree from St. Xavier College of the University of Bombay in 1960 and continued his education at the University of Michigan, where he earned Bachelor's and Master's degrees in Mechanical Engineering.

Punwani joined the Dresser Transportation Equipment Division of Dresser Industries, Inc., as a junior research engineer and became a research engineer. He accepted his present position with the AAR in 1973.

He has been extensively involved in railway systems and equipment research, including track structures. He is a member of the American Society of Mechanical Engineers and the American Railway Engineering Association.

It is my privilege, Jack, to be invited here by the Federal Railroad Administration and to share with you our enthusiasm for the Advanced Coupling Concepts Project, which we hope to get under way very shortly as a cooperative effort with the Railway Progress Institute. I will undertake to describe the nature and scope of the project and the way in which you might help in achieving the goals of the project.

You have all heard about the truck-capability gap this morning. I believe there is a similar "operations gap."

The pressures facing the railroad industry to improve productivity of capital and labor are greater today than ever before. The construction of the many computerized ultramodern yards has done much for the industry in improving operations.

In these yards and every other yard and terminal in the country, whether old or new, the same operation of coupling is performed millions of times each week, with almost no questions asked—just as routinely as waking up or brushing your teeth. This happens perhaps three million times each day in a variety of locations, in the heat of day or in the cold of night, and sometimes not quite so successfully. That the performance of this mundane operation needs improvement has been appreciated by many. The number of new design ideas proposed has been astounding, considering the resistance to acceptance in a big way of any of them. Let me show you some of these, and enumerate the individual function concepts illustrated by them. Some of these ideas go back prior to the days of the Great Depression.

In the early 1930's the American Railway Association, predecessor of the AAR, tested several different train air line connectors. These tests were conducted, under ARA supervision, at Purdue University, where the test rigs were installed. Figs. 1 and 2 show these rigs. Essentially, the test rigs checked the ability of train air line connectors to gather at various offsets—vertical and lateral—conditions under which the coupler itself is expected to gather. They also checked the ability of these connectors to perform their intended function—that of maintaining a tight air connection.

Fig. 3 shows the Robinson wing connector. The wings perform the gathering function. Fig. 4 shows a passenger car version of the connector with two air and one steam connection.

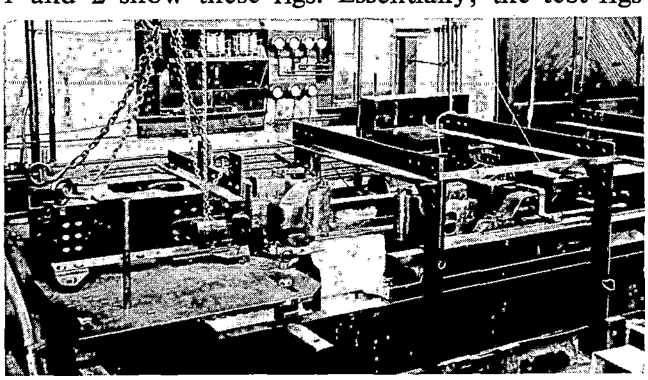


Fig. 1. Test rig, ARA tests.

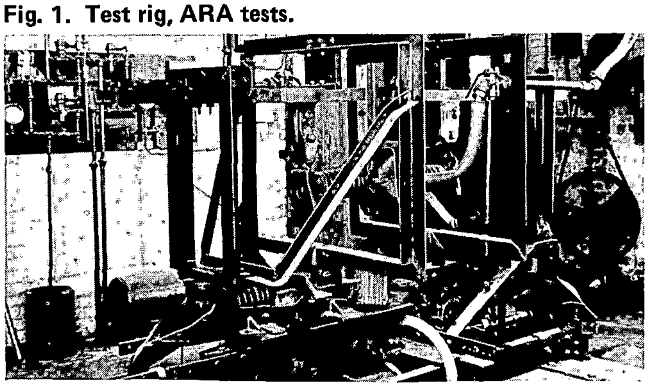


Fig. 2. Test rig, ARA tests.

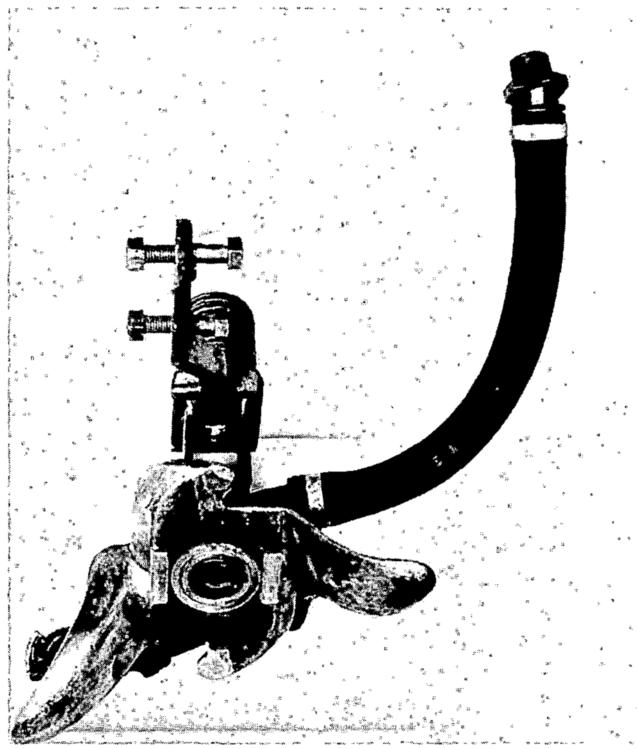


Fig. 3. Robinson wing type freight connector, ARA tests.

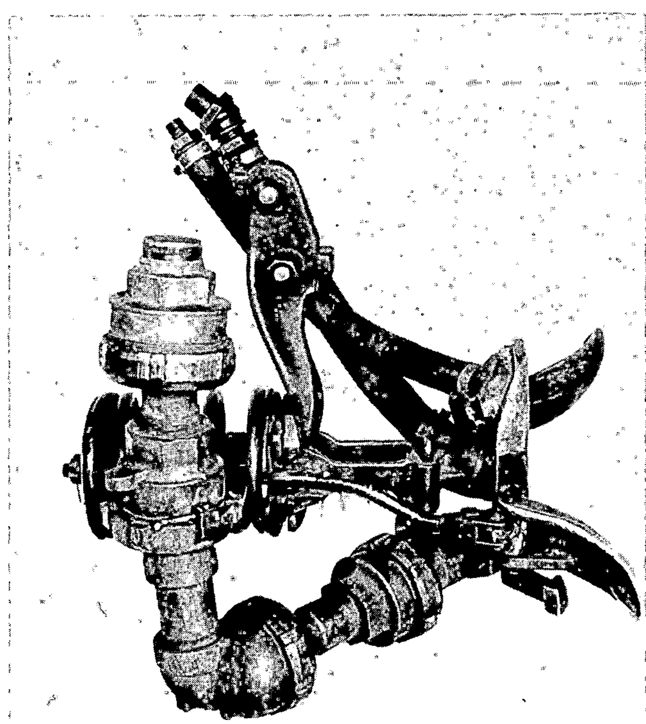


Fig. 4. Robinson wing type passenger connector, ARA tests.

Fig. 5 shows a Robinson connector with the pin and funnel design concept to perform the gathering function.

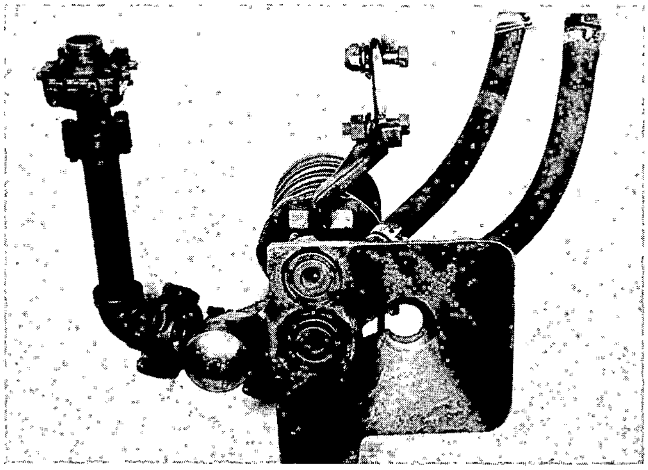


Fig. 5. Robinson pin and funnel passenger connector, ARA tests.

Fig. 6 shows the National freight connector.

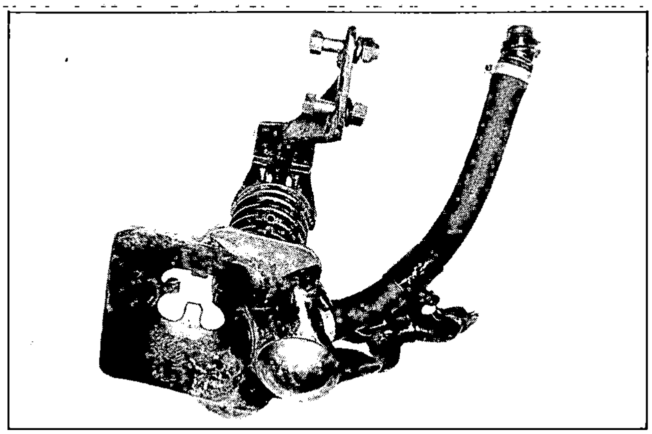


Fig. 6 National freight connector, ARA tests.

Fig. 7 shows the Roberts freight connector.

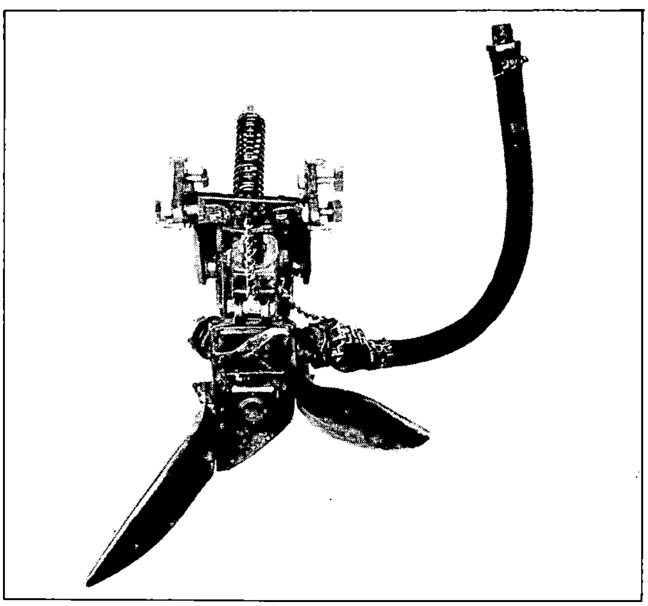


Fig. 7. Robinson freight connector, ARA tests.

Fig. 8 shows the Johnson freight connector.

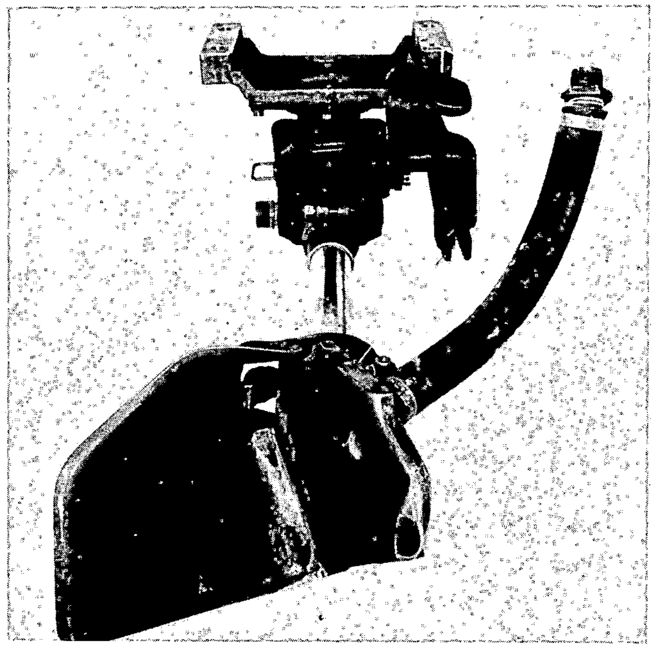


Fig. 8. Johnson freight connector, ARA tests.

More recently, coupler manufacturers have advanced many new concepts and designs and invested in their development. Through the courtesy of both Dresser and National Castings, I can show you some of these. This is just another example of the cooperative spirit that exists in the industry and has been alluded to earlier by Dr. Harris and others. My main purpose in showing these is to show that the technology is here today to do anything for which we can demonstrate the economic justification.

Fig. 9 shows the UIC European coupler of the Willison type; this is also the Russian SA-3 type.

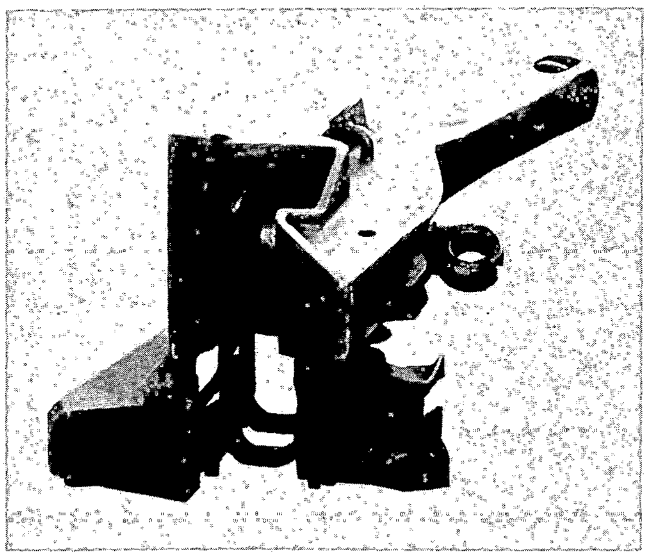


Fig. 9. Willison type coupler (courtesy National Castings Div.).

The key characteristics to note are its gathering range and that it is always ready to couple.

Fig. 10 shows a picture of a Scharfenberg mounted on a high speed DB train in Germany.

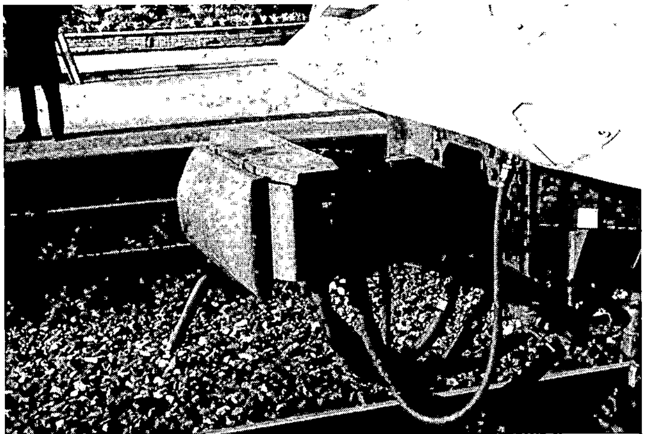


Fig. 10. Scharfenberg type coupler.

Fig. 11 shows the Dresser hook type coupler. This shows a five-wire electrical connection developed by Dresser, known as the ESACS concepts using time division multiplexing.

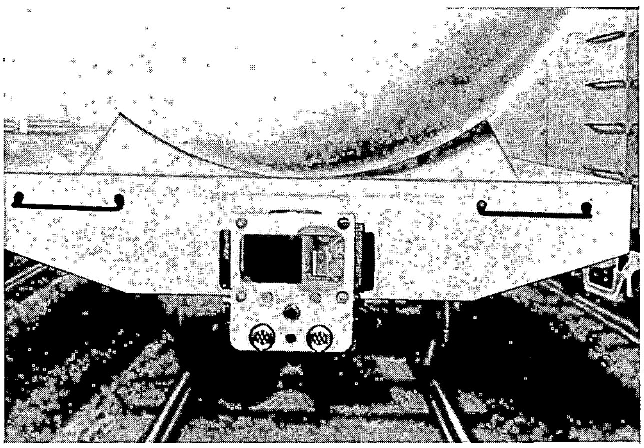


Fig. 11. Dresser hook type coupler (courtesy Dresser Industries).

Fig. 12 shows the National Castings freight car connector on a compatimatic coupler. While retaining compatibility with all knuckle couplers it is always ready to couple.

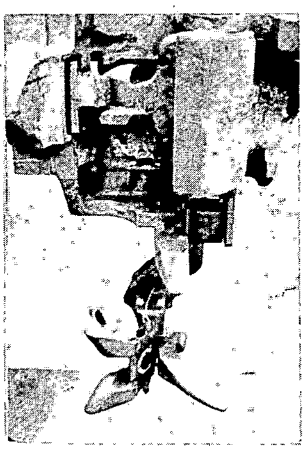


Fig. 12. National Castings connector with compatimatic coupler (courtesy National Castings Div.).

Fig. 13 shows a Dresser connector. In addition to providing the physical air connection, it can, with a control system, switch the air on upon coupling and off in conjunction with uncoupling. Other manufacturers, such as ASF, also have concepts. In the area of coupler centering and positioning there are many design concepts which, in their unique way, address the clearance problem on each type of car. As you can see there is no shortage of ideas—but rather a lack of any definition of the value to be achieved.

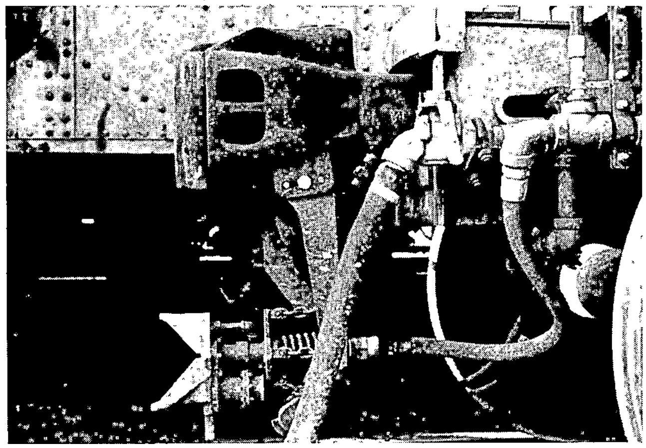


Fig. 13. Dresser connector (courtesy Dresser Industries).

There are logical functional characteristics associated with each of these designs. Fig. 14 lists the mechanical characteristics suggested by an informal review of some of these ideas. Fig. 15 lists the train line air connection characteristics suggested by an informal review of some of these ideas. In addition to these basic characteristics suggested by the designs, there are characteristics that provide for auxiliary services, most of which come about only with an electrical train line. This list of auxiliary services is long and not immediately relevant to the discussion on coupling systems, and perhaps as a group it detracts from the basic issues.

- IMPROVED GATHERING RANGE- LATERAL(VERTICAL)
- ALWAYS READY TO COUPLE.
- COUPLING RELIABILITY (REDUCTION IN BY-PASSES AND NO-COUPLES.)
- LOWER MINIMUM COUPLING SPEED.
- COMPATIBILITY WITH PRESENT COUPLERS.
- REDUCED SLACK BETWEEN COUPLERS. (LONGITUDINAL)
- REDUCED VERTICAL MISALIGNMENT.
- REDUCED CONTOUR ANGLING.
- INCREASED STRENGTH-VERTICAL,LONGITUDINAL, & ROTATIONAL.
- IMPROVED MECHANICAL UNCOUPLING MEANS.
- ELIMINATE NEED TO PROVIDE SLACK PRIOR TO UNCOUPLING.

MECHANICAL CHARACTERISTICS

Fig. 14. Review of mechanical characteristics suggested by state-of-the-art systems.

- MAKE THE PHYSICAL CONNECTION BETWEEN CARS FOR TRAIN AIR LINE COMMUNICATION.
- MEANS TO SWITCH AIR ON-UPON MECHANICAL COUPLING.
- MEANS TO SWITCH AIR OFF-UPON MECHANICAL UNCOUPLING.
- EMERGENCY BRAKE APPLICATION UPON UNINTENTIONAL UNCOUPLING.
- COMPATIBILITY WITH "GLAD-HANDS" AND ANGLE COCKS.

TRAIN AIR LINE CHARACTERISTICS.

Fig. 15. Review of train air line characteristics suggested by state-of-the-art systems.

The Advanced Coupling System, if one is eventually selected, must be defined on the basis of the economic benefits to be derived. This can be done first by examining, in modular form, the economic benefits of each individual characteristic, and then by combining those characteristics that logically complement each other into a system. The system with the greatest benefits will be then considered for selection. It must be remembered that there may be desirable characteristics which may be suggested by an in-depth critical examination and analysis of operations. We will also welcome any characteristics that any of you may wish to suggest for consideration. We believe that it is necessary and imperative that we in the industry pursue vigorously a program that will improve the profitability of the railroad industry.

We also believe that the industry has better tools for planning today than ever before and is in a better position to do so. We will discuss some of these tools later. An overview of the total program is shown in Fig. 16. Phase I will be conducted as a joint AAR-RPI project–most of you are familiar with the management of cooperative programs.

OVERVIEW

1. ADVANCED COUPLING CONCEPTS.
(THIS PROJECT)

2. DEVELOPMENT PLAN.
(TO BE FORMULATED LATER)

3. TEST PLAN.
(TO BE FORMULATED LATER)

4. IMPLEMENTATION PLAN.
(TO BE FORMULATED LATER)

Fig. 16.

Fig. 17 shows the fundamental objectives of the project. If the results of Phase I so warrant, then the plans for the remaining phases will be developed and the plan will be in accordance with the needs as determined at that time.

I DETERMINE AREAS IN WHICH SAFETY AND EFFICIENCY COULD BE IMPROVED BY CHANGES IN THE COUPLING SYSTEM.

II QUANTIFY VALUE TO BE ACHIEVED BY SUCH IMPROVEMENTS.

III DEFINE FUNCTIONAL REQUIREMENTS IN THE FORM OF A SPECIFICATION TO GUIDE DEVELOPMENT OF IMPROVED SYSTEMS.

FUNDAMENTAL OBJECTIVES OF – ADVANCED COUPLING CONCEPTS PROJECT

Fig. 17.

Briefly, we hope to get a contractor to perform the central tasks and to set up tasks to support the efforts of the contractor (see Fig. 18).

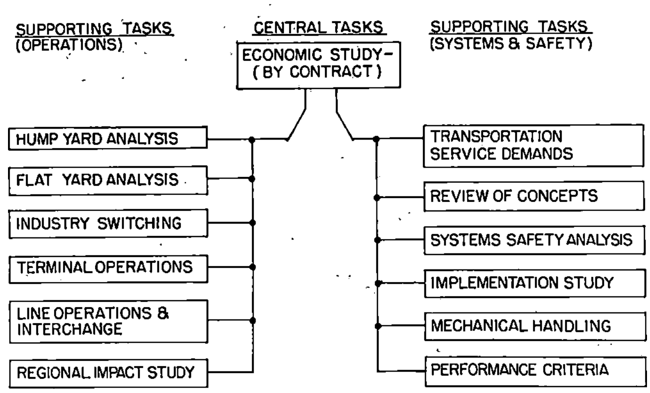


Fig. 18. Summary of tasks.

The contractor will be primarily responsible for developing the methodology and for devising the sampling and data reduction plans to support and effectively use the methodology.

The supporting tasks will help broaden the base for the study by making a systems consideration more viable and by making a more viable data base possible. The need for an interdisciplinary approach is paramount on this project–industrial engineering, operations research, economic modeling, marketing and pure finance.

Fig. 19 lists the essential steps to be followed by the contractor, with support from other tasks.

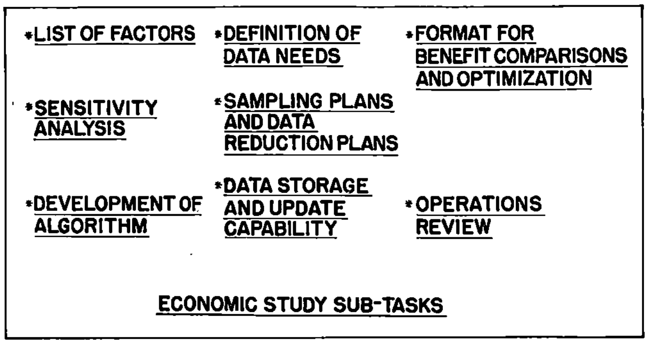


Fig. 19.

List of Factors. A list of factors that could conceivably figure in the potential benefits will be developed. Just to convey the scope, I will read off a "back of the envelope type list":

1. Benefits from work simplification–yard crews, switch crews, inspection forces, carmen, engine crews, overtime, distance based wages, arbitraries.
2. Safety related: accident, derailment, lost-time and minor accidents, insurance costs.
3. Benefits from meeting increasing transportation market (other than by improved competitive position).
4. Benefits from reduced lading damage.
5. Benefits from reduced packaging.
6. Benefits from reduced maintenance to cars.
7. Benefits from reduced fleet through better utilization.
8. Benefits from better utilization of physical plant–hump yards, flat yards, terminal, TOFC/COFC and marine terminals.
9. Service reliability improvement.
10. Lower O-D times.
11. Larger share of market not now possible to enter due to O-D time performance.
12. Lower total inventory costs to industry.

Sensitivity Analysis

The "laundry list" developed will have to be pruned on some rational basis. The sensitivity analysis for a factor may take the form of a simple review of literature that may point the way to a decision to include or reject a factor from consideration. In some cases, this decision may be made on the basis of some pilot data collection. This is an area where many of you can help by making a case for or against excluding a factor.

Development of Algorithm

The exact nature of the methodology should not be prejudged. Surely it will involve cash flow, present worths of future benefits. Comparisons in various different formats may be necessary:

1. Annualized costs.
2. Covering cash flow to various time frames.

The quantification of benefits will require the economic model, the use of some of the available tools for operations planning. Fig. 20 shows a network model such as the AAR Midwest Research Institute model or the CN model, from which the illustration is borrowed. Some of you are intimately familiar with the use of network models. These models, for those who are unfamiliar, can be used on a micro-level or a macro-level. For example, the illustration could have been that of a flat yard and the analysis used to quantify the increased capacity or improved productivity of resources for the yard. Network analysis has also been used to determine the increase in hump yard through put capacity for a given physical configuration (present investment in physical plant) and the effect on minimum yard time to process cars.

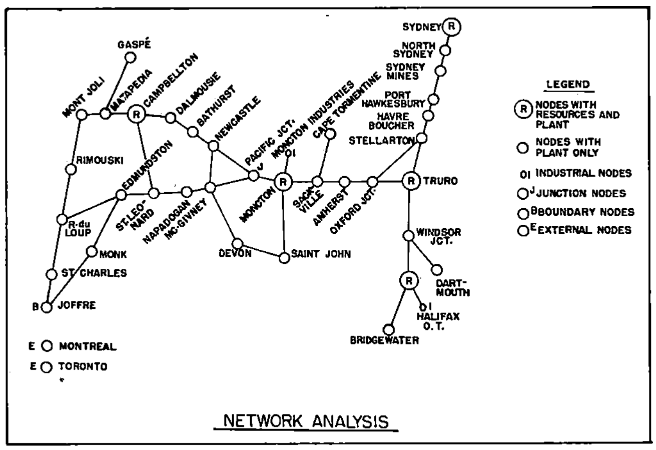


Fig. 20. Network analysis--illustration.

For the purpose of quantifying total system benefits, the "universe" of railroad operations needs to be modeled and sampling plans developed to quantify the essential elements. The railroad fraternity has generally opted for the development and use of network analysis as a planning tool for many good reasons. Examples of use are:

1. Changes in operating policy–such as switching to schedule-based train dispatching in lieu of minimum-size base dispatching–can be tested.
2. Yard through put capacity can be determined for proposed changes in physical yard layout.

An alternate form to model the "universe" of railroad operations would entail stratification by considering revenue movements. A major drawback of this approach would be the inability to consider adequately the single or small car lot business.

Yet another form of modeling the "universe" of railway operations may entail the use of car tracing. The method eventually would be selected after considering the list of factors we wish to pursue, and the available resources for data collection.

Data Collection Planning, Execution of Plan and Reduction

There is a lot we do not know about coupling operations as they exist today. So, one of the first steps will be to precisely define each move, as in any industrial time study (or MTM), for the full range of variance that can be expected from yard size, cut size, location, time of day, weather. This is one type of data that will be needed. Some of you may have some of it already and we will be out in search of it.

For every factor we select for consideration some data base will have to be developed—using previously collected data or by developing sampling plans, executing them and reducing the data to the usable form.

Transportation Service Demands

We should not assume that every freight car need be the same forever, or that every class of car needs the same origin-to-destination trip time reliability. Also, we must examine pertinent non-rail transportation markets to see if improved O-D times and improved reliability may significantly alter the railroads' share of this market. These are part of the transportation service demands task.

The Systems Safety Analysis Task will review and audit the available safety data from all sources for accuracy, comprehensiveness, and identification of safety elements. A review of all laws relevant to coupling systems safety, such as the power brake law and supplementary carrier rules, will also be conducted and possible rule modification considered. Also, the prudent investment limits will be established to the extent possible for each safety benefit element.

The Implementation Study Task objectives are to initiate consideration of alternative implementation plans and to evaluate each of the alternative plans for incompatibility problems, cash flow considerations, and industry manufacturing capacity.

It is well to point out that there is a sequential aspect to some of the tasks. The tasks on mechanical handling and performance criteria will be initiated only if the work up to that point warrants it.

Finally, it is well to emphasize that we do expect a "fallout" of immediate benefits to result from the review of operations and the data collection we undertake. For example, some operating practice changes might make it possible to cut frequency of coupler bypasses. The methodology developed and the variety of sampling plans developed will be useful for other studies as well.

In conclusion, let me reiterate that:

1. We must maintain total objectivity in determining the potential benefits from any advanced coupling system.
2. We need to define the characteristics that the system should possess on the basis of benefits to be derived—recognizing the present investments.
3. The emphasis in the advanced coupling concepts project will be on the economics, and without the support of many of you in developing an adequate data base the economics cannot be defined adequately.

Moderator Loftis: Thank you, John. I would like to introduce our next speaker, Mr. Jack Jones, of SP. Jack will also serve as Discussion Leader for our next session of comments and discussion.

DISCUSSION LEADER
W. J. Jones
Engineer-Maintenance of Way and Structures-System
Southern Pacific Transportation Company

W. J. Jones is Engineer, Maintenance of Way and Structures-System for the Southern Pacific Transportation Company, San Francisco, California. He received a BS in Mining Engineering from the University of Texas in 1935 and attended the Senior Executive program at Massachusetts Institute of Technology. He is a registered Civil Engineer in the state of California.

Jones's railroading experience dates back to 1936, when he was a statistician for the Southern Pacific Co. In 1940 he joined Southern Pacific permanently, serving in positions ranging from rodman and draftsman to Roadmaster to his present position. He is a fellow of the American Society of Civil Engineers and has served as a Vice President of the American Railway Engineering Association and President of the Roadmasters and M of W Association.

Gentlemen, this afternoon you have been furnished an insight into the nature of the cooperative research program being pursued on behalf of the railroad industry, under the direction of the AAR. Also, you have heard a rather comprehensive and highly informative synopsis of the results of a specific research effort, Track/Train Dynamics, which has the support of Government, railroads, railroad associations, and industry.

To round out Session II, I will touch upon some of the highlights of track/train dynamics, with emphasis upon the track aspects. I feel that it is particularly fitting that this subject is included in this year's program. It marks the first such Conference conducted under the auspices of the Federal Railroad Administration. As one of the prime sponsors of the Track/Train Dynamics project, FRA has reason to be justifiably proud of the positive contribution this research effort is making to the railroad industry in the form of improved train handling and reduced train mishaps. Additionally, this isn't a one-shot subject. It will continue to involve all of us who are engaged in any aspect of train operations for all time.

On the chance that some of you are not experienced in track maintenance, I will say a few words about it. When I transferred out of the Engineering Department to accept a subordinate supervisory position in the Track Department over 30 years ago, I knew absolutely nothing about track. It was all a mystery. An old-time roadmaster offered encouragement by advising me that there was nothing mysterious about track maintenance. To him it was simple. "All you need for good track," he said, "is line, gauge, and surface."

His logic was 100% correct, as far as it went. But in the practical sense, we know that in order to preserve line, gauge and surface to an acceptable standard we must have a stable subgrade, an adequate depth of free-draining ballast, sound ties, strong track fastenings, and a rail section heavy enough to support the loads. Curves must be designed with the proper amount of superelevation and the appropriate length of spirals. Finally, authorized train speeds must be consistent with the character of track, giving due consideration to gradients and grade changes.

As my roadmaster friend said, there was nothing to it. However, since the days when he was active, we have seen the lumbering steam engines replaced by several generations of higher-powered heavy diesel electric locomotives. Cars are longer and bigger. Car loadings and axle loadings have increased. With the increase of average weight of cars, we have also experienced the increasing of the allowable height of the center of gravity in free interchange to 98 inches. Trains have grown in number of cars. The 45–50-mph maximum freight train speeds of the 1940s are considered intolerable speed restrictions in today's highly competitive transportation struggle. Today, many main-line expedited freight schedules are based upon 65–70-mph speeds.

Meanwhile, the track structure design has remained substantially unchanged.

It was in such an operating environment that problems developed, almost simultaneously, involving rock and roll, tracking of six-axle locomotives, and wheel lift as reflected in L/V ratios. Independent investigations looking into these particular problems were being conducted by individual railroads and the supply industry. The AAR recognized that all of the problems being studied had one common denominator—the interaction of trains with a track structure. The widespread and genuine interest in track/train dynamics demonstrated by the supply industry, the railroads, the AAR, and the FRA led inevitably to the cooperative research study as we know it.

The study began in 1972. It consists of three phases, programmed to extend over a total of 10 years. The objective of Phase I is to analyze the present dynamic aspects of track, equipment, and operations and to formulate interim guidelines to reduce excessive train action and the adverse effects resulting therefrom.

Phase II will set out to develop improved track and equipment specifications and operating practices to increase dynamic stability. Phase III will apply more advanced scientific principles to railroad track, equipment, and operations to improve dynamic stability.

Phase I has already reached its objective.

It is a safe bet to say that when one hears the term "track/train dynamics" he automatically associates it with "L/V", and vice versa. Lateral/vertical ratio (L/V) is the catchword of track/train dynamics studies, particularly as related to train performance simulations and derailment studies. As important as the ratio is, the track maintenance man must realize that the lateral and vertical forces represented by the ratio are real forces exerted upon the track structure. The lateral stability of the track must be such as to resist any tendency to shift or to increase gauge. Also, all of the forces of starting and stopping trains are ultimately passed to the track structure and must be absorbed by it.

The true significance of the L/V ratio is appreciated by the track man when he realizes that when the L/V ratio exceeds certain critical values, a derailment is likely to occur. We have learned that these values are:

1. 0.64: Unrestrained rail may overturn. This is hypothetical and we hope that it does not occur in practice.
2. 0.75: Flange may climb worn rail.
3. 0.82: Wheel may lift, disengaging flange from ball of rail.
4. 1.29: Flange may climb new rail.

All of these values are time dependent and are considered serious when they endure for 0.3 of a second or longer.

Vertical wheel forces are affected by car weight, condition of track, track curvature, superelevation, and speed. The wheel load decreases markedly when the track has large and continuous irregularities, especially in the line. The effect is further aggravated when cross-level irregularities are present in combination.

The research team has learned that excessive lateral forces are generated in curve negotiations which can cause rail turnover on curves of moderate to heavy curvature. The lateral forces capable of creating a derailment come from the dynamic stresses produced by run-ins—by having long cars coupled to short cars; by having long, light cars ahead of blocks of heavily loaded cars; by having slack run in against the locomotive; by truck characteristics; or by high, continuous buff or draft forces.

We are aware of the possibility of a train derailing by light cars being pulled over the inner rail of a curve, when heavily powered locomotive consist is slowly hauling a heavy tonnage train around a sharp curve. At least one railroad overcame this problem by making a fairly simple line change that reduced the degree of curvature only moderately.

As important as the lateral and vertical forces are, we must not lose sight of the longitudinal forces which are also created in starting, operating, and stopping trains. The greatest changes in these forces are introduced by continually increasing dynamic braking.

Prior to the introduction of large-scale dynamic braking, trains were stopped by relatively evenly spaced air-brake applications throughout the train. The increased use of dynamic braking to reduce brake shoe and wheel wear and reduce the heat generated so as to lessen component failure has resulted in concentrating unusually large forces at the head end of the train. Frequently, these dynamic forces exceed the forces which a comparable amperage in power generates. With constant amperages, these forces increase as speed decreases down to about 22 mph. This situation increases rail wear.

Truck hunting is a serious problem with some equipment on certain track. It is ironical that the forces which are created by truck hunting tend to increase the gauge problems, and as the gauge widens, the tendency for truck hunting increases. The equipment which is of particular concern to the track man includes the six-axle locomotives and the roller bearing cars, especially the tapered bearings, with their restricted lateral freedom.

In my opinion all track maintenance men should become intimately familiar with the lessons to be learned from the Track/Train Dynamics project. They should alert themselves to the presence of those vulnerable locations on their territory where critical L/V ratios might exist due to track condition. They should take a little more interest in the maintenance of such track. Where practical to do so, they should place their slow flags so as to avoid dynamic or air brake application within the limits of a curve, a trestle at the foot of a grade, or a switch. Finally, our track maintenance people should be aware of every opportunity to apply computer technology to maintenance of track.

Thanks to the knowledge developed in the Track/Train Dynamics study, we are all now better informed regarding the extreme forces at work between the engine and caboose of trains moving under various operating and track conditions. More importantly, we are better equipped to deal with these forces which heretofore have caused problems. Naturally, we look forward to the further developments coming out of the research work involving Phases II and III.

Following are some track-related subjects that have been suggested for inclusion in this project:

1. The effect of wheel and rail profile and switch points on L/V ratios.
2. The effect of wide and narrow gauge on L/V ratios, including wheel lift and rail turnover.
3. The effect of successive low joints in curve territory.
4. The effect of superelevation with particular reference to amount of elevation and rate of runoff.
5. Required length of tangent between reverse curves.
6. The effect of placement of slow orders based on track conditions.
7. For all cars and locomotives the effect that track geometry has on equipment at various speeds and the effect on the track structure of the unsprung weight of equipment at various speeds.
8. The effect of engine braking (independent and dynamic) on curved track.

We are indebted to the sponsors of this research endeavor, and to the people engaged therein, for the new knowledge and guidelines formulated looking toward an improvement in safety of train operations.

Delegate Comment: Did I understand correctly that there is an association between loose roller bearing backing rings with flood loading of hopper cars?

Speaker Response: Often these cars are overloaded. Because of this, these cars are subject to more severe dynamic action. The net result is some loosening of backing rings on runs over territories where the track is not maintained.

Speaker Response: We are always interested in learning what environmental conditions our products are being subjected to in order to develop better performance criteria. We have great opportunity in our testing activities at Pueblo to develop this type of information. Reducing all the recorded data is a large undertaking, but the job should be completed in early February. It is certainly encouraging to hear so many people are working at trying to improve truck performance. We only hope that they don't attempt to concentrate their entire effort in the area of design.

Delegate Comment: I heard a number of railroad analysts associated with track, and if I am interpreting what they were saying correctly, there is much concern about the 100-ton car destroying the roadbed. Someone stated they have first-generation track and third-generation cars—we have third, maybe fourth-generation cars, and they are still failing, so we both are in the same boat. What's your impression of the track, and where are we going?

Speaker Response: For the moment it is obvious that the trackman's responsibility is to prepare a track that will safely carry all types of equipment. From the lessons we are learning from the various on-going research activities, there may be a need to change both car and track structure designs. Maybe the car dimensions and loads are something our people in freight traffic service feel that they can live with because of the rate of return. Right now I believe that the existing track structure design is capable of supporting all traffic, provided the people who are charged with the responsibility of maintaining the track do their job properly, and don't limit themselves to trouble-shooting.

Delegate Comment: What do you consider to be the optimum or maximum allowable axle loading . . . axle loading that should be permitted to operate trains over our track structure?

Speaker Response: Four-axle cars weighing 315,000 lbs. or 77,000 lbs. per axle are now moving over 75-lb. rail. Some of our practices, I don't recommend. You must realize that our bread and butter comes from the movement of loads—heavy loads, and therefore, this is what we are forced to live with. I would like to see some reductions in speed and axle loads. Since we don't usually get what we want, we are going to have to become more imaginative and ingenious in maintaining our track.

To answer your question specifically, we should have a load no greater than the load which the rail can safely carry without damaging the track structure.

Speaker Response: It depends on the condition of your rail. If you are talking in terms of loads in the area of 60,000 to 65,000 lbs., then we are in agreement. I don't like the 77,000 lb. axle loads.

Speaker Response: One of the intentions in our current track research with the U.P. Railroad & Battelle is to develop a correlation between speed, axle loadings and deterioration of track. After this data is analyzed, I think we will be in a position to give you some definite answers on how deterioration of track is dependent upon speed and axle loadings. We already know that they are very critical. We are also looking at the distribution of loads within the rail and how this is related to various type track material such as different tie plates, etc. Within two months, we should have a report that may give us more insight into the specific problem associated with widening of gauge. We do intend to run additional tests in January, when we know that the rail is subjected to the highest loading because of the frozen ballast conditions. We also plan to do our second test for approximately the same length of time, five weeks.

Delegate Comment: We have a representative from the British Railways here. In Britain and Europe you have established the limits of 15-25 tons per axle, I believe, depending on speed. Could you give us the basis for your decisions?

Speaker Response: Our civil engineers have certainly established a limit of 60 mph for a 25-ton axle load. We are running 100-ton oil tankers currently and the shippers are prepared to accept these cars. We have suffered a great deal of rail damage on our west coast main line where we are running at high speeds with no suspended traction motors. The work done by our research people in conjunction with civil engineering departments has led us to clearly understand that our own maximum speeds must be reduced to 60 mph for 25-ton axle loads and 75 mph for 10-ton axle loads on our Freightliner trains. The Freightliner trains are fitted with the Ridemaster type bogies. This is the same three-piece bogie we have been speaking of this afternoon. Our experience with this is that it has been difficult to get it to run satisfactorily at high speeds. I think in the future we shall certainly go into the base-type bogie that was referred to earlier with a different type of primary spring suspension system to satisfy our civil engineers, because like all civil engineers, the ideal situation for them would be no traffic at all.

Delegate Comment: On the continent, we are always limited to 20-ton axle loads with some exceptions. You have just heard that British Railways and the Swedish Railways run 25-ton axle loads. We are just beginning a new study to evaluate the effects of increasing our axle loads from 20 tons to 22 tons on a high-speed track (about 120 km per hour).

Delegate Comment: Earlier this year in Russia we had discussions with their civil engineering and government personnel. The track people were most emphatic in their opinion that we are wrong in operating 31½-ton axle loads. They pointed out that all their research indicates that 24 tons is the absolute limiting capacity for the rail to support the wheel (that is for the size of wheel being used in our operations). Using their own words "the metal bruises at any loads over 24 tons per axle." So it was with great interest that I recently noticed that they are conducting studies with 28-ton axle loads.

Delegate Comment: In connection with these big cars, it seems to me that on our line we do break some rails with the 125-ton cars. But apparently at a track/train dynamics standpoint the 125-ton cars have different characteristics than the 100-ton cars.

In Mr. German's talk, he specifically pointed out that in designing our future cars we should modify the distance between the centerplates. Have you studied the different dynamic characteristics of the 100-ton and 125-ton cars?

Speaker Response: We are currently in the process of developing the characterization for different types of vehicles at Pueblo. Even though the 125-ton car represents a substantially different acting animal, it is still the 100-ton and 70-ton equipment that constitutes most of our car fleet. Therefore we are concentrating on describing the dynamic characteristics of 70- and 100-ton cars.

Delegate Comment: I would like to direct one comment for possible consideration in connection with this series of tests to correlate the track deterioration with the weight of the car. I think there is certainly one parameter that you didn't mention, but perhaps are considering. If not, I think it is a very relevant one, and that is the initial condition of the track. There is growing evidence to support what I think most track people would tell us intuitively—that the same loads operating over track which is in poor condition to begin with will cause much more rapid deterioration than when operating over track that is in good condition at the very outset. We have done some cost maintenance investigations on the Rock Island to see what effect moving the same traffic in 100-ton cars is having on our maintenance cost, but these approaches so far have been based on overall system averages, and I think we are just getting to the point of starting to look at the variations in track quality in the beginning. The point is that it appears that if you have good track to begin with the maintenance cost increases will be substantially less than if you have poor track in the beginning.

Speaker Response: When we talk about the rail loads, what is your criteria for determining life of rail or track? Would somebody care to explain this to me? I feel that our yardstick of measurement should be that the condition of the rail is no longer serviceable because of its worn condition and has decreased from its original section strength. Most tangent rails do not wear out unless a series of defects, surface imperfections, or internal defects are detected. We have had lightweight rail, 112 lb. and 113 lb. rail sections, carrying over 800 million gross tons since 1937, 1938, 1939, and 1940 in track serving the WP and SP. I recently ran tonnage figures on this line and it was 777 million gross tons of traffic, and it is not up for renewal. It is carrying 28½ million tons annually. So what are you people thinking of when you raise the question, "How long will the track stand up under these loads?"

Speaker Response: I don't want to answer the question directly, but I would like to make some comment on axle load. We are investigating the effect of contact stresses and development of shelly rail as a result of the axle load. The heavier rail does not reduce the contact stresses, and the contact stresses are greatly responsible for our rail fatigue problems since the stresses are located just below the surface of the rail. In many cases they reach a point where they actually exceed the yield point of the material. Now, there is one way of reducing these contact stresses very considerably, and this is by using a profiled wheel. If you use a conical wheel you have a very high contact stress, but if you modify that wheel contour by adding another radius, you can greatly decrease the contact stresses for a given axle load. We have done theoretical studies and found that some contact stresses for the same axle load are reduced by as much as 60%. This means that you can increase the load by four times before you would achieve the same sheer stresses. This is something we are looking into because it is now becoming practical to use such profiled wheels. In the past it was not possible because you would not have the required hunting stability. But if you can maintain hunting stability with such wheels, you can get the second benefit by greatly reducing your contact stresses which would enable you to go to higher axle loads, even higher than the 25 or 30 tons. In fact, you can go to lower contact stresses at the moment you find some difficulty with your track. I would say if you do find problems of shearing then it is definitely an indication that for the wheel profile you are using your axle load is too high. I dare say that the damage is being done with brand new wheels, wheels which still have the conical profile. Once a wheel is worn in, the contact stresses will be reduced automatically.

Delegate Comment: I would like to direct a question. It seems throughout the day that we have been considering the action of freight cars on the rails. I wonder if your program has looked at effects of unsprung mass on the locomotives. We seem to be ignoring this on this continent, while they are most concerned with it in the UK and in Europe.

Speaker Response: One of the intentions in conducting our high speed locomotive tests was to look at this phenomenon. We have also done work in the area of curve negotiations using locomotives. One of the reasons that we just recently ran the AMTRAK locomotive at speeds up to 112 mph at

Pocatello was to evaluate the secondary damping characteristics of this locomotive.

Delegate Comment: Are you running tests on just one type of locomotive or are you concerned with four-axle locomotives as well?

Speaker Response: We were primarily concerned with six-axle locomotives, although we have done previous studies to look at forces generated by four-axle locomotives versus six-axle locomotives. We found the steady lateral forces associated with the six axle locomotive to be somewhat higher—about 20% higher—but we found the transient forces on the four-axle locomotive to be higher than the six-axle locomotive. We haven't ignored it, but we are concentrating in other areas right now.

Delegate Comment: Could someone give some specifics on repair and/or maintenance cost analyses, the type which was mentioned in one of the prior presentations?

Speaker Response: We have the capabilities of maintaining mileage, in fact our fleet of 70,000 cars has been maintained on a mileage basis, and the mileage basis relates to conditions that are observed on cars. In other words, we established the fact that after 400,000 miles, Piggyback cars must undergo a series of program repairs, e.g., trucks, draft gears, etc. Another thing that is done is to provide engineering improvements on older cars that have been applied to more recently built cars. In other words, we have seen the need to upgrade older cars and reduce the maintenance. We have the capability of reviewing AAR billing and contract shop billing. This has further substantiated our conclusions for this type of program maintenance. Auto rack cars, of course, are in a different category; they must undergo program repairs at 340,000 mi.

Delegate Comment: In other words, you are saying that it is important to know what your costs and performances are by item?

Speaker Response: Yes.

Delegate Comment: We have gone to higher loadings because of the economics—presumably part of the economic analysis includes factors associated with increased maintenance costs. Now, has anyone gone over the available data to see if the anticipated economic benefits on an overall system basis are in fact being obtained?

Delegate Comment: To the best of my knowledge the data is not available. Mr. Ruprecht could probably develop this information for you, but I am sure he wouldn't want to compare 100-ton cars versus 70-ton cars. I am sure Trailer Train has this data on their fleet of cars, but they are somewhat different than the average car fleet operating in this country. If there is anyone in the room who does have that data, maybe they could respond at this time. I don't think we know at this time what our maintenance cost is on the 100-ton car.

Speaker Response: I think it is important to recognize that the FRA has an important contract to develop data based in the area of maintenance cost. The contract is with the SP. This remark isn't directed specifically to the question that was asked, but we all recognize that the ICC format data simply doesn't enable us to generate this type of information in the form that will enable us to make these kinds of decisions. I am confident that when the FRA contractor comes forward with this report, we are going to have a much better insight into what has to be done with the data. We have other research programs being conducted within our Research and Test Department looking at the rail-wheel contact stress issue along lines that have been alluded to here earlier, or explicitly mentioned. Surely the data base deficiency is a very real problem, however.

Delegate Comment: I would like to direct a question regarding the chart that indicated considerable truck hunting, on both empty and loaded cars. From the information we have and my own personal viewing of cars under load, we get very little, if any, truck hunting under load. Most of the truck hunting occurs when the cars are empty. I would like someone to comment on that please.

Speaker Response: I mentioned one must differentiate between wheelset hunting and body hunting. It is really correct to say that it is light cars that are most prone to wheelset hunting. Now the two forms of hunting are really easy to recognize, because if it is a wheelset hunting instability you can go faster but your ride is going to continue to deteriorate. If it is on the other hand a body hunting instability you can in fact ride smoothly through the instability. This is provided it occurs at a low enough speed and you have the courage to increase your speed.

The two instabilities I referred to were in the one case for the light car, the wheelset type instability. This car is very light, in fact it is only 15 tons, and this increases the probability of wheelset instability. In other words, increasing our running speed does not help us in any way. The other example, with a loaded car, is on the other hand body instability, but because it did occur at a speed of 50-55 mph, we did not in that case have the courage to go faster. I can assure you of one thing. When a loaded car does hunt, the forced feedback is of a considerably higher magnitude than when an empty car hunts. So I cannot really say that it would have been possible to ride through this zone to increase the car's stability. There is one car in particular where you get an instability which starts at about 60 km per hour, and beyond that speed the car will run absolutely stable again.

Delegate Comment: We have observed that empty cars having new wheels generate very little hunting. We can pick out cars that hunt in the light condition and put these wheels on cars that do not hunt . . . and, in fact duplicate the hunting condition. So it definitely relates to the worn tread condition in our case.

Delegate Comment: The worn tread condition, or the worn wheel condition?

Speaker Response: Well, a case of both. Generally we have some worn flanges coupled with the hollow worn tread.

Speaker Response: Generally a new wheel will have a higher wheelset and body hunting stability than a worn wheel, but types of wheels in practice are very sensitive to rail contour.

Moderator Loftis: Gentlemen, this concludes the afternoon session. We look forward to seeing all of you tonight at the Dinner Session.

EVENING SESSION

Edward Ward, Acting Associate Administrator for Research, Development, and Demonstration for the Federal Railroad Administration, opened the after-dinner program by commending the speakers who had been heard in the opening sessions for the quality of their presentations and thanking Dresser Industries for making the Conference an outstanding affair and for providing cocktails and dinner. He also thanked Jack Loftis for all the work he had done to organize the Conference, noting that Loftis was "the spark plug who really put this Conference together, and the quality of this Conference, in large part, is due to Jack." He then presented John Ingram, FRA Administrator, who welcomed the guests.

WELCOME ADDRESS

John Ingram, Administrator, FRA: Thank you very much for your kind indulgence in listening to me twice, and I want to wish you a good evening and a good time tomorrow in the continuation of the program. I certainly consider it an honor as well as a pleasure to have the chance to talk to you and welcome you twice in one day.

I am going to be as brief this evening as I was this morning. I want to join you in welcoming our main speaker for this banquet, Gus Aydelott, who is in the midst of showing the nation and the world that he can not only operate a heads-up railroad running through the Rocky Mountains, but he can also play a key role in the United States Railroad Association in bringing about restoration of heads-up railroading in the Northeast. We are extremely fortunate to have him with us this evening because, if you would like to see something horrendous, then see the schedule of events of the Board of Directors of USRA. I don't see how they are going to find enough time to do all the things that are on that program.

As I am sure some of you know, I have collected my three-year perfect attendance button from the Federal Government and shortly will return to the bramble bush of private enterprise. If everything works out well, I'm headed for a railroad that does not really enjoy a reputation of head-over-heels financial success. Some of my good friends have said being Administrator of the Federal Railroad Administration is sort of like being the social director on the Titanic. Now I am headed for the Rock Island Railroad.

As I leave the FRA I can appreciate one thing, that my department is concurrent with the first annual Railroad Engineering Conference sponsored by the FRA. I am delighted about that. With the wholehearted support of those who are here, this Conference can be a pacesetter for other railroads and suppliers. I hope that the success of this Conference will encourage others to conduct FRA conferences on, say, railroad economics, bringing together the financial market, key shipping agencies, FRA rail planning, and other Federal and local people. Annual conferences on rail safety could also be effective.

After three years I've come to the not necessarily unhappy conclusion that the best thing the Government does, the one thing the Government does best, is to talk. However, sometimes Government people just talk to each other, and I don't think that's too good. When Government people can talk with industry people and financial people and other concerned people who make up an industry, then I think you can produce the kind of interaction that's needed.

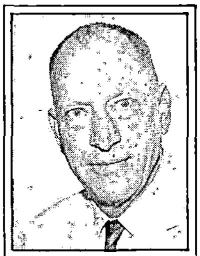
I again want to express my heartfelt appreciation to Dresser Industries for making us their heirs to this technological conference. I certainly express appreciative enthusiasm for the lessons this Conference has developed. I enjoyed being with you. I am confident in the railroad's future and look forward to learning from all disciplines in the years ahead. Thank you very much.

Edward Ward: We do plan to continue having the FRA Engineering Conferences here in Pueblo; our plans are beginning for the next one here in October of next year. We would certainly appreciate any thought that any of you may give us on a theme for next year's Conference. Jack Loftis has assured me that if I don't start work on next year's Conference next week, we won't make it, so we are going to start right in. Now a few words from Jack.

Moderator Loftis: I told Ed Ward you fellows have heard enough of me, but he said I have seniority on both Gus Aydelott and Gerald Phipps. I went to work for the Rio Grande in 1934, and they didn't come until 1936. It took me until 1942 to find out that Gus was going to be President, and I had to get the hell out. It took Jerry about six months longer, and he made the same decision.

Jerry Phipps, the man who will introduce our speaker, is a graduate of Williams College and came to work for the Rio Grande about the same time Gus did. He went into service and when he came back he went into the contracting business and did a few other things. His Denver Broncos football team won last Sunday so I think he's happy, and I am happy for him.

Keynote Address Introduction



Gerald H. Phipps
President
Gerald H. Phipps, Inc.

Gerald H. Phipps is President of Gerald H. Phipps, Inc., Denver, Colorado, general contractors in building construction. He is a director of numerous enterprises and organizations, including the Denver and Rio Grande Western Railroad Company, Rio Grande Industries, and the Southern California Edison Co. He has taken a leadership role in interests ranging from banking to philanthropy, education, and sports.

After being graduated cum laude from A.B. Williams College in 1936, Phipps was with the D&RG until entering service with the Navy during World War II. He has held his present position since 1952.

Gentlemen, it is a real pleasure to be here with you and to be back, at least for an evening, in the business that I thoroughly enjoy and that I respect and that has been a hobby, if nothing else, of mine all my life. I also want to join in thanking Dresser Industries for their hospitality tonight, speaking as a 100% freeloader. However, speaking as a stockholder of Dresser Industries–quit spending so much of our money!

Gale Benson Aydelott. That's a name that strikes terror in almost everybody in the business. No wonder he goes under the name of Gus. Gus was born in LaGrange, Illinois, July 22, 1914. That's important only for one reason; it wasn't until I picked up that date that I was sure that Gus was older than I am. Gus's father retired as General Manager of the Burlington and then went on to be Vice President for Operations and Maintenance of AAR. Gus graduated from the University of Illinois in 1936 and went to work very shortly after that for the Denver and Rio Grande Western as a laborer on a track gang. He has been with the D&RGW ever since.

To really understand and appreciate Gus, you have to know a little about the history of the Denver and Rio Grande Western from 1936, or perhaps 1935, up to 1974. In 1936 the D&RGW was just ending its first year of its fourth bankruptcy. I think it was the fourth; if you read the history of the D&RGW, you lose track. It was 13 years in trusteeship and waiting for the reorganization that brought about the fine organization that you see today. The situation and condition of the property was, to say the least, sad. I know about the first days as Jack does, because, as Jack mentioned, I went to work at the Office of the Transportation Department on the third floor of the Equitable Building in Denver in the fall of 1936, and if you ever saw a seedy operation–that was it. Just to give you one example of the way things were, about every three months the chair that you were assigned to would start to vibrate about the same as a tea kettle on a narrow gauge, and you would find yourself in a heap on the floor. No new chairs were available, so you hunted up and down the building to locate some antique piece to serve for another two or three months and put it behind your desk.

Out on the line, things were a bit better. Most trains got to Salt Lake, and occasionally, on time. At that point, some intelligence was beginning to show in the organization, and someone, somehow, also demonstrated that they had ideas of how to put the property back together. Most fortunately, the Honorable John Foster Symes of the United States District Court carried the primary responsibility for the property, and he had the foresight and intelligence to establish a trusteeship rather than a receivership. As trustees, he appointed Judge Wilson McCarthy and Henry Swan. I don't want to take anything away from Mr. Swan, whose financial and engineering background contributed greatly; however, I think that anyone familiar with the history of the D&RGW would agree with me 100% that the guiding genius was Judge McCarthy.

With the approval of the court the Trustees poured funds into the property and, by the time World War II commenced, the Rio Grande was in physical condition to handle the traffic increase that came their way—a far cry from the World War I history of the Colorado Midland, whose deteriorated condition, aggravated by increased traffic, led to its collapse. By the time the end of the war came, the Rio Grande was in remarkably good condition. It did not have quite the traffic it had during the war, but it was making money.

During all this time, Gus Aydelott was working his way up the ladder—track inspector, engineering assistant, roadmaster, division superintendent. A key man in the organization was Alfred E. Perlman, who, with the 1948 reorganization, held the position of Vice President and General Manager, the number two position to newly elected President Wilson McCarthy. When Mr. Perlman departed for what he thought were greener pastures at the New York Central, he was succeeded by Gus Aydelott. When Judge McCarthy died in February, 1956, Gus became President.

He is now President of the Rio Grande, President of Rio Grande Industries, Director and member of the Executive Committee of The First National Bank of Denver, and a director of Ideal Basic Industries. He is also a Trustee of the University of Denver. His most recent distinction is appointment to the Executive Board of the newly created United States Railway Association, an indication of his stature within the industry. On this new board, he serves with two representatives of shippers, two representatives of the financial community, one representative of the Conference of Governors, one representative of the Conference of Mayors and representatives of the Secretaries of the Treasury and of Transportation. The board is chaired by a representative of the private sector, who happens to come from the financial community. Obviously, he is outnumbered, but he will not be outfought. I don't know what the accomplishments of the United States Railway Association may be, and the jury will be out for a long time. However, if it proves to be a viable organization and of benefit to the railroad industry, the industry's representative will have a major part in that accomplishment. I have no idea what he is going to say this evening, but I do know one thing—his remarks are not going to be dull—Gus Aydelott.

Keynote Address

Gale B. Aydelott
President and Chairman
Denver and Rio Grande Western Railroad Company

Gale B. Aydelott is President and Chairman of the Denver and Rio Grande Western Railroad Company and President of Rio Grande Industries, Denver. His entire business life has been spent with the D&RG; he started on a track gang shortly after his graduation from college in 1936 and has worked in all areas of the company's operations. He was named Vice President and General Manager in 1954 and two years later was elected President of the company.

Aydelott was born in Illinois and received a BS degree from the University of Illinois. He attended the Institute for Management at Northwestern University in 1953. He is a member of the American Association of Railroad Superintendents and the National Defense Transportation Association.

Editor's Note: Mr. Aydelott presented a most informative summarization of his views on the existing operating conditions of the railroading industry in general... and suggested possible courses of action which he felt would contribute to the advancement and progress of the industry.

It is regretted that when this Proceedings Book went to press, due to some unavoidable circumstances, it was not possible to have Mr. Aydelott's presentation included here.

Edward Ward: Thank you very much, Gus Aydelott, for a very entertaining talk. You discussed worthwhile things. As host, Dick Lich has the last word tonight.

Richard Lich, President, Dresser T.E.D.: Dresser Transportation Equipment is most pleased to have had the opportunity to be host to all of you tonight. We are particularly pleased with the cooperative tone of the Conference from the railroads, Government, railroad associations, railroad suppliers, and our overseas guests. As I made mention of this morning, I now believe we can forge a new direction to our railroad interest. Thank you very much for being with us.

SESSION III
NEW DEVELOPMENTS

Moderator Loftis: The session today is on New Developments, and new developments are most important. But, as you all know, and as Gus Aydelott noted last night, there are many aspects of new developments, all the way from a better roadbed to better utilization of railway freight cars.

As you heard in the discussions yesterday, we are learning about the railroad environment each day, and as we learn we are able to open up new vistas for improvement. This is not like taking a giant step to the moon; it must solidly build upon what we have and make as rapid strides as possible without stumbling. This takes knowledge in which we must all share so that the strides we take will be rapid but in the right direction. That is the reason it is so important that we all—AAR, FRA, railroads and industry—cooperate to continue to make the fine industry progress we have been making. I am hopeful and enthusiastic for the future.

Our first speaker today is erroneously listed as Sam Casey of Pullman, Inc. I am sorry that that error in printing occurred, but I am certainly happy to welcome E.T. Ahnquist, President, Pullman-Standard, a Division of Pullman, Inc.

KEYNOTE ADDRESS

The Other Shortage

Elwyn T. Ahnquist
President
Pullman-Standard Division
Pullman, Inc.

Elwyn T. Ahnquist is President of Pullman-Standard, a division of Pullman, Inc., Chicago, Illinois. He attended Northwestern University and Illinois Institute of Technology and is a graduate of the Institute for Management at Northwestern.

Ahnquist began his career at Pullman-Standard in 1940 as a template maker in the Pullman Car Works. He held various managerial positions there primarily in sales and marketing before being named President in 1971. He is a member of the Western Railway Club, past Chairman of the Railway Progress Institute, and a board member of the Institute for Rapid Transit.

You are aware, of course, that your program listed Sam Casey, President of Pullman Incorporated, as your keynote speaker today. However, when Mr. Casey learned he had to be out of the country on business, he asked that I fill in for him. To say the least, I am delighted to be with you, for it allows me to renew many acquaintances, and at the same time talk to you on several subjects on which Mr. Casey and I are in agreement.

Our panel discussion today will highlight a number of new developments in the rail industry—developments which should increase our efficiency, our capabilities, and, hopefully, our profitability. Working with people like our own George Rousseau, I have learned that none of these new developments comes easily. Each is purchased with hard-earned dollars, long hours of work, and the skill of our people. I thought it might be appropriate, before our distinguished panel begins listing our accomplishments, to consider the obstacles we face on the road to technological improvements.

Traditionally, we have learned to recognize and, to some extent, learned to live with limited money and limited time. More recently we have also faced shortages of materials. But what I want to talk to you about this morning is another kind of shortage. It's a shortage that will make anything you talk about this morning an unreachable goal unless we do something about it—*now*. Solutions to this shortage are much more difficult to pinpoint than those for our current materials shortages.

I am referring to the people shortage—a shortage of the people who put in the long hours and possess those innate skills we need for technological developments—the engineers, scientists, and technical people we need to bring a better tomorrow closer. Who should know better than those of you gathered here in Pueblo the demands that will be placed upon the railroad and railroad supply industries in the years ahead? Demands for greater vehicle stamina, safety, and reliability.

Meeting these demands will require far more technical knowledge than we ever dreamed necessary. Knowledge of what each car part is supposed to be doing—and of what is going on inside that part while it is working.

There's no question that the demand for bright, well-trained engineering personnel in our industries is going to become acute. And don't forget that we're playing in the big leagues, with other hungry industries that are already conducting fierce campaigns to lure young—and not-so-young—engineering talent into their folds. Look in your Sunday paper and you'll quickly see that the demand for this human resource exceeds the supply. Yesterday's assumption of an abundance of engineers is no longer valid.

Much like wheels, castings, and steel in our industries, the supply of engineers for business in general is tight. In the 1974-75 school year, we can expect less than 32,000 students to graduate with bachelor's degrees in engineering, a shortfall of 18,000 from what American industry needs. That graduation figure is down considerably from nearly 46,000 a year at the outset of this decade. At the end of the present decade we should see a small rise from today's level of graduations—to a little over 38,000 for the year. Although up, this graduation figure is hardly something to cheer about in light of the task ahead of us.

Let's examine our own actions: What have we been doing to encourage young people to choose engineering as a profession? Sputnik came along in 1957 to spearhead the restoration of excitement in engineering. We found ourselves behind, and suddenly there was a desperate need for engineering talent to help us catch up. The nation needed the space vehicles and systems for our game of catch-up with the Russians. Our engineers more than met the challenge, putting men on the moon, surpassing anything the vaunted Russian technicians had ever hoped to accomplish.

Then came 1971, and with it the wholesale layoff of skilled engineers in the aerospace industry. The next thing they knew, instead of being our means of saving face, engineers were a glut on the employment market. Potential enrollees in engineering schools across the nation began looking for more promising occupations to follow.

Engineering simply has not regained the allure it enjoyed in the decade of the sixties. Restoring it to its former eminent stature is the job facing all of us here today. Unfortunately, some engineers are downgrading their own profession and discouraging young students. That's something we can't afford, because high school graduating classes are getting smaller.

One way for us to expand the marketplace for new engineering talent is to stop making it a man's world. Why can't we encourage more women to enter the profession? Actually, we're doing that right now at Pullman. This year we sponsored the enrollment of a number of young women from the Chicago area in a week-long seminar at Michigan Tech that was aimed at pointing out the role women could play in the realm of the slide rule. We're already laying plans to broaden our sponsorship next year.

During a recent visit to the Houston headquarters of Pullman's Kellogg division, visitors from Peking were surprised to see how few women were performing engineering work. They volunteered that over 35% of their engineers are women. In sharp contrast, women make up barely 1% of our engineering force here in the United States.

Another thing we're doing—also in the Chicago area—is participating in a program aimed at introducing inner-city high school students to the sciences. Students with potential are sent a couple of hours a day to university centers in the city where they receive instructions in the sciences. We've recognized that youngsters with the aptitude to become engineers aren't receiving the proper science instruction—sometimes none whatsoever—in their inner-city schools. We want to avoid this waste.

For years Pullman-Standard has been engaged in a cooperative education program for student engineers. We seek to interest them, through "hands-on" projects at our facilities, in becoming vital parts of our industry. Other Pullman divisions have similar programs, and I'm sure most of you have them, too.

Getting young people interested in the engineering profession will not be an easy task. Of those who do become interested, how many will select the field of transportation as their life work? Ours, then, is a double-barreled problem. I think, though, that we've got enough exciting things going on in our industries, enough challenges, to capture and hold the interest of budding engineers. Certainly, the pace of developments by and for the railroads is quickening.

In the sixties, new R&D projects began emerging from the shadows. In our own Pullman tech center, we began a detailed analysis of the effect of long-travel cushioning on freight car performance. Later, our Research and Development Vice President, Dr. Bill Manos, whom most of you know, and his crew of engineers began delving into one of the biggest problems to hit our industry in many a year—freight car rock and roll. Of course, this one is still under study, and if any young engineers are in search of a real challenge, they could undertake the task of finding a way to fully whip this problem.

I could go on and on with the list of tantalizing projects that have been undertaken in recent years by our engineers, as well as others in our industries. The analytical simulation developed by our engineers for dynamic analysis of train derailments may bring more concrete benefits to this country than developing a guidance system for a space vehicle aimed at Mars. Challenges like this surely couldn't be labeled a dull undertaking by a young engineer seeking a field to enter. And look at the developments–some of them very futuristic–that are taking place right now at the nearby FRA Test Center. Young engineers couldn't help but become excited over what is happening there and what will be coming along in the months and years ahead.

I think we've got quite an exciting tale to tell young people about developments on the technical side of our business. By no means could ours be labeled routine engineering.

As we look back over the past ten to 15 years, we can recount a number of significant accomplishments. Looking ahead, I see challenges that demand a capable engineering force to meet them head on. The recent cooperative study of certain car part stress characteristics is an example of the complicated, exacting job that an engineer can encounter in our business. And we can't forget the ever-increasing number of computer-directed math models our industries are using to help reach solutions to technical questions.

Today, I believe the AAR is doing more on behalf of improving the technical side of railroad operations than ever before. My hat is off to Bill Harris for the work he and his people have done and are doing. We're doing more, too. We, and others in the supply business, are cooperating in every way possible with the railroads, with Federal agencies, to improve the rail vehicle, to improve its efficiency and safety.

And we aren't likely to run out of challenges. Who can argue about our need for a better coupling system, better trucks, a better understanding of the wheel-rail relationship? We need better testing methods. Tomorrow's freight car will be subjected to more punishment than I like to think about. This means our designs will have to undergo almost constant scrutiny as we seek product perfection. We'll never succeed without a dedicated, inspired engineering corps.

Engineering is a prestigious occupation. So is railroading. And so is the building of the railcars and motive power that give mobility to American industry.

Let's do more boasting about the work we do. Let's lure more engineering candidates into our camp. We'll be better off for it. And so will they.

Moderator Loftis: Thank you, Mr. Ahnquist for your presentation. Our next speech will be presented jointly by John Abramson and Dennis Ojard, both of the Duluth, Missabe and Iron Range.

Innovative Concepts in Unit Train Operation

John E. Abramson
Shop Superintendent-Mechanical Department
Duluth, Missabe and Iron Range Railway Company

John E. Abramson is Shop Superintendent in the Mechanical Department of the Duluth, Missabe and Iron Range Railway Company, Proctor, Minnesota. He began his service with the railway in 1951 as an assistant electrical engineer, and after a series of promotions was named to his present position in 1972. His previous employment was as a transformer design engineer with Allis-Chalmers Manufacturing Company.

Abramson received a BS degree in Electrical Engineering from Michigan Technological University in 1942 and has participated in numerous technical and management courses and seminars. He is a member of the Diesel Locomotive Electrical Committee of the Locomotive Maintenance Officers' Association, a member of the Air Brake Association, and a Registered Professional Engineer.

Dennis R. Ojard
Electrical Engineer-Engineering Services Department
Duluth, Missabe and Iron Range Railway Company

Dennis R. Ojard is an electrical engineer in the Engineering Services Department of the Duluth, Missabe and Iron Range Railway Company, Duluth, Minnesota. Before joining the railway company as an electrical engineer in 1973, he was a research engineer at Boeing Company.

Ojard received the BS degree in Electrical Engineering from the University of Minnesota in 1965. His MS degree in the same field was earned at Seattle University eight years later. He is a member of the Instrument Society of America.

Introduction

John Abramson: The Duluth, Missabe and Iron Range Railway is a Class 1 common carrier with approximately 900 mi. of track, of which 500 mi. are main line. The DM&IR main revenue derives from hauling iron ore and taconite pellets from the Mesabi Iron Range to the ports of Duluth and Two Harbors on Lake Superior. The DM&IR employs approximately 1,700 people, owns about 10,000 cars, and operates 79 locomotives. Last year, the DM&IR hauled approximately 40,000,000 tons of commodities, 28,000,000 long tons being natural iron ore and taconite pellets.

Prior to the development of an economic upgrading process for taconite, a low-grade iron-bearing rock, the DM&IR main commodity was iron ore in its natural state, with some washing and other beneficiating. Natural ore requires sorting and blending by car prior to loading into boats. The mining, processing, and shipping of natural iron ore is seasonal, due to freezing conditions. Such shipments are, therefore, limited to the approximate period from April to October.

Taconite concentrate is formed into pellets about the size and shape of a marble, relatively hot and dry when loaded into cars and uniform in physical properties, so it does not require any sorting or blending prior to vessel loading. Taconite processing plants are major facilities which operate year-round. Shipping to the docks continues throughout the year, with the taconite pellets being stockpiled at railroad storage facilities during the winter season when the upper Great Lakes are no longer navigable.

Taconite pellets, because they are uniform, are ideal for unit train operation. However, several factors have inhibited successful continuous unit train operation. The weather in northern Minnesota is quite severe, with temperatures reaching as low as -45° F. Cold weather created severe train-line leakage, to the extent that train lengths were limited to from 40 to 75 cars in order to meet the Federal gradient requirements of 15 psi between the locomotive and caboose. In addition, the DM&IR requires a maximum gradient of 5 psi on loaded trains when descending major grades, further reducing train lengths. Normal unit train lengths are 124 cars, each carrying about 75 long tons of taconite, or 9,300 LT per train. Shorter train lengths, dictated by prevailing weather conditions, are undesirable, with respect to both scheduling and operational efficiencies.

The DM&IR unit train operation, as planned, was limited not only by weather but at times by running-time restrictions. The general terrain away from Lake Superior is about 800 ft. above lake level, and severe descending grades must be negotiated to reach our docks. At Duluth, a 5-mi., 2.1% grade (650 vertical ft.) starts near the Proctor sorting yard and ends on the ore docks. At Two Harbors, 1,000 vertical ft. must be negotiated over a 10-mi., 1.3% grade, increased to a 2.9% grade for 3 mi., ending in the Two Harbors yard. Safe operating practices dictate that retainers must be set and released on all cars for each grade. The time consumed in this retainer manipulation added up to one hour to the operation, with the result that some trips could not reliably take place within the Federal 12-hour law.

The two basic problems of air leakage in cold weather and time spent on retainers required a solution. The main source of the brake pipe leakage is at angle cocks and glad-hand hose couplings, since rubber gaskets lose resiliency in cold weather. The most logical means to solve this problem was to eliminate most hose couplings and angle cocks and to use welded fittings wherever possible. The first approach was to eliminate couplers between every other car and use a solid drawbar similar to that formerly used between steam locomotives and tenders. Our operating people felt that, due to the short length of ore cars (24 ft.), they could operate with four cars solidly coupled together in a 96-ft. unit.

It was highly desirable from a cost standpoint to retain the existing draft arrangement if at all possible. An experimental drawbar was fabricated from the shanks of two "E"-type couplers, annealed, and used to solidly couple two cars together for test. Several road trips proved this approach would work.

DM&IR ore cars have a 17½-in. pocket, a short-shank "E" coupler with a horizontal draft key, and a 2-in. follower block against which the coupler butt fits. Fig. 1 is a drawing of a standard ore car. Note the short distance between truck centers of adjacent cars (8 ft. 10 in.), and the relatively short distance of 3 ft. 2 in. from the truck center to striking casting. In fact, there are only 13 in. between wheels of adjacent cars.

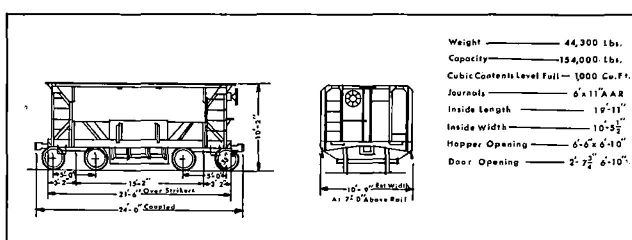


Fig. 1. 70-ton ore car.

Because of the truck center spacing of 15 ft. 2 in. and the very short overhang from the bolster to the end of the car (3 ft. 2 in.), it was felt that swivel butt couplers and yokes could be avoided, thus reducing conversion costs. The carrier iron was removed and the through bolt reapplied. In the event the cross key fell out and the cars separated, the end of the drawbar would be supported approximately 7 in. above the rail by this through bolt, eliminating any hazard of "pole-vaulting."

The solid drawbar has an advantage over "E" couplers in that it will keep the car in line on the ties in the event of a derailment. To remain consistent, the "E" coupler was replaced with an "F" type to prevent vertical disengagement during a derailment. The "F" type couplers required a spring-loaded carrier iron which the DM&IR fabricated. The key slot in both the drawbar and "F" coupler shanks was tapered seven degrees to allow for vertical movement (normally accommodated by vertical slippage between couplers). The yield strength of the drawbar is the same as the "F" coupler and greater than the coupler knuckle, assuring that failure in draft would occur at the knuckle rather than the drawbars or coupler shanks.

Several operating benefits were achieved by going to solidly coupled units. Free slack has been reduced by more than 7 ft. on a 124-car train, from a typical value of 21 ft. to 13.9. ft., a 34% reduction. Table 1 shows the sources of this reduction. The ride in the caboose is much smoother, and crews highly prefer the unit trains.

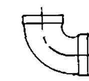
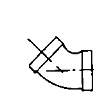
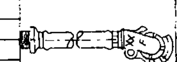
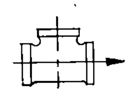
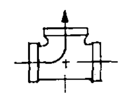
Normal slack, "E" coupler	=	25/32″
Normal slack, "F" coupler	=	3/8″
Normal slack, drawbars	=	0″
Normal slack, key slot	=	5/8″

4 ore cars with "E" couplers + key slot = 4 x 25/32″ + 8 x 5/8″ = 8-1/8″
1 miniquad car set with "F" couplers + key slot = 3/8″ + 8 x 5/8″ = 5-3/8″
Total free slack, 124-car normal train = 21 ft.
Total free slack, 124-car miniquad train = 13.9 ft.
Net reduction in free slack = 7.1 ft. or 34%

Table 1. Free Slack Reduction in Miniquad Train

As mentioned previously, angle cocks and hose couplings were eliminated by going to solid drawbars. These components in the brake pipe system have an adverse effect on brake pipe flow resistance. Table 2 shows some equivalent lengths of fittings, including glad-hand connectors. By eliminating 3/4 of our angle cocks and hose couplings, plus going to welded fittings, a net reduction equivalent to 72 ft. of brake pipe per four cars, or 2,232 ft. per unit train, is achieved. This is a 32% reduction in air flow restriction. As a result, train control, handling, and charge time have improved accordingly over a conventional train. The train line gradient on a 124-car train at -25° F is typically 3 psi, equal to, or better than, conventional trains in the middle of the summer. Brake pipe leakage at these cold temperatures is typically 2 psi after one minute during conventional terminal leakage tests. To assure minimum possible air leakage, each four-car set must pass the shop air-brake leakage test as if it were a single car.

Going to solidly coupled, four-car units has tremendously improved cold weather operation by permitting full 124-car trains to run throughout the winter.

CAST OR WROUGHT STD. PIPE FITTINGS	NOM. PIPE SIZE	EX HVY IRON PIPE I.D.	EQUIV LENGTH FT(1)	MISCELLANEOUS FITTINGS AND DEVICES	NOM. PIPE SIZE	PC NO.	EQUIV LENGTH FT(2)
 90° ELBOW	1-1/4	1.278	3.45	 ANGLE COCK	1-1/4	564350	2.5
 45° ELBOW	1-1/4	1.278	1.61	 1-3/8″x22″ HOSE W/FP-5 COUPL. AND 1-1/4″ NIPPLE	1-1/4	87101	11.5
 TEE THRU RUN	1-1/4	1.278	1.80	 FP-5 COUPLING	1-1/4	86739	7.5
 TEE THRU BRANCH	1-1/4	1.278	6.90				

EQUIVALENT LENGTH = MEASURED LENGTH + LENGTH ALLOWED FOR FITTINGS

Note: All data must be considered only approximations and may vary between different suppliers.

(1) Sabin, Crocker, M.E., "Piping Handbook", 4th Ed., McGraw-Hill, 1945.

(2) WABCO Test Data.

Table 2. Effective lengths of some brake pipe connections.

The use of retainers, as mentioned earlier, at times imposed time-limiting problems to unit train operation. A straight-air retainer system designed by Westinghouse Air Brake Company for the Orinoco Mining Company cars in Venezuela seemed to provide an ideal solution.

Fig. 2 shows a simplified piping diagram of the straight-air retainer system. A separate air line, similar to the brake pipe, runs the length of the train and is supplied from the locomotive main reservoir through a separate independent brake valve controlled by the engineer. Each car has a double-check valve to the brake cylinder which is connected to the straight-air line on one side and the AB control valve on the other. The side of the check valve carrying the higher pressure will supply the brake cylinder. In operation, the engineer first makes an automatic brake pipe reduction, resulting in a proportionate brake cylinder pressure, such as 30 psi, and brakes are applied. He then opens the straight-air line to apply 20 psi to the straight-air side of the check valve. The automatic brakes are then released, and brake cylinder pressure drops. When slightly below 20 psi the check valve moves and connects the brake cylinder to the 20 psi supply from the straight-air side. Release of brake cylinder pressure, therefore, stops and is held at 20 psi. The engineer can now add to or decrease this pressure at will. In the meantime, with the automatic in release, the brake pipe auxiliary reservoirs are being restored to full pressure for any need that may arise. Standard retainers were left on these cars so they can be intermixed on conventional trains. The variable straight-air retainer has significantly improved train handling and control and has assured operating within the time frame imposed by mine operations, dock loading, and the 12-hour law.

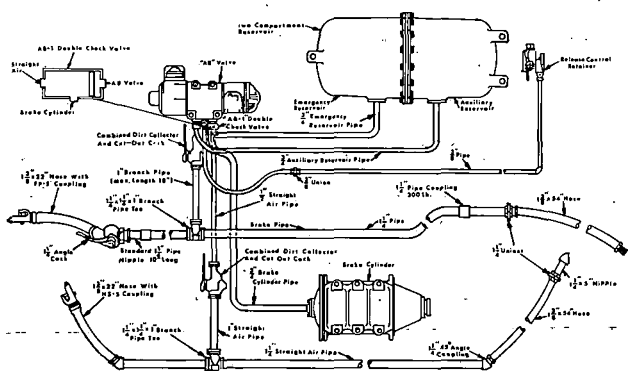


Fig. 2. Piping diagram of the complete AB freight car brake with straight air piping used on DM&IR miniquad ore cars. (NOTE: Portions of this drawing are from a WABCO piping diagram.)

Since the cold weather and grade operating problems appeared to be solved, the DM&IR in 1971 proceeded to modify some ore cars in the manner just described. These solidly connected units were called miniquads and were equipped with a straight-air retainer system. Fig. 3 shows this car set. The term "mini" in miniquad comes from the 9¾-in. extension on the top of the car (as compared with previous cars in taconite service, which had 19.5-in. extensions), which allows loading these cars to a 75-ton capacity but prevents overloading. The corner posts of the end cars are painted fluorescent orange to delineate the coupler location. Fig. 4 shows a general view of the drawbar-coupled cars at the B ends. Note that this allows the brakeman to set brakes or retainers on two cars from the same location. Each DM&IR ore car has a high train line, with both brake pipe and straight-air lines above the coupler. This provides an easy and safe means for the brakeman to couple these cars, an arrangement especially appreciated on the ore docks.

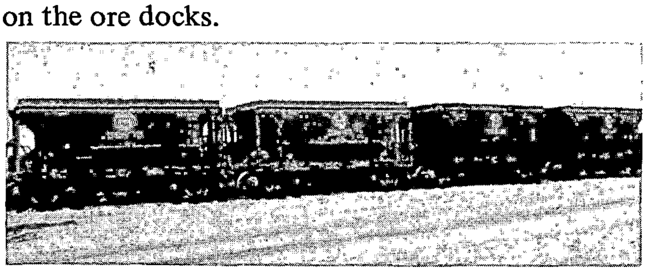


Fig. 3. Overall view of 4-car unit. Orange corner posts denote coupler location.

Fig. 4. General view of drawbar-coupled cars at B-ends. Note regular and straight-air retainer hoses are one piece and well separated to avoid chafing. Except for removal of uncoupling lever, no changes were made in existing safety applicances.

The hose couplings on a straight-air line are type "HS," which will not mate with standard brake pipe "F" type host couplings. There are no angle cocks on the straight-air line or on the brake pipe within the miniquad; i.e., angle cocks are only on each end of the miniquad. The only angle cocks on the straight-air system are on the locomotive and caboose.

Unit miniquad trains have been successful beyond everyone's hopes. The train line gradient at subzero temperatures is better than expected. Steep grades can be traversed without having to stop at the top and bottom to set and release retainers. This operation is safer because the straight-air system can be used for braking while the brake pipe is recharged and remains charged. No danger of stalling is present, since the straight-air braking can be modulated according to grade. Slack action has been considerably reduced, providing a much smoother ride for the crew in the caboose.

The only operating changes required with these trains are testing the straight-air system, and the engineer getting used to starting a train with 34% less free slack. After adjusting to these conditions, the crews have no starting problems; in fact, they are very pleased with the way these trains handle.

In addition to standard air brake terminal tests, the straight-air line of loaded trains is tested prior to leaving a terminal by applying 25 psi at the locomotive. When the conductor observes 20 psi at the caboose, he notifies the engineer, at which time the straight air is released and the train proceeds. A running test is made prior to the grades by the engineer applying 25 psi and the conductor observing when 15 psi occurs at the caboose, at which time he informs the engineer to release the straight air. If the train fails either test the train is stopped, retainers are set, and all actions and procedures are as with a conventional train.

By the end of 1973, the DM&IR had converted 776 cars to miniquads with 244 more in a current program and another 168 planned, geared to further pellet plant expansions. These trains average over one round trip between the docks and mines each day and have accumulated over 46,000,000 car miles. This high usage, averaging over 35,000 mi. per year, requires a rigid schedule of maintenance, with these cars programmed through our shop once each year. It should be noted that cars involved in these extensive modifications for high sides, drawbars, welded fittings, and straight air are over 20 years old, but because of a high level of maintenance through the years, their condition still makes it possible to reap long-term benefits from the relatively low cost of the modifications. They are particularly adaptable to any unit train operation in a severely cold, mountainous environment.

On-Train Monitoring System—Present

Dennis Ojard: The DM&IR is always looking for ways to make its operation more efficient. For example, the DM&IR is the first railroad in the United States with a straight-air retainer system and, in 1964, was the first to utilize automatic car identification in daily railroad operations. The DM&IR was also the first to weigh trains automatically at unmanned scales using ACI. Because taconite is a uniform product, weight deviation on a fully loaded car is generally not significant. Specified unit trains of taconite are, therefore, weighed on a statistical basis, with only 10% weighed automatically to establish a statistical base.

The DM&IR is close to reaching a goal of having hot box detectors every 20 mi. of main line track where high tonnages occur. For the last five years, the fleet averaged 9.3 million mi. per hot box, and in 1973 it averaged one every 15 million mi., while the miniquad fleet has averaged 23,000,000 mi. per hot box. This record is established on cars with plain bearings. This can be compared with the AAR average of 1,000,000 miles per hot box on cars with plain bearings and 16,000,000 for roller bearing cars.[1] However, the best hot box record does not eliminate the awesome damage and expense of even one train wreck.

In 1973 a standard ore car derailed and dragged 7 mi. before it hit a switch and piled up. Over 18,000 ties and 25 cars were destroyed, and ten other cars were damaged. This incident and others have created a strong need to develop a wheel-on-the-ground indication to alert the train crew, without reliance on visual observation which, under adverse weather conditions, becomes impossible.

In researching for a means to detect wheels on the ground, hot boxes, and other functions described later, an FRA-funded Naval Ordnance Laboratory (recently changed to Naval Surface Weapon Center) report was found which described a system which theoretically detects these two critical functions and automatically applies the train brakes. This study has been briefly described in many trade magazines. A block diagram of the system is shown in Fig. 5. Briefly, the system consists of a combination impact and heat sensor switch which is activated by a derailment or a hot box. This combination sensor is placed in the bearing of each journal. When triggered by a derailment or hot box, it activates a thermal battery which, in turn, fires a small contained explosive charge which ruptures an orifice to vent the brake pipe on that car. This orifice, sized at approximately 11/32-in. diameter, applies a service reduction to the train. We feel that a service reduction is more desirable than an emergency application since, under many conditions, an emergency could lead to a pileup. The engineer would be warned by a flow meter in the brake pipe line and, hopefully, a controlled stop would take place without a pileup, which usually destroys or damages considerable equipment.

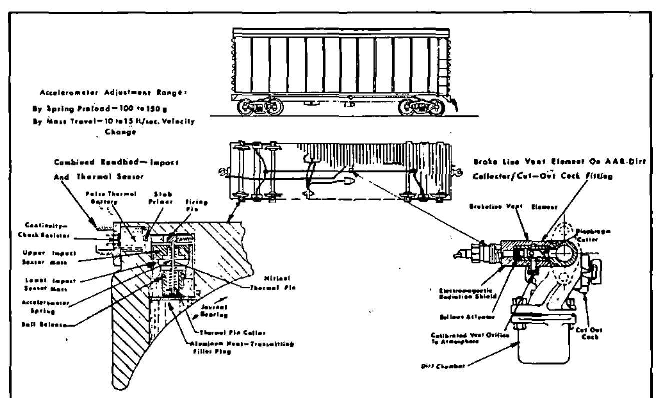


Fig. 5. Anti-derailment sensor system concept (see reference 2).

In more detail, a derailment is detected with an acceleration switch located on the truck side frame. As the wheels leave the rails, the compressed springs of the truck accelerate the truck much faster than the car itself would be accelerated in a fall, due to gravity. The vertical speed of the truck as the wheels leave the track is

[1] "AAR Getting Better Equipment Data," *Railway Locomotive Cars*, June-July, 1974, p. 26.

dependent upon the load in the car. For example, the energy stored in the compressed springs of a fully loaded car would vertically accelerate the truck to over twice the speed generated by an empty car. Anticipated vertical velocities, the instant before the wheels strike ground, range from about 18 ft. per sec. for a loaded car to about 8 ft. per sec. for the same car empty. Impact acceleration could be detected by a simple preloaded spring and seismic mass. The trick in the design is that vertical accelerations of trucks of loaded cars going over vertical drops in the track at poor joints or switch points can be almost equal to the acceleration of a derailed light car. This may not create as difficult a design problem as it seems, since it has been the DM&IR's experience that almost all main-line derailments occur with loaded cars. If this has been typical of AAR experience, the design can be biased more toward that to be expected with a loaded car.

The thermal sensor (hot box detector) design proposed by NOL utilizes a material known as Nitinol-55, where Nitinol stands for *Ni*ckel *Ti*tanium *N*aval *O*rdnance *L*aboratory. Nitinol is a unique alloy composed of 53 to 57% nickel by weight, with the remainder titanium. Nitinol is unique in that it has a thermal memory such that it can be restored to an original shape after being "permanently" deformed, by heating to a moderate temperature. Considerable force is exerted, and mechanical work can be done as the material "snaps" back to its original shape. Test units functioned at an average temperature of 273° F, with a standard deviation of 14.4° F. NOL's concept for a hot box detector using this material appears well thought out and theoretically would operate before any permanent damage could occur.

The thermal battery consists of a percussion-activated primer which produces flame to ignite layers of pyrotechnic material within wafer cells. Heat generated melts the electrolyte, a salt such as lithium-potassium chloride, which melts at about 500° F. This battery will produce about 5 amps at 5 volts for about three seconds, power more than sufficient to activate the brake pipe diaphragm cutter. The melting temperature is sufficiently high to eliminate effects of cold or hot weather.

The venting of brake pipe air through a 11/32-in. diameter orifice after the diaphragm has been cut provides a service reduction to the brake pipe. The locomotive engineer can be warned by a flow meter and act to shut off this flow.

Westinghouse Air Brake Company conducted limited tests of this system with various orifices on their AB-D test stand. The DM&IR, in turn, has tested various orifices in several locations on our 124-car unit trains which have AB valves. We confirmed that venting through an 11/32-in. orifice provides a service reduction on the whole train if located near the head end. If the venting is at the caboose, brakes apply at a full service on most of the train. The brakes applied on the cars at the head end, but we don't know to what extent. Extensive testing is planned in the near future.

The sensors and thermal battery will be mechanically connected. All thermal batteries will be wired together in parallel via a wiring harness to the diaphragm cutter. Further information on the NOL concept is available in the FRA/NOL report.[2]

Two functions which are most important but have not yet been discussed are reliability and false alarm rate. The system must be able to withstand all environmental conditions for years with minimum maintenance, yet operate properly when required. Excessive false alarm rates will quickly destroy the effectiveness of any system. Acceptable reliability and false alarm rates have not been established to date. Mostly, this will be a function of the system cost and the costs of stopping a train under a false alarm, traded against the protection the system affords.

There is reason to believe that this system will work, and, if technically sound and economical, the DM&IR will equip the miniquad fleet with these sensors. The FRA, NOL, and the DM&IR have proposed a cooperative project agreement for developing and testing of the system. The FRA is funding NOL to develop prototypes which will be tested on the DM&IR. If this development is successful, the NOL will make a sufficient quantity to equip one of our 124-car miniquad trains. The DM&IR will, in turn, test this system for operational reliability and false alarm rate. DM&IR internal research funds are being used for the DM&IR portion of this development.

The DM&IR feels that, within a few years, we will be using mainly miniquads and that the investment in our ore car fleet will be substantially reduced because of these high-usage cars. We cannot afford to have one of these trains pile up because of a derailment or hot box. If a derailment occurs, damage can be minimized by an instantaneous automatic brake application, without having to wait for the crew to observe and respond to the derailment. The cost of equipping one train, if the system is developed and in production, appears reasonable, and the prevention of one major accident could cover the cost to equip several unit trains.

On-Train Monitoring System–Future

Plans for on-board monitoring systems for unit miniquad trains are not limited to the strongly needed derailment detection or hot box system. It is felt that the engineer should have continuous knowledge of the status of the brake pipe pressure

[2] *Anti-Derailment Sensor System–Phase 1, Feasibility Study,* Naval Ordnance Laboratory Report No. FRA-ORD and D 74-17, April 1973.

and straight-air pressure at the caboose. Presently, DM&IR cabooses are equipped with gauges to provide this information to the conductor, and he in turn radios the information to the engineer. Also, to eliminate walking terminal air brake tests, the status of brakes on every car should be monitored automatically, as should the status of the bottom dump door on each ore car.

All this implies the need for an electrical train line, with a minicomputer in the locomotive and an integrated-circuit monitoring system on each car. A separate electrical train line would pose considerable reliability problems, especially when trains are broken apart for switching. It may be possible to modify the glad-hand brake pipe connector to carry two wires, over which all data required can be reliabily sent digitally. Fig. 6 is a block diagram of a possible system. The circuits on each car would be provided with power from the locomotive. The minicomputer would digitally address each car in turn, with the car replying digitally the status of each function monitored.

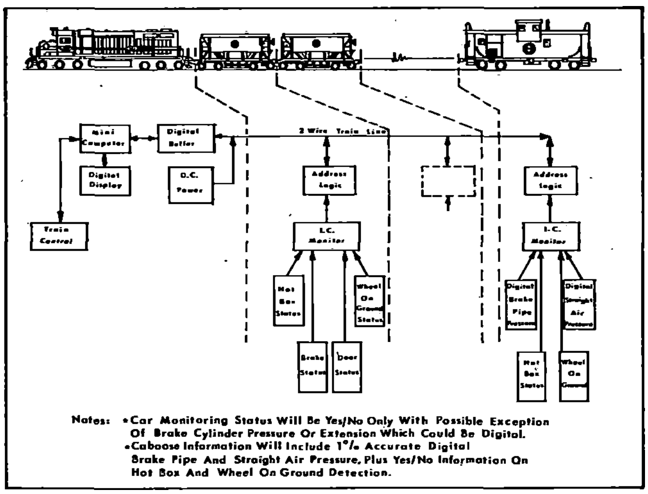


Fig. 6. Possible electrical monitoring system on unit trains.

The technology to do this is here today and in common use throughout the country. Digital integrated-circuit monitoring and communications systems are used extensively. However, the acute problem is to develop a reliable means to electrically connect between cars. DM&IR miniquad trains are a partial solution in that the need for three-quarters of the connectors has been eliminated. Hardwired (no connector) systems within cars of a miniquad are desirable. It may be possible to go to minisixes, for example, further reducing connector requirements.

If a reliable electrical train line is developed, electropneumatic air brakes are a natural addition and would likely be included in the development program. Train control would be much smoother, and slack action would be virtually eliminated on these trains.

Conclusion

There is much that can be done to unit trains to provide improved train control, operational efficiencies, and safety. Elimination of the manual part of terminal air brake tests would be the next big step.

The DM&IR now operates heavy unit trains year around. Cold weather no longer limits operations. Brakemen no longer have to walk the train at night or in rain or blizzards to set and release retainers, except in the few instances where the running straight-air brake tests fail. DM&IR unit miniquad trains are high-mileage, heavy-load trains which, with high standards of maintenance, provide relatively trouble-free service.

The DM&IR found that 20-year-old cars could be modified to provide safer and much more efficient year around, profitable service. With 46,000,000 car miles of experience to date, there is every reason to believe the same cars will be in service 20 years from now, operating with the same reliability and efficiency. In other words, it is not necessary to buy new rolling stock to incorporate new ideas, providing your present equipment is properly maintained.

Those who also operate heavy unit trains, who operate in cold weather, or who operate on heavy grades may be able to profit from our experience. We will be happy to arrange a tour of our operation for any of you who would like further information on our miniquad trains.

Moderator Loftis: Thank you, gentlemen. Our next speaker is Max Bellis from General Electric.

Recent Developments in Electric and Diesel Electric Locomotives

Max W. Bellis
Manager-Locomotive Engineering
Locomotive Products Department of Transportation Systems Business Division
General Electric Company

Max W. Bellis is Manager of Locomotive Engineering in the Locomotive Products Department of the Transportation Systems Business Division of General Electric Company, Erie, Pennsylvania. He received the BS degree in Electrical Engineering from Lehigh University in 1944 and served as a military government officer with the Army before joining the test program at General Electric in 1946.

During his years at General Electric Bellis has designed control devices, control systems, and locomotives. He is a member of the Institute of Electrical and Electronic Engineers. Nonprofessional interests include the College Advisory Board, the Great Ideas Program, and community theater.

Nothing makes the manufacturer more aware of the importance of correct design and quality than listening to the users of his product. Many of you are users of our product, and for the moment, at least, you're listening to me. I plan to discuss what we think the trends of design in locomotives are and will especially touch on the real world of the user and his economics, for they are the criteria for present and future design.

The three subjects I will discuss—(1) trends of design in the diesel electric locomotive, (2) trends in design in the electric locomotive, and (3) the increasing sophistication of testing—are shown in Fig. 1. We'll examine the ever-important stress on reliability and maintainability, the effect of various environmental controls and agencies on our customers and ourselves, adhesion complexity versus economics, the use of electronics in locomotive control, self-checking and checking simplicity, automatic testing, fuel economy, and horsepower (see Fig. 2). By way of introduction, Fig. 3 shows a modern 3,600-hp. six-axle diesel electric locomotive.

TRENDS IN DESIGN -
DIESEL ELECTRIC LOCOMOTIVE

TRENDS IN DESIGN -
ELECTRIC LOCOMOTIVE

INCREASING SOPHISTICATION OF TESTING

Fig. 1.

- STRESS ON RELIABILITY AND MAINTAINABILITY
- EFFECT OF ENVIRONMENTAL CONTROLS ON DESIGNS AND DESIGN COSTS
- ADHESION COMPLEXITY VS. ECONOMICS
- GROWTH AND USE OF ELECTRONICS IN LOCOMOTIVE CONTROL
- SELF CHECKING – AND CHECKING SIMPLICITY
- AUTOMATIC TESTING
- FUEL ECONOMY
- HORSEPOWER

Fig. 2. Trends in design of the diesel electric locomotive.

Fig. 3. Modern 3,600-hp. six-axle diesel electric locomotive.

First the overall guide—the user's values (Fig. 4). The important costs to him are first cost, fuel cost, maintenance cost, and crew cost. The first three are the ones which are strongly influenced by design. The designer controls fuel economy, but not the fuel cost per gallon. How much of the time is the locomotive available for use? It can be unavailable due to scheduled maintenance, or, worse, unscheduled maintenance. The availability on American railroads varies from .85 or 85% of the time to 95% of the time. Another factor is the reliability of accomplishing the mission to which the locomotive is assigned. Will it get there if committed to haul the train? In the United States, about three times per year a road failure occurs on each locomotive. It's obvious that whatever caused that road failure should be avoided in every possible way in the design construction and maintenance of the locomotive.

COSTS
FIRST COST
FUEL COST
MAINTENANCE COST
CREW COST

AVAILABILITY
HOW MUCH OF THE TIME IS IT THERE TO USE?
- DUE TO MAINTENANCE (SCHEDULED)
- DUE TO UNSCHEDULED MAINTENANCE

⟶ AVAILABILITY VARIES .85 – .95

RELIABILITY
WILL IT GET THERE "IF I COMMIT TO HAUL THE TRAIN"?
⟶ ABOUT 3 TIMES PER YEAR A ROAD FAILURE OCCURS

Fig. 4. The user's values in locomotive use.

We can give a few examples of things that are important in a design to aid the user. The General Electric fluid amplifier system shown in Fig. 5 has only one moving part, responding directly to the flow of the water that it is controlling. One of the problems that every railroad has to deal with is water treatment and the effect on the cooling system when water is either drained or not treated. Our locomotives are being supplied with roll-out stainless steel screens which collect debris in the system and allow easy cleaning (Fig. 6). Dirt is another enemy of the engine and the electrical equipment. Self-cleaning, primary filters like the one shown in Fig. 7 take out 92% of all of the dirt ahead of the secondary paper filters for engine air. This simplicity and ease of maintenance lead to reliable performance and low costs.

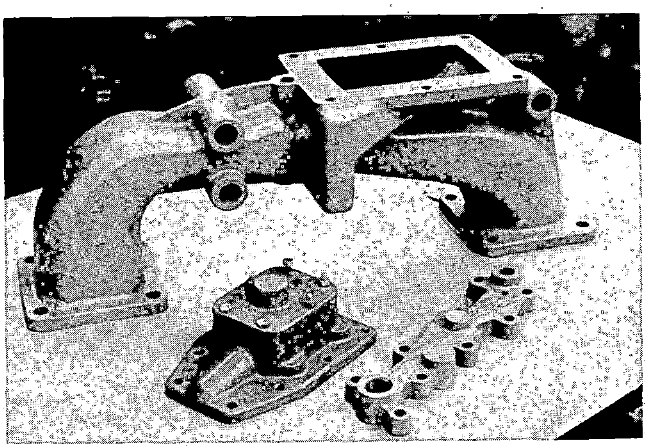


Fig. 5. Fluid amplifier system.

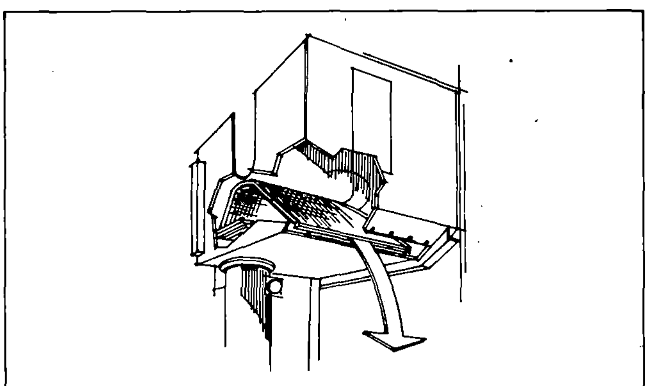


Fig. 6. Roll-out bubble screen for simple cleaning.

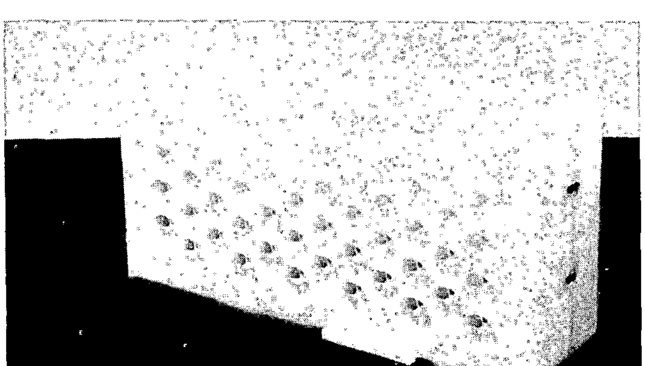


Fig. 7. Fully plastic module for self-cleaning primary filter.

The railroads, like all other segments of American industry, have had to face environmental demands on their funds and time. One of the earliest to go into effect were the OSHA standards for locomotive cabs shown in Fig. 8. Fortunately, our cabs as supplied to the railroads meet the OSHA standard, in fact better them. This came, in part, from insulation put into the cabs for crew comfort, another absolute necessity in the design of the locomotive.

	CAB	HORN ON WINDOW CLOSED	HORN ON WINDOW OPEN
DBA FULL POWER	83	88	107
OSHA 8 HR. STD.	90	90	
OSHA 1/2 HR.			110
OSHA 1/4 HR.			115

Fig. 8. OSHA standards for locomotive cabs.

The Environmental Protection Agency is about to put into effect laws affecting the sound external to the locomotive. Fig. 9 shows the proposed EPA laws for 1975 and 1978. Locomotives now being manufactured meet the 1975 schedule, but some sound reductions will have to be made at full horsepower for 1978 units. The major noise sources identified on the locomotive are the engine exhaust, the fans and blowers, the structure and engine block, and gearcase noise transmission and wheel/rail noise. The proposed EPA laws, which will probably be met by the manufacturer in time for the locomotives shipped in the period proposed in the law, mean a large hardship for the railroads because they will probably be retroactive; that is, all previous units in service must meet the same requirements as new units at the time the law is enacted.

DECIBELS ON DBA SCALE – 100 FEET FROM LOCOMOTIVE

	IDLE	FULL POWER
1975	73	93
1978	67	87

TO MEET 1978 STANDARDS, SOME REDUCTION MUST BE MADE AT FULL HORSEPOWER ON NEW UNITS

MAJOR NOISE SOURCES: ENGINE EXHAUST
FANS AND BLOWERS
STRUCTURE AND ENGINE BLOCK AND GEAR CASES
WHEEL RAIL

Fig. 9. Proposed EPA laws for sound.

There is one great advantage of the EPA sound law to the manufacturer and to the railroads—"Federal preemption." State laws contrary to Federal laws cannot be enacted which will mean that the locomotive can be one thing in one state and something else in another—sheer chaos. Fig. 10

shows the smoke meter developed jointly by AAR and industry to more accurately read smoke output from locomotives at the time of locomotive maintenance or manufacture. In smoke laws, innumerable problems faced the railroads because there was no Federal preemption stipulation. They were besieged on all sides by good intentions, bad intentions, zealous and overzealous administrators of laws that were sometimes misunderstood.

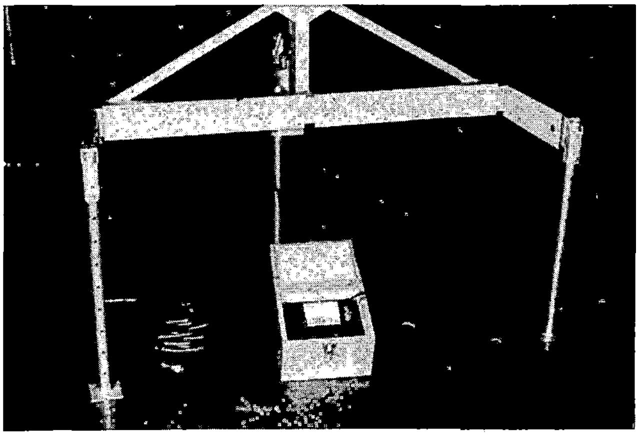


Fig. 10. **Celesco smoke meter.**

Still facing the railroads are possible laws affecting the gaseous emissions from the diesel engine. The curve shown in Fig. 11 depicts the oxides of nitrogen compared to fuel efficiency. As specific fuel consumption decreases, the oxides of nitrogen tend to increase. Therein lies the problem facing all of us. As you can see in the chart in Fig. 12, if the California proposed truck law applies to off-highway vehicles and perhaps even locomotives, we will have to reduce the oxides of nitrogen and hydrocarbons from 16 to five. Many years and many millions of dollars haven't disclosed how to reduce that 16 by more than two without affecting fuel economy. The moment of truth in the United States is going to have to come, for such a law would, as we now see it, of necessity affect the fuel economy of the most efficient method of hauling freight in the United States.

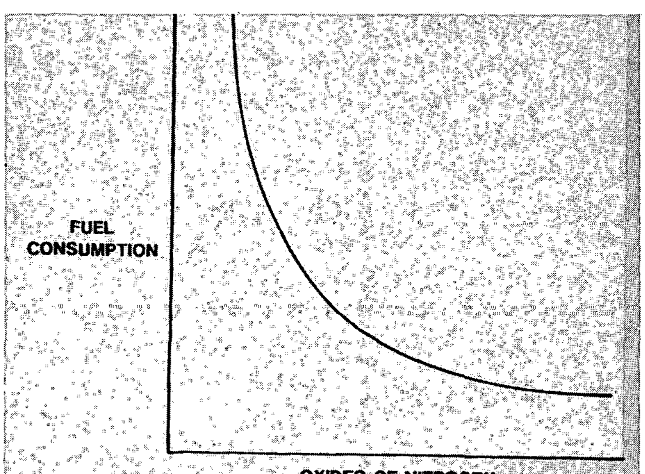


Fig. 11. Oxides of nitrogen compared to fuel efficiency.

	GRAMS/HP HOUR		
	PRESENT ENGINE*	FEDERAL TRUCK STANDARD	CALIFORNIA 1977-78 PROPOSAL FOR TRUCKS
CO	3		
NO_x	14		
HC	2		
NO_x + HC	16	16	5

*AAR DUTY CYCLE

Fig. 12. Railroad diesel engine gaseous emissions.

Adhesion is a popular subject in locomotive design about which there is a great deal of discussion. Fig. 13 shows the basis from which all discussion must start, the friction factor (friction factor times 100 equals percent adhesion) vs. speed. The lines I've drawn here are from literally millions of data points produced here, in Europe, and in Japan. They are characteristic of wet rail vs. dry rail adhesion. One can see that under the worst conditions, at low speeds where the highest adhesion is required, no matter how perfect the mechanical or electrical system, we're always fighting a friction factor of around .2 or .25.

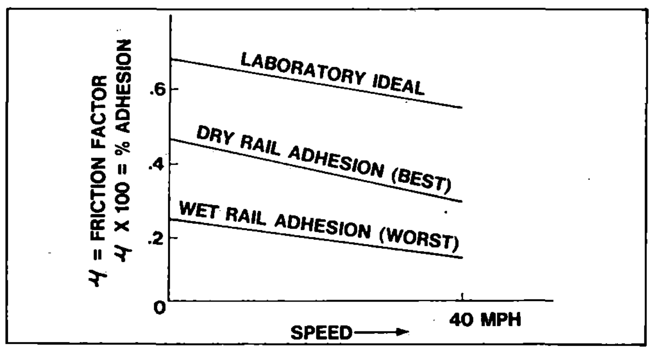


Fig. 13. Friction factor, steel wheel to steel rail—percent adhesion.

Fig. 14 shows some numbers on adhesion characteristics of present design and future design. Present dispatching is from .18 or 18%, to 20%. If the truck were perfect, that .2 could go to .215 or 21½, if nothing else changed. If we use the present sophisticated electrical control of wheel slip in the present truck, .2 could be .23. With control of individual axle power, the .2 could be .26 to .30. All of this doesn't come for nothing, and so it behooves us to examine what this really means in freight operation. Fig. 15 shows the practical value of a locomotive operating at .25 rather than .2 adhesion. If that were the case, then a train pulled by two diesel electric units could have one more loaded freight car. The real value is probably not this great unless extremely short high-speed trains are run. But as a manufacturer supplies better adhesion, the likelihood of a successful trip without loss of tractive effort is increased at whatever adhesion factors the dispatcher chooses.

ADHESION" = FRICTION FACTOR WHEEL TO RAIL

- PRESENT DISPATCHING .18 TO .20
- IF PERFECT TRUCK (BOGIE) .20 COULD BE .215
- PRESENT SOPHISTICATED ELECTRICAL CONTROL OF WHEELSLIP – AND PRESENT TRUCK .20 COULD BE .23
- WITH INDIVIDUAL AXLE WHEELSLIP CONTROL .20 COULD BE .26 TO .30

Fig. 14. Some numbers on adhesion.

IF A LOCOMOTIVE OPERATED AT .25 RATHER THAN .20 ADHESION

THEN IN A TRAIN PULLED BY TWO DIESEL ELECTRIC UNITS, ONE MORE LOADED FREIGHT CAR COULD BE PULLED

Fig. 15. Practical value of locomotive operating at .25 rather than .2 adhesion.

A great deal of study and experiment has shown that, on a diesel electric locomotive, when a wheel slips we must remove the power on all wheels by removing power at the generator. In this case the times shown in Fig. 16 have to occur or wheel slips persist—50 milliseconds between the time the wheel slip is detected and a 10 to 20% power reduction is complete; 150 milliseconds after the stop of slip until 90% of tractive effort is recovered. Fig. 17 shows a modern wheel slip system (GE CMR), which is extremely responsive to wheel slip and to meeting the response time required. It is quite capable of producing higher than the present operating adhesion if called upon to do it.

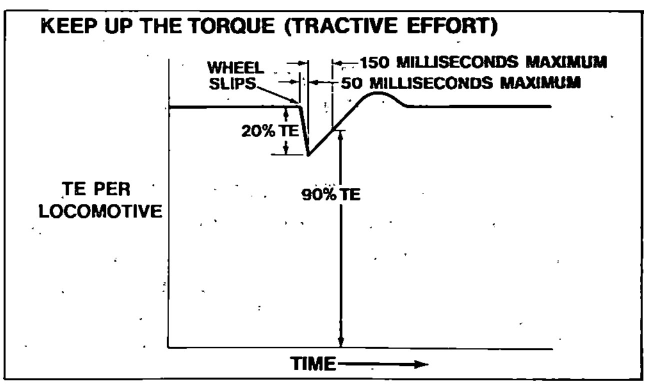


Fig. 16. Wheel slip detection and correction.

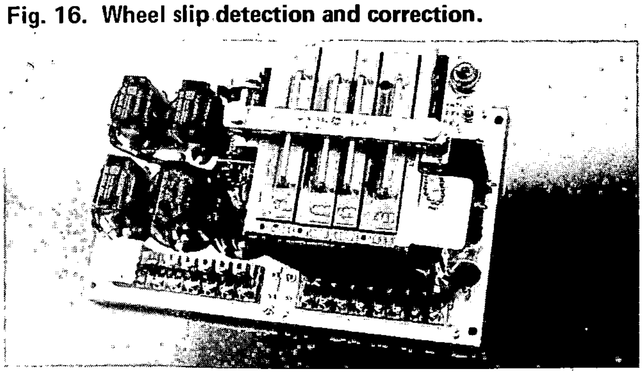


Fig. 17. Modern wheel slip system.

Control evolution has taken place during the years that most of us have worked in the locomotive field. Fig. 18 provides a little history of the kind of control that has been characteristic of GE locomotives over the years. In 1935 we started with split pole—a magnetic approach with a variable field in the exciter. In 1938 locomotives had three-field excitation. That three-field excitation has been used by most builders since that time, but you saw it first on U.S. railroads on early domestic EMD locomotives. Following that the amplidyne control was used, coming very much out of wartime system design. The magnetic amplifier was used in 1954, discrete solid state devices in 1955, the integrated circuit in 1973. All of these developments have come about as the devices have become reliable enough to be aboard a locomotive. The great difference between a locomotive control and most other electronic control equipment is that the locomotive control is expected to run with both minimum maintenance and minimum skill of repair for long periods of time—*without* attention. Understandability and reliability have to be the chief criteria for such systems. Most people are surprised to find that the largest number of sophisticated servosystems with electronic control are riding around on the nation's railroads on locomotives manufactured by General Motors and General Electric. The future might well see the use of the microprocessor. These are programmable integrated circuits. The whole processor and the replaceable memory which allows one to choose any kind of control logic desired fit into a very small package—about the size of a ham sandwich. Proven reliability is still *out there.*

● SPLIT POLE	1935
● 3 FIELD	1938 - EMD
● AMPLIDYNE	1945
● MAGNETIC AMPLIFIER	1954
● DISCRETE SOLID STATE DEVICES (GE TYPE E)	1955
● CHEC – INTEGRATED CIRCUITS	1973
● FUTURE MICRO PROCESSER ?	

Fig. 18. Control evolution—GE locomotives.

Locomotive builders have used power diodes on three-phase alternators to feed their direct-current series motors for many years now; the locomotive again is one of the largest users of power diodes in the United States and, for that matter, in the world. The diode panel shown in Fig. 19 is one phase of the output of the main generator aboard a modern diesel electric locomotive.

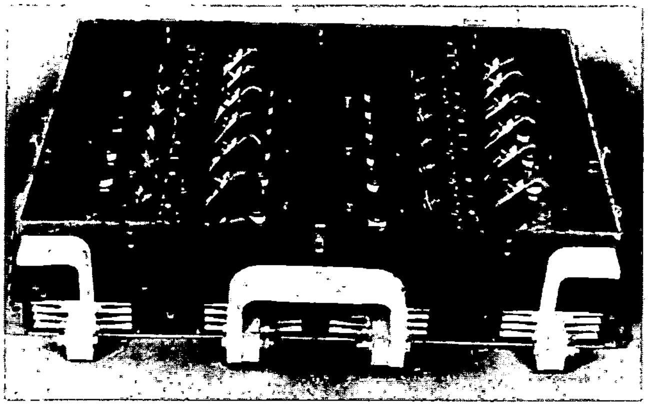


Fig. 19. Diode panel.

The railroads and the manufacturers have gone through a learning period to find the best way to allow for self or automatic checking of the electrical system aboard locomotives. Since the electrical system has charge of locomotive operation, its analysis is usually the quickest way to pin down problems on a dead or sick locomotive. Fig. 20 is a simple CHEC kit for the GE excitation system. It is portable, battery operated, inexpensive, and will make a complete check of the locomotive operation, either with the locomotive engine on or with it off. Fig. 21 is the control previously mentioned which uses integrated circuits. Again thinking of the maintenance man, all of the electronic cards of this panel can be checked by use of a standard volt ohmeter, without the portable CHEC kit. All measurements are made in a range of 0-10 volts. There are no ammeter insertion requirements. These instruments provide *simple checks* and *simple understandability* to help when in trouble.

Fig. 20. CHEC kit for excitation system.

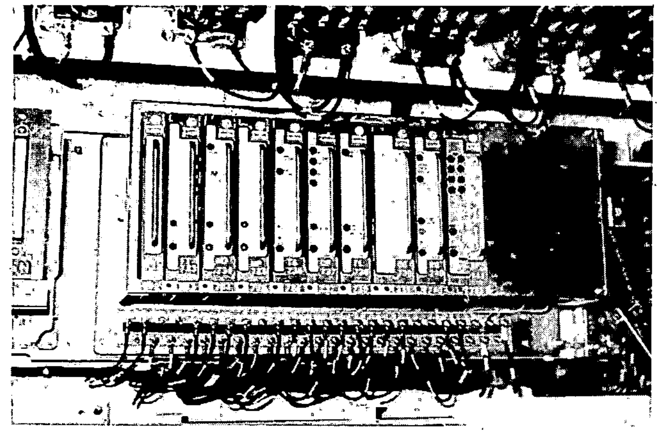


Fig. 21. Control using integrated circuits.

Modern diesel electric locomotives have dynamic brakes, that is in the braking mode the motors on the axles are used as generators and feed train energy into resistors aboard the locomotive. The resistors dissipate the train energy as heat. Those same resistance units can be used to self-load the locomotive. The man shown in Fig. 22 is throwing a single switch which puts a locomotive into a self-testing mode which fully loads the engine. The single most important way to be sure that any locomotive is ready for work in the shortest time is to operate this self-load switch.

Many locomotives have been shipped in recent years carrying aboard a built-in test harness. While many railroads have the automatic testing equipment to use the built-in test harness, we see fewer purchases of such harnesses. But our own experience, I think, indicates the future. We've made small overlay harnesses in our factory for use on automatic test which give a quick (*not a 100%*) check of a locomotive before we put it through its more exhaustive test.

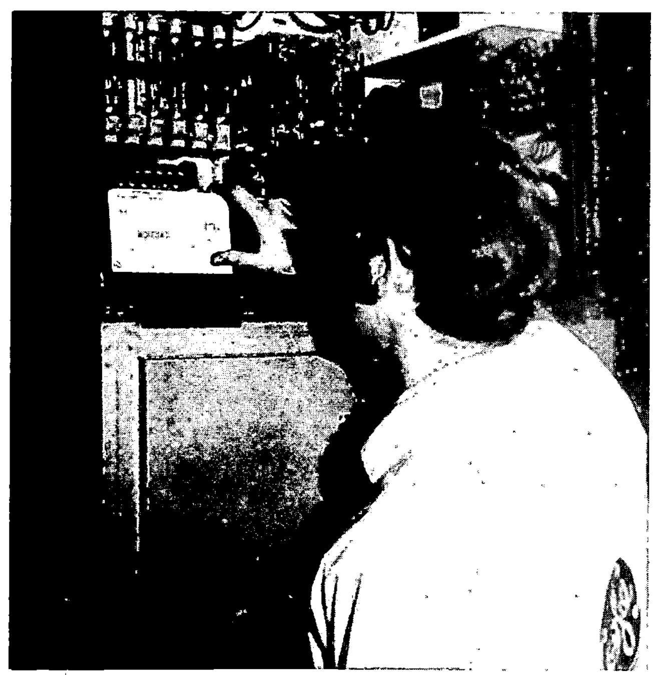


Fig. 22. Single switch which fully leads locomotive engine.

Many of the diesel items we've touched upon apply directly to the electric locomotive, yet it is unique in some significant ways. Some brief comments on the electric locomotive follow.

The electric locomotive is used on only a few railroads in the United States. But in most of the other advanced countries in the world the main locomotive power source is electricity from an overhead wire. We feel the economics now favor main-line electrification in the United States.

Electric locomotive design trends are listed in Fig. 23. The first is higher horsepower; the electric locomotive is limited in horsepower application *only* by the capacity of the motors. We will have more on that as we proceed. The electric locomotive as GE has been manufacturing it is controlled by solid state SCR's (silicon control rectifiers), which minimize losses and simplify control of the high-power electric locomotive. I'll discuss later on high-voltage breakers and commercial frequency and the roller bearing axle suspension. But before going on, let me briefly discuss AC/DC vs. AC/AC and automation. By AC/DC I mean alternating voltage power enters the locomotive from the overhead wire through the locomotive pantograph and into a transformer. The transformer makes lower alternating voltage, which is then rectified and controlled by the SCR control. AC/AC substitutes a great deal of solid state electronics for the commutator of the DC motor. The present cost of AC/AC is far above that of the AC/DC system. An open question is the reliability, understandability, and maintainability of the large amount of electronics required on AC/AC. Our trade-off studies of both systems continue. We see the AC/DC locomotive as the present and likely future product.

- HIGHER HORSEPOWER
- SCR CONTROL
- HIGH VOLTAGE AND HIGH VOLTAGE BREAKERS
- COMMERCIAL FREQUENCY
- AC/DC VS. AC/AC
- AUTOMATION
- ROLLER BEARING AXLE SUSPENSION

Fig 23. Trends of design for the electric locomotive.

In the last two orders of electric locomotives that we have shipped, we have supplied automatic operation. Buried inert signal devices in the right of way control the total train operation and void the necessity for an operator. The savings on the operator are not critical and sometimes disappear, for reasons beyond our control. We have found the automation systems do furnish a preprogrammed and planned operation method, built around the most efficient operation—*not the most expedient* operation. The locomotive shown in Fig. 24 has been operating for five years, day in and day out, with automatic operation, including loading and unloading, track switching, and road operation. During that period not one SCR or diode has failed, by the way.

Fig. 24. Locomotive with five-year automatic operation record.

The Black Mesa and Lake Powell locomotive shown in Fig. 25 operates under conditions of high mileage and very heavy-duty service. It is a thoroughly modern electric locomotive with thyristor control. Fig. 26 shows the power input to the electric locomotive, an example of some of the major design trends that have been pioneered by GE. It provides for high-voltage operation; the equipment you see here operates at 50,000 volts, 60 hertz—the power of the land. The long device you see to the right is a vacuum breaker. This breaker is capable of effectively isolating a locomotive from the line and allowing continuous operation of all other locomotives in the area. The speedy, reliable operation of the breaker is a major breakthrough. In the breaker (Fig. 27) there are vacuum bottles that are very simple, very high speed, and, for all practical purposes, have infinite life.

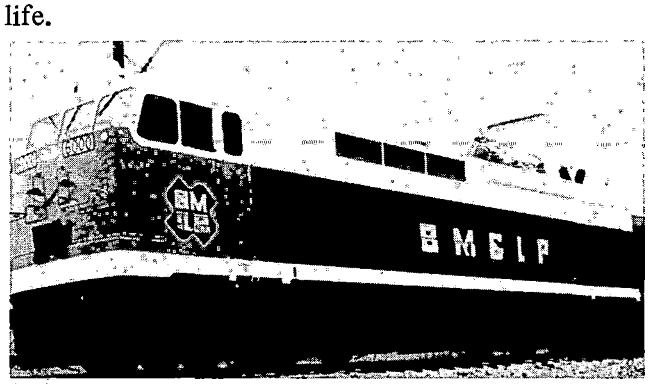


Fig. 25. Modern electric locomotive with thyristor control.

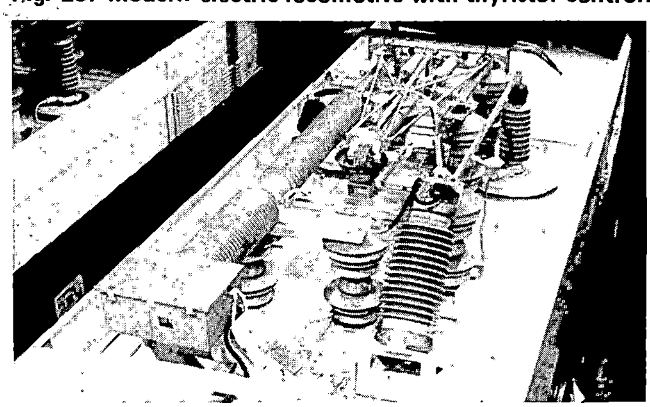


Fig. 26. Power input to electric locomotive.

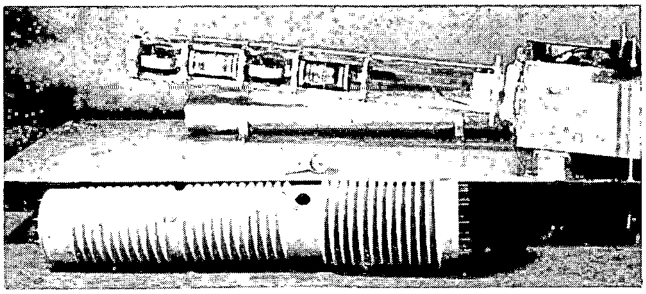


Fig. 27. Closeup of the 25 Ku vacuum breaker.

High-power electric locomotives use silicon control rectifiers. Fig. 28 shows the diodes and SCR's of a 6,000-hp. electric locomotive. The locomotive motors are speed controlled by silicon control rectifiers. Fig. 29 provides a closer look at the SCR. These are larger diameter wafers with cooling on both sides, thus vastly increasing the current capacity. The locomotives now being built for AMTRAK use on the Eastern Corridor have double packs to reduce operating temperatures. We call these pre-pacs, and the wafer itself a hockey puck.

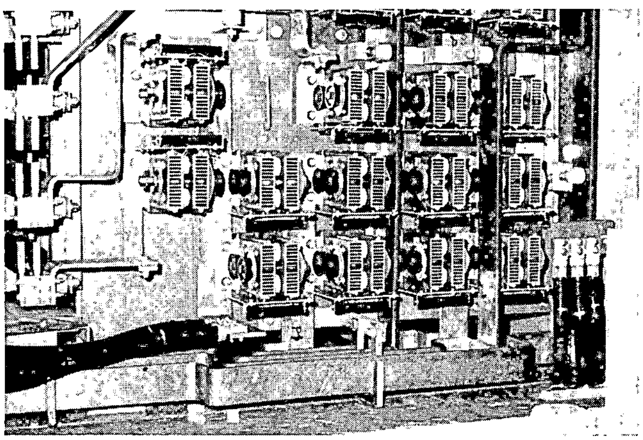


Fig. 28. E60 silicon-controlled rectifier assembly.

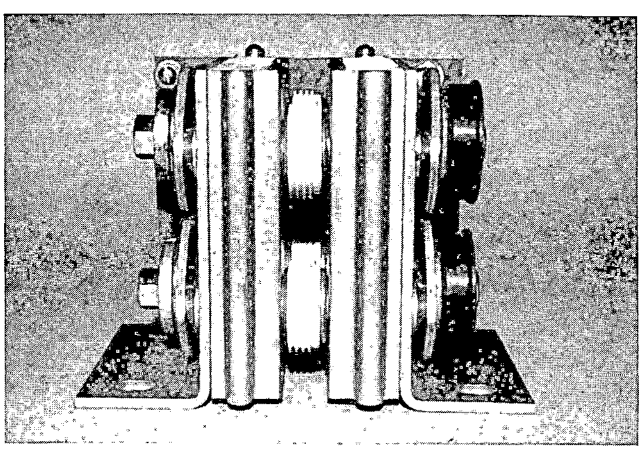


Fig. 29. Closeup of E60C silicon control rectifier.

Fig. 30 is a roller bearing axle. The motor is ordinarily carried on the axle on sleeve bearings. These bearings are replaced by roller bearings, which operate for the length of the wheel life before any lubrication is required.

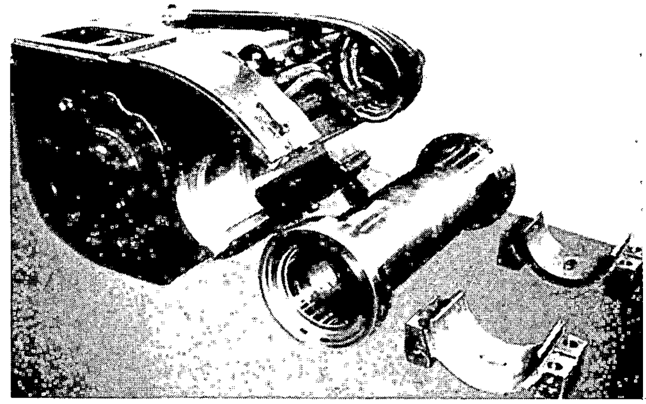


Fig. 30. Roller bearing axle.

The locomotive in Fig. 31 is indicative of the high-horsepower trend on electric locomotives. This 6,000-hp. locomotive is the double-ended AMTRAK Eastern Corridor passenger electric locomotive.

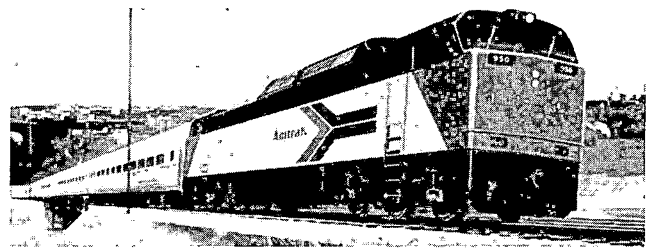


Fig. 31. 6,000 hp. AMTRAK passenger electric locomotive.

The electric locomotive is primarily based upon the motor, which is its base and strength. On the diesel electric locomotive the total available horsepower from the diesel engine is the limitation on both short-time ratings and total power. The short-time rating of the electric locomotive is equal to the short-time rating of the motors. The power supply is not limiting.

Fig. 32 lists some factors which are being measured by the increasing sophistication of testing methods. I'm not talking about sophistication in the sense of esoteric instrumentation or exotic approaches to taking measurements, but sophistication in *producing results.* Almost all data taken for testing and development of locomotives are taken under conditions that are anything but ideal. I believe the earth-moving people are the only ones who can look at us and say their job might be more difficult.

- RIDE QUALITY
- SMOKE AND EMISSION METERING
- SOUND MEASUREMENT
- TORSIONAL TELEMETRY
- MOTION PICTURES
- THE TRANSDUCER AS A VILLAIN

Fig. 32. Increasing sophistication of testing procedures.

I will start my discussion of the new testing methods with a view of the interior of GE's new test car (Fig. 33), a fully equipped modern laboratory with an on-board computer. It allows us to have real-time output and to acquire more complete data for later review. The sound test setup in Fig. 34 looks crude, and it is. But sound testing must be done with reliable, but portable, equipment, and such equipment is now a reality. It allows us to take data, get rapid integrated results, and produce base data for future study. Fig. 35 shows hundreds of strain gauges that are put onto a locomotive truck for static and dynamic test. Fig. 36 shows a wheel temperature in stress being taken with mercury slip rings.

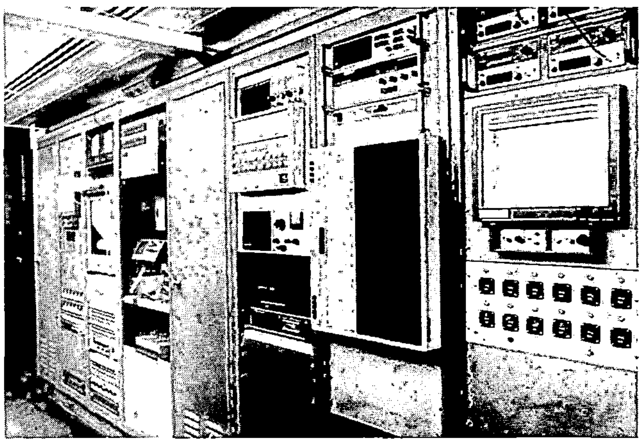


Fig. 33. Interior—GE test car.

Fig. 34. Sound measurement setup.

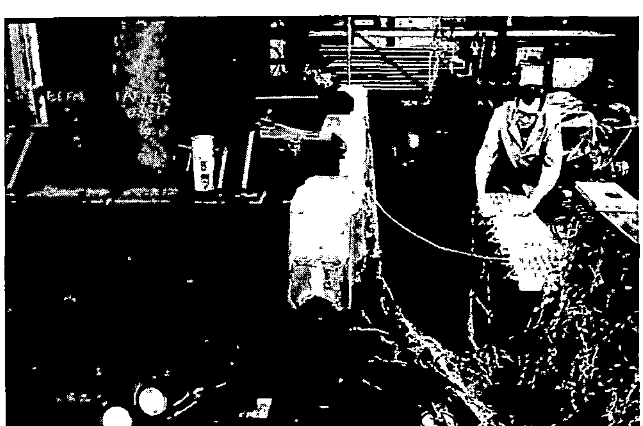


Fig. 35. Strain gauging for locomotive truck testing.

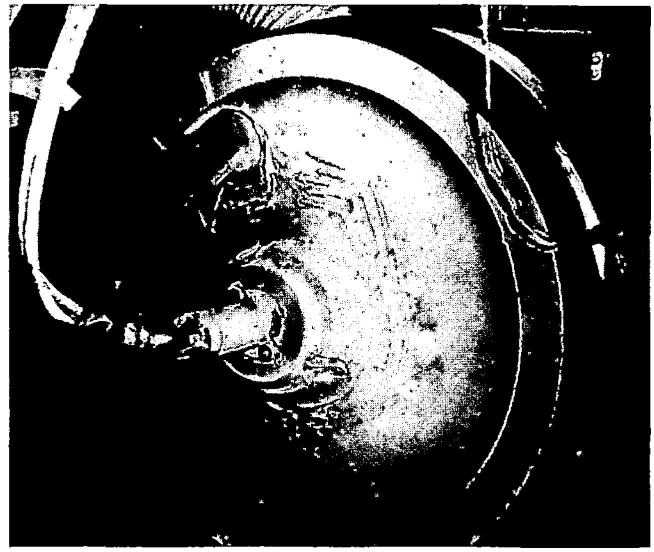


Fig. 36. Mercury slip rings test wheel temperature and stress.

All of these methods produce large quantities of data. The interpretation and quick use of some data, and the separation of important from unimportant data, are the real sophistication of modern data collection. Fig. 37 shows what is *very* important in the data collection process—automatic production of output iteration and separations by preplanning of the experiment and the data, followed by modern reduction of the data.

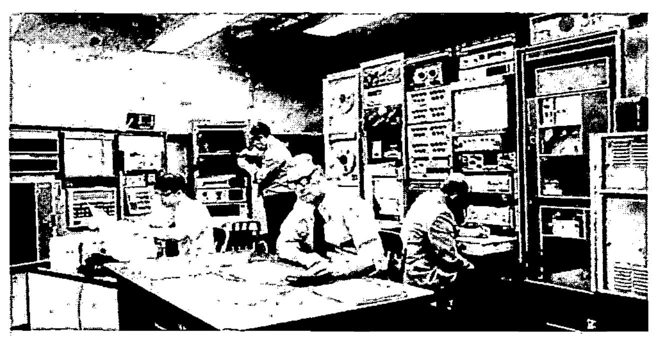


Fig. 37. Data production, separation, and reduction facility.

Design information which used to require tremendous amounts of separate devices and data reduction can sometimes be beautifully done by something as simple as this British ride meter (Fig. 38). We get good repeatable results with this fine portable instrument. Integrated circuits make it a little computer.

Fig. 38. British ride meter instrument.

The high-speed motion picture is certainly an old method of acquiring information, but now it can invade the firing chamber and (even more important) live to tell the tale. Fig. 39 is a film sequence of the combustion process. The little gem in Fig. 40 will tell us exactly what the locomotive operator has done in terms of what throttle position he chose and for how long. It's shockproof, completely reliable, and completely portable, and accurate data comes from it by the unusual and shockproof method of unplating plated material.

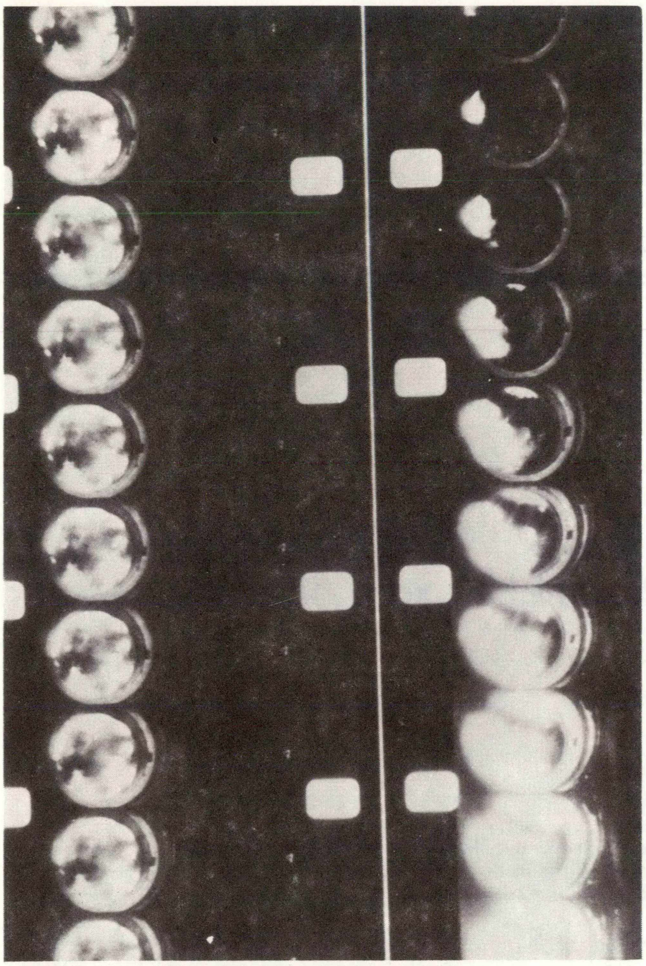


Fig. 39. Film sequence of combustion process.

Fig. 40. Device for recording throttle position.

The "grasshopper" shown in Fig. 41 takes thermocouple data directly from the cylinder head, in spite of hot oil and severe mechanical loads. It does this for four hours before it needs to be repaired. Four hours is an eternity compared to the beginnings of such data acquisition.

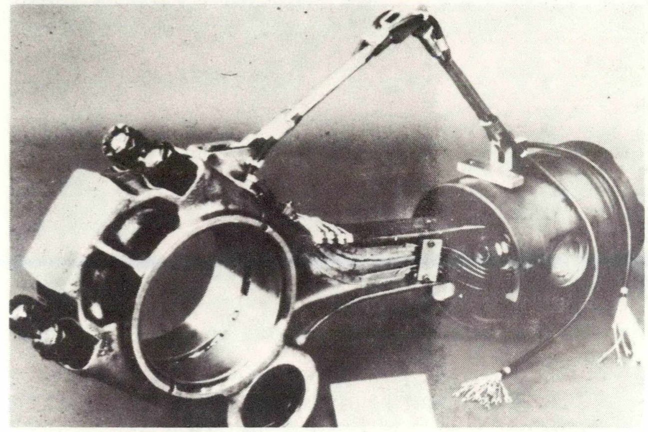


Fig. 41. Device for taking thermometer data directly from cylinder head.

Why not take the data off the radio transmitter? Not so simple! The most expensive and the best of the "space probes" that we have ever used have lasted up to an hour in engine test. But Fig. 42 shows some radio transmitters which are finally useful *and* which we can use in the field. Torsional readings on rotating parts are always a problem. Fig. 43 shows how stresses are read directly (the *only* way) and the data are taken off with radio transmission. Some of the instrumentation people who are involved with ecology have produced excellent equipment which allows us to make continuous analyses of gaseous emissions (Fig. 44).

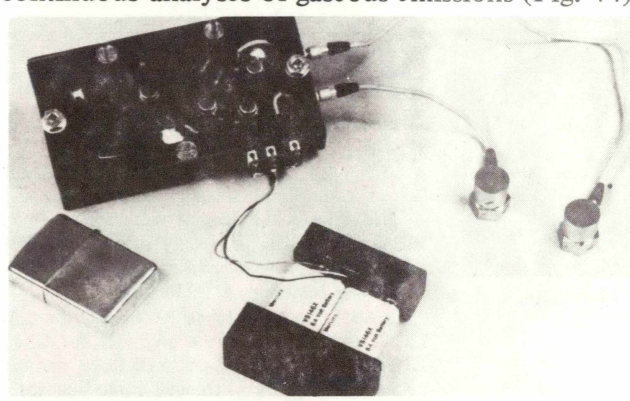


Fig. 42. Radio transmitters designed for engine test conditions.

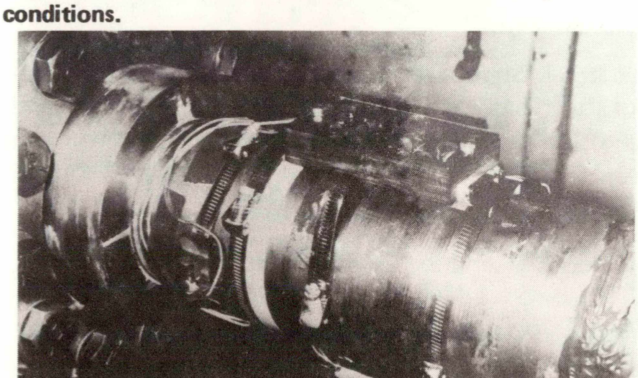


Fig. 43. Device for reading stress and radio transmissions of data.

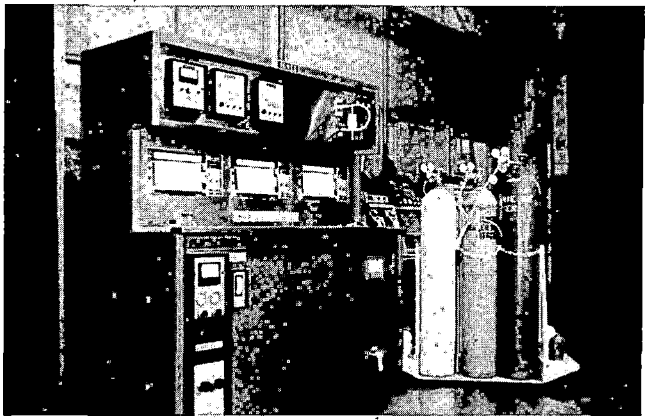


Fig. 44. Equipment for continuous analysis of gaseous emissions.

I'll close with my standard challenge: *a high-temperature transducer,* one that continually tells what the preturbine temperature is (Fig. 45). I challenge anyone in this audience who can come up with a high-temperature transducer that will really live, so we can put it on a locomotive and depend upon it, and the user won't be spending the rest of his time repairing it. We have spent three years on testing all of the available devices. If there is one that is really good for two years' life, or for that matter for even two to three months, it has eluded us.

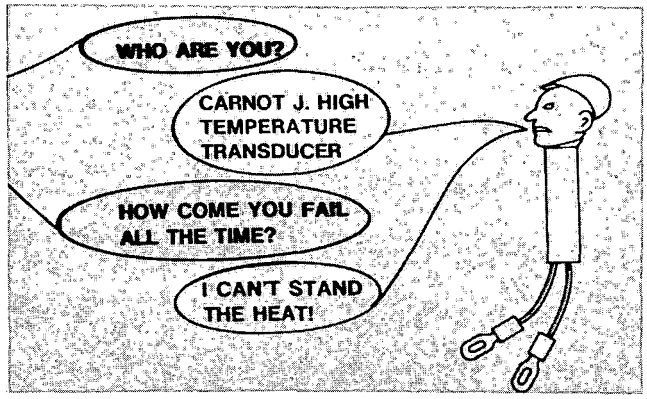


Fig. 45. The challenge: Development of an effective high-temperature transducer.

I've enjoyed telling you a little bit about locomotive design trends today. I'd be very happy to answer questions during the discussion period.

Moderator Loftis: Thank you, Max. Our next speaker is Mr. A.N. Addie of General Motors.

New Locomotive Developments at Electro-Motive Division

A. N. Addie
Manager-Advance Engineering
Electro-Motive Division
General Motors Corporation

A. N. Addie is Manager of Advance Engineering for Electro-Motive Division of General Motors Corporation, LaGrange, Illinois, where he is closely associated with divisional efforts in the area of railroad electrification. He received a BS degree in Mechanical Engineering from Illinois Institute of Technology in 1944 and a Master's degree in the same field from Case Institute of Technology in 1947.

Addie was employed by the National Advisory Committee for Aeronautics (now NASA) Aircraft Engine Research Laboratory as a research engineer for three years and has spent the remainder of his career with the Electro-Motive Division. With the exception of three years as Assistant Chief Engine Design Engineer, he has been in charge of a variety of advanced design projects, including gas turbines, automatic transmissions, turbochargers, free-piston engines, and railcars.

Introduction

Electro-Motive Division of General Motors Corporation has for many years led in the design and manufacture of diesel electric motive power for U.S. railroads. Our products have played an important part in the dieselization of American railroads, with a total number of locomotive deliveries over the period 1935 through January 1, 1974, of 31,183 units. In 1972, we introduced our Dash-2 locomotive product line, which currently includes the following units (see Fig. 1):

1. A 3,600-hp. six-axle, heavy-duty freight locomotive for high-tonnage, high-speed, long-distance operations.
2. A 3,000-hp. six-axle, heavy-duty freight locomotive for main-line, high-tonnage operations.
3. A 2,000-hp. six-axle, heavy-duty locomotive for low-speed, high-tonnage freight service on branch and main lines.
4. A 3,000-hp. four-axle, general-purpose locomotive designed for a full range of main-line freight operations.
5. A 2,000-hp. four-axle general-purpose locomotive for multiduty main and secondary line service.

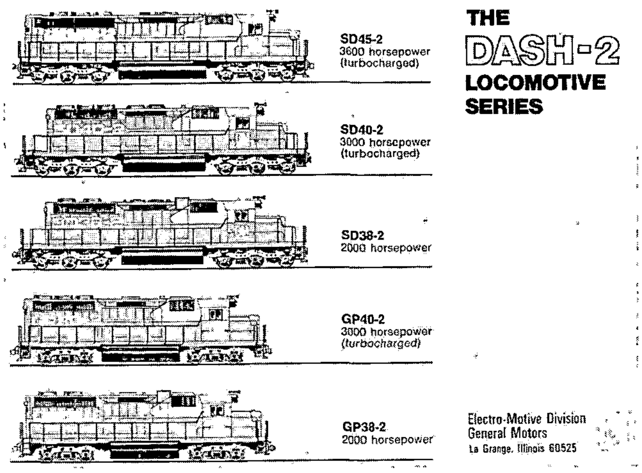


Fig. 1. Electro-Motive Division Dash-2 locomotive series.

In addition to the Dash-2 locomotive product line, Electro-Motive has introduced a new passenger locomotive for AMTRAK, a new commuter locomotive, and a multipurpose locomotive. These diesel electric units follow well-developed design principles which have evolved from experience obtained from application of 109 diesel electric models to U.S. railroads over a period of 39 years. The description of new features of the passenger, commuter, and multipurpose locomotive is the first subject of this paper.

There has been a renewed interest in electrification in the United States over the past two years which has more recently been intensified by the rapid escalation of fuel prices. Until recently, the price of the energy converted from diesel fuel to propel a locomotive was considerably lower than the price of electrical energy to accomplish the same task (Fig. 2). Thus the economic justification of electrification was not normally possible. The recent escalation of the price of diesel fuel has prompted some U.S. railroads to again consider the

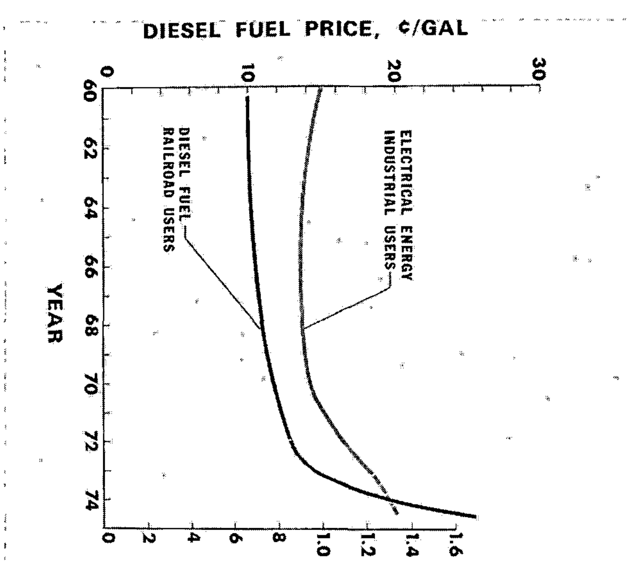


Fig. 2. Diesel fuel and electrical energy price trends.

large capital expenditures required to electrify *high-traffic-density railroad routes*. In *anticipation* of possible future electrification programs in North America, Electro-Motive Division is preparing to become a viable manufacturer of modern electric locomotives to the American railroads. Two major steps have been taken, the first of which is an agreement between ASEA and General Motors Corporation for collaboration in the design and manufacture of thyristor locomotives; the second is a decision to build two electric locomotives for demonstration on the Penn Central Railroad in 1975. The description of these electric locomotives is the second subject of this paper.

New Diesel Electric Locomotives

AMTRAK Passenger Units. In 1974, Electro-Motive Division delivered 110 new SDP-40F diesel electric units to AMTRAK for passenger service between Chicago and Houston, Los Angeles and San Diego, and Los Angeles and Seattle. These units, part of an order for 150, are the first all-new locomotives received by AMTRAK and will replace 20-year-old 1,500-hp. locomotives on a two-for-one basis. The SDP-40F locomotives (Fig. 3) develop 3,000-hp. for traction using a 3,300 brake hp., 16-cylinder 645E3 engine, and are geared for a top speed of 100 mph. The engine drives an AR10 three-phase alternator at 900 rpm. Rectified current from the alternator supplies six D77 traction motors connected in parallel. The motors are mounted in a high-adhesion three-axle truck.

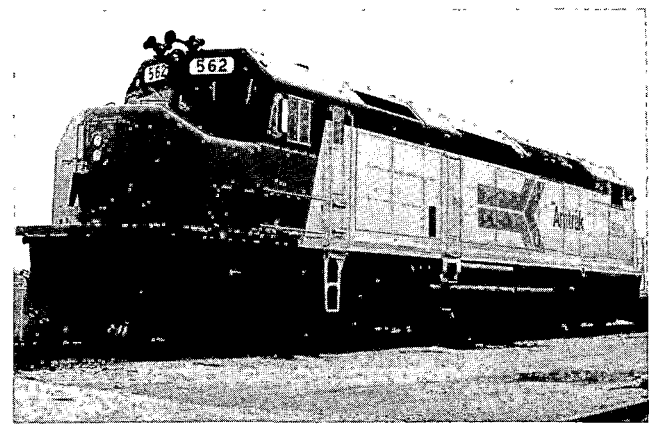


Fig. 3. EMD SDP-40F locomotive for AMTRAK.

The 16-645E3 engine represents substantial improvements over Electro-Motive 1971 production turbocharged diesel engines. The current engine used in the AMTRAK locomotives utilizes pistons with the top rings raised and low sac fuel injectors. These changes have resulted in a 1½% improvement in full-load specific fuel consumption, while reducing emissions. At steady state, smoke emissions are virtually invisible, and the measured emissions of carbon monoxide and hydrocarbons are both reduced over 1971 production.

The high-adhesion HT-C truck used under the SDP-40F locomotive represents a significant advance in truck design. As a result of the orientation of motors in one direction, use of a large diameter centerplate, a high-rate secondary suspension, and lower driving faces between the truck and the bolster, it has been possible to improve adhesion efficiency between 10 and 20 percentage points. Thus the use of this truck significantly reduces the tendency for slip under adverse adhesion conditions. In addition to the improvements in adhesion characteristics resulting from truck design, the SDP-40F locomotives are all equipped with the WS10 wheel slip control which includes features improving the Instantaneous Detection and Correction (IDAC) wheel slip control system. This system detects rate of change of the difference between traction motor currents and controls the main generator field in three stages to correct the initiating wheel slip.

The first 150 AMTRAK units will utilize steam for air conditioning and heating which is provided by two steam generators, each capable of evaporating 2,500 lbs. of water per hour. When new AMTRAK passenger cars are available with electric heating, the SDP-40F locomotives can be modified to provide train-lined 440-volt, three-phase, 60-hertz AC current which will be generated by two auxiliary diesel generator sets to be substituted for the present steam generators.

Performance of the AMTRAK locomotives is illustrated in Fig. 4, which shows the tractive effort available at speeds up to 100 mph.

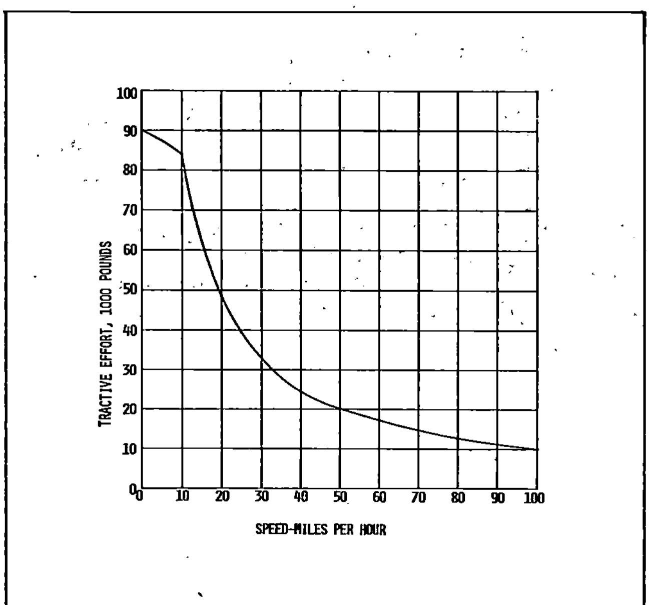


Fig. 4. Speed and tractive effort, 3,000 hp. Model SDP-40F locomotive.

As do all current Electro-Motive diesel electric locomotives, the AMTRAK units incorporate modular control system components (Fig. 5) facilitating troubleshooting procedures and making replacement of critical electrical control components convenient. Use of control modules eliminates the need to make adjustments to critical settings on the locomotive.

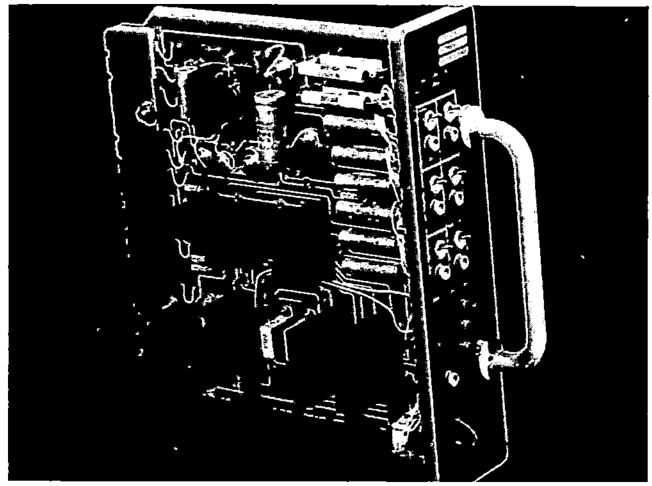


Fig. 5. Control module for EMD diesel electric locomotive.

All of the AMTRAK locomotives also include a locked-wheel detection system which is of considerable importance on locomotives intended for passenger service.

Commuter Locomotive. Fig. 6 shows a view of the F-40-C commuter locomotive. Thirteen of these units have been delivered to the Northwest Suburban Mass Transit District of Illinois, and two units have been delivered to the North Suburban Mass Transit District of Illinois in 1974. These locomotives are designed to pull commuter trains between Elgin and Chicago and between Fox Lake and Chicago, respectively. The six-axle, six-motor locomotives are rated at 3,200 hp. for traction and utilize the 16-645E3 engine modified to accommodate an engine-shaft-driven 500 kW alternator to supply train heating, lighting, and air conditioning. The engine operates at a constant speed of 904 rpm in 1 through 7 throttle positions and 927 rpm in run 8 to supply the 480-volt, three-phase, 60-hertz auxiliary power, but can be brought to 705 rpm for standby, at which time 60-hertz auxiliary loads are supplied from the traction alternator. Particular emphasis has been placed on engine pollution control and noise reduction. Four gear ratios are available to permit maximum

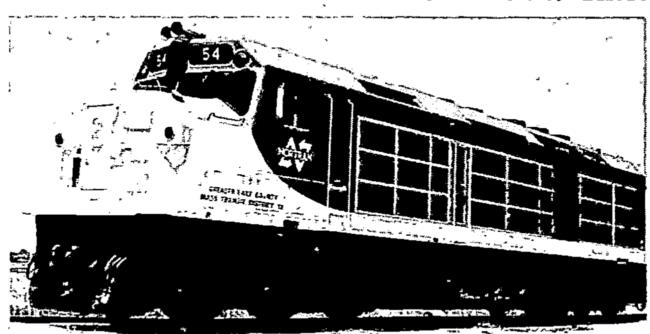


Fig. 6. EMD F-40C commuter locomotive.

locomotive speeds from 65 to 103 mph to be selected. As in the SDP-40F locomotive, the high-adhesion truck and IDAC wheel slip system are utilized.

Multipurpose Locomotive. To satisfy a need for a versatile locomotive for use in branch-line and switching operations, the MP-15 locomotive has been designed (Fig. 7). This unit, rated at 1,500 hp., utilizes the 12-645E Roots blown engine to drive a D32, DC generator and four DC traction motors. The locomotives are equipped with modern four-wheel freight locomotive trucks, making the unit suitable for speeds up to 60 mph. Principal objectives in the design of these locomotives were operational flexibility, low cost, and low maintenance.

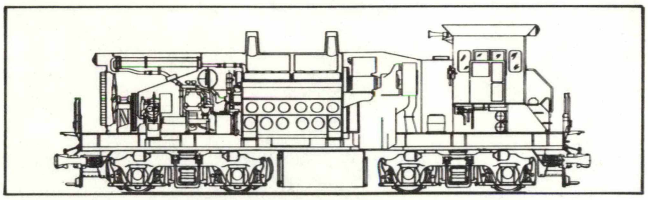


Fig. 7 EMD MP-15 multipurpose locomotive.

The tractive effort–speed relationship of the MP-15 locomotive is shown in Fig. 8. Full power is available up to 22 mph without motor shunting. Addition of a motor field shunting step permits operations up to 65 mph.

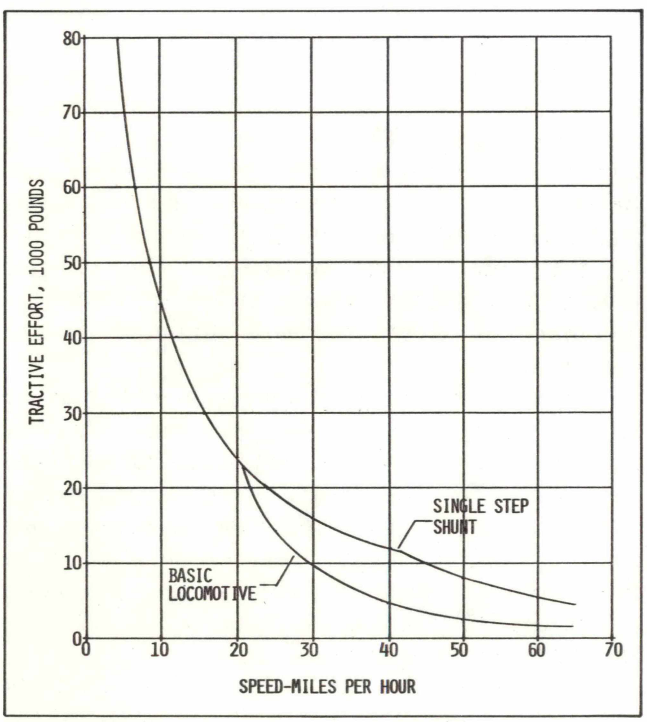


Fig. 8. Speed and tractive effort, 1,500 hp. Model MP-15 locomotive.

Environmental Improvements. The current concern being expressed for the effects of operation of various types of petroleum fuel-burning prime movers in vehicles in the United States has been recognized by Electro-Motive, and work continues in close cooperation with the railroad industry. A voluntary schedule to reduce exhaust emissions which has now been completed includes the following:

1. Reduction of visible exhaust emissions on production turbocharged engines as shown in Fig. 9 and for Roots blown engines as shown in Fig. 10. The opacity measurements for both of these engines at full load are considerably lower than representative state regulations. This has been accomplished by adoption of the following features:
   a. Relocation of the top compression ring on the piston.
   b. Use of low sac fuel injector.
   c. Use of optimum tip configuration.
   d. Use of enlarged liner air inlet ports.
2. A cooperative program with the Association of American Railroads, locomotive manufacturers, and the railroads to establish procedures for evaluation and implementation of smoke meters for railroad application.

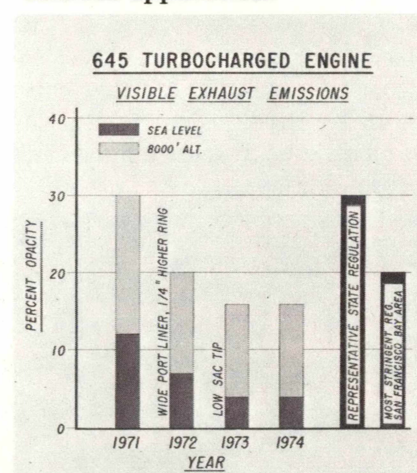


Fig. 9. Visible exhaust emissions from EMD 16-645E3 turbocharged engine.

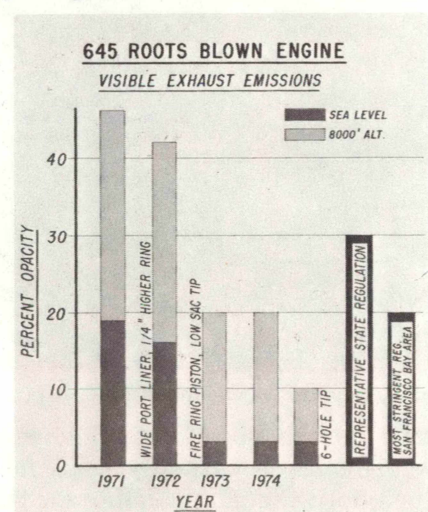


Fig. 10. Visible exhaust emissions from EMD 16-645E Roots blown engine.

A drain from the air box is normally provided to ensure that any liquids collecting in the air box are continuously drained. In view of the relatively small amount of drain liquid, it has been the practice to direct the discharge overboard between the rails. A 100-gal. vented holding tank integral with the fuel tank structure has been made available as a customer option on new units. When this system is employed, any external lube oil, fuel, or water leaks are also directed from the locomotive underframe cavity to the holding tank.

Safety Improvements. As a member of the Control Compartment Committee made up of representatives from the AAR, FRA, and Brotherhood of Locomotive Engineers, Electro-Motive has been active in studies to improve locomotive cab safety. A safety cab mock-up (Fig. 11) has been made which embodies the improved features to be included in a first phase, effective July 1, 1975. Included are a new door handle, a rubber hinge guard, and head bump pads. Also provided are protective covers on the windshield wiper motor, a rubber boot on the windshield wiper handle, and an outside access number box to eliminate the possibility of ingress of debris during collision. In a second phase, tentatively effective January 1, 1976, extensive redesign of the cab is being undertaken to improve access to the short hood, provide for electric heat, reduce noise, and improve control component layout.

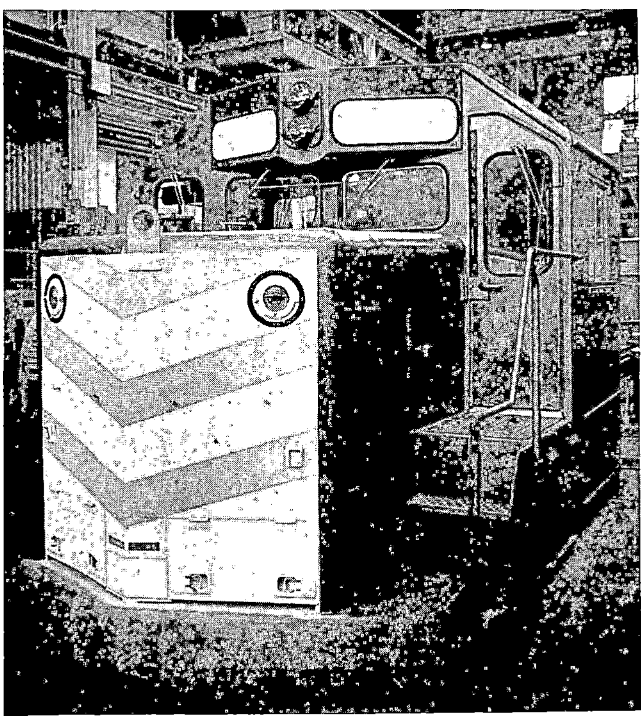


Fig. 11. Safety locomotive cab mock-up.

A new locked-wheel detection system has been developed and is currently being field tested on 338 locomotive units, including the AMTRAK units, to establish reliability. The locked-wheel detection system is composed of a magnetic pickup and amplifier located at the end of each motor shaft (Fig. 12). The speed signal from each motor is used in logic circuitry to detect a 5-mph. speed difference between axles, at which time a wheel slip light and bell are energized. Because of the severe vibrational environment in which the pickup and amplifier must operate, extensive field tests have been initiated to determine reliability of this system.

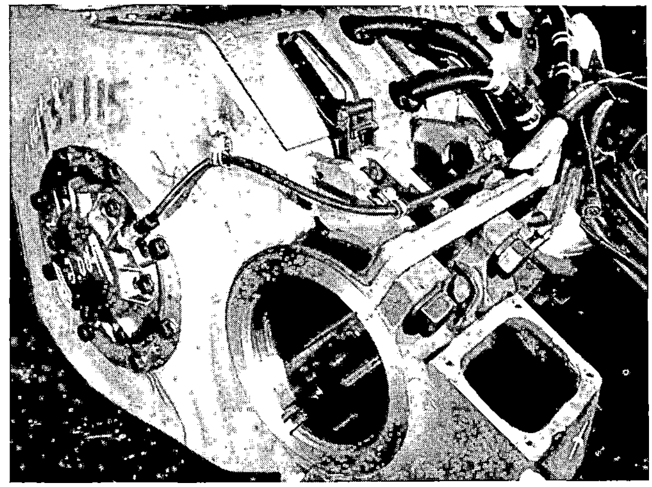


Fig. 12. EMD locked wheel magnetic pickup installation.

Electric Locomotives

In the field of electric motive power, Electro-Motive is developing two types of all-electric locomotives to cover the two general types of railroad operations being pursued today.

The first of these is one that is most prevalent in the United States and is generally referred to as a drag operation. The practice here is to load a consist of locomotive units to the lowest continuous speed of the locomotive on the ruling grade. The number of units in the consist is limited by the coupler force restriction. This practice results in long trains moving at low speed, with a minimum of crew cost and minimum energy consumption.

The second mode of operation is frequently referred to as manifest freight, where relatively light trains are hauled at high speed to minimize trip time, offer more frequent service, and reduce yard congestion, at the expense of higher crew costs and higher energy consumption. This is the operating mode used by European railroads and a few of the U.S. railroads, such as the Union Pacific and Atchison, Topeka and Santa Fe.

The diesel electric locomotive is admirably suited to the first type of operation (drag), but the electric locomotive, because it is not limited in power by the on-board prime mover, has a much greater power capability and, therefore, exhibits a distinct advantage in the high-speed freight range.

In order to cover the full range of possible future freight applications, Electro-Motive is designing two six-axle locomotives: the GM6C (Fig. 13), which utilizes six modified Electro-Motive traction motors and is nominally rated at 6,000 diesel equivalent horsepower, and the GM10B (Fig. 14), which uses six ASEA traction motors and is nominally rated at 10,000 diesel equivalent horsepower. While both GM6C and GM10B locomotives are suitable for drag service, the GM10B locomotive is particularly advantageous for high-speed operation. The selling price of the GM10B, however, is expected to be higher that that for the GM6C, due largely to more expensive motors and final drive gearing.

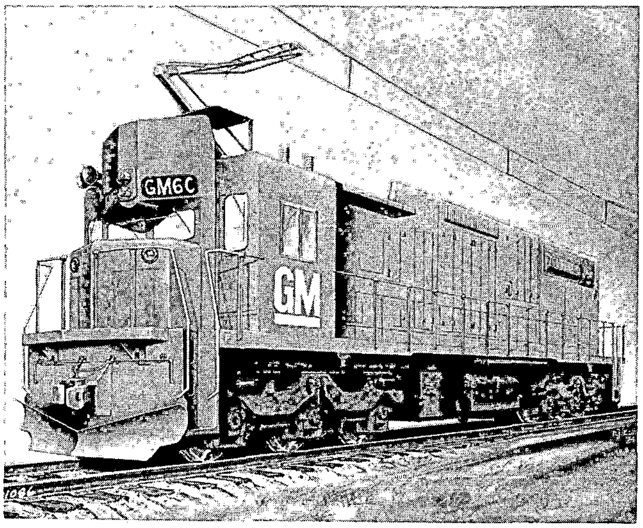


Fig. 13. EMD GM6C electric locomotive.

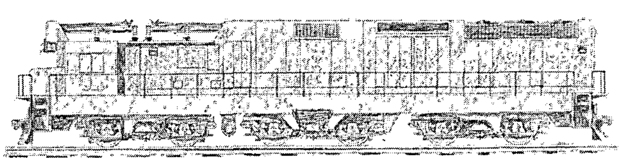


Fig. 14. EMD GM10B electric locomotive.

Both locomotives will employ the most modern technology in electric locomotive propulsion. Specific features include:

1. Full thyristor control of separately excited traction motors.
2. Individual wheel slip control of each axle to optimize adhesion capabilities.
3. Oil cooled transformer, thyristor, reactor, and filter.

In addition, certain outstanding features of Electro-Motive diesel electric locomotives will be incorporated, including:

1. Low weight transfer three-axle truck (GM6C).
2. Rigid buff-resistant underframe.
3. Central air handling and filtration system.

Fig. 15 shows the general arrangement layout of the GM6C. The transformer, thyristor converter, filter capacitors, and smoothing reactor, together with the electronic control, are mounted above deck. The two trucks will be the three-axle Electro-Motive high-adhesion model, modified to accommodate the Electro-Motive E88 motor. This motor is a modified version of the well-developed D77 motor used in Electro-Motive domestic locomotives and includes laminated interpoles, a separately excited field, and roller axle support bearings.

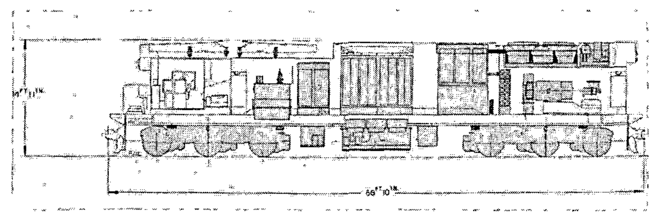


Fig. 15. General arrangement, GM6C electric locomotive.

Auxiliaries for both locomotives are driven from a motor-alternator set which is supplied rectified current from taps on the main transformer. The 1,800-rpm motor-alternator set drives a traction motor blower and a screw-type, 179-cfm rotary air compressor. Three-phase, 60-hertz, 440-volt current from the alternator is used to power all the oil circulating pumps, dust bin blower, and oil cooling fans. At idle, the motor-alternator set is reduced in speed to 600 rpm.

Fig. 16 shows the general arrangement layout of the GM10B. The Bo-Bo-Bo truck arrangement differs noticeably from Electro-Motive's past practice in locomotive axle arrangement. The truck assemblies follow closely designs developed in Europe to accommodate large frame-mounted DC motors with flexible drive to the axle (Fig. 17) via

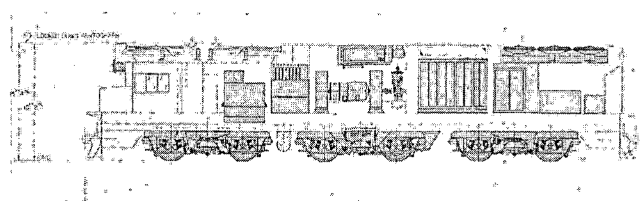


Fig. 16. General arrangement, GM10B electric locomotive.

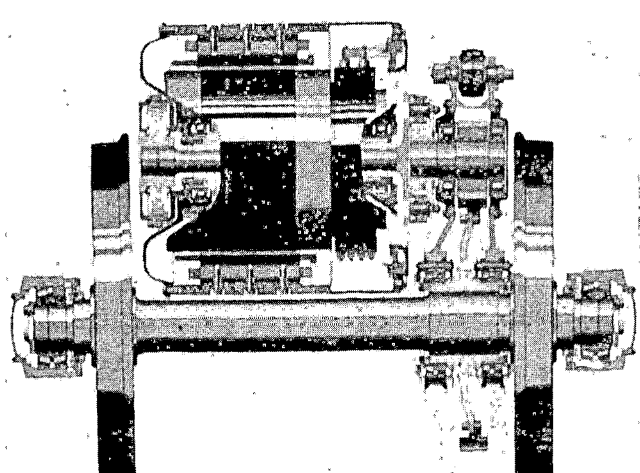


Fig. 17. ASEA motor and drive.

a quill shaft and rubber couplings. Other features (Fig. 18) include the use of rubber in the primary suspension, four pendulum rods in tension to support the bolster on the truck frame and permit rotation in lieu of a centerplate, use of traction rods to minimize weight transfer, and fabrication of the frame as a weldment instead of a casting.

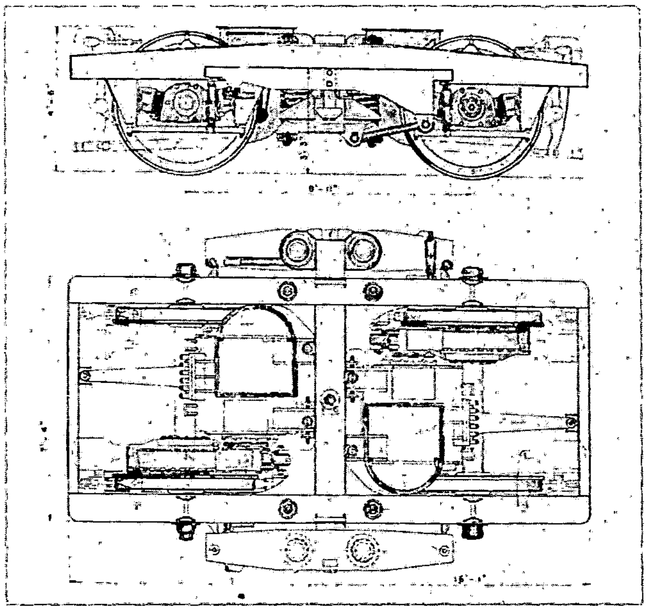


Fig. 18. ASEA-EMD truck.

Of particular interest is the center truck, which must sustain a 7-in. lateral displacement relative to the carbody on an 18-degree curve. This is accomplished by utilizing a combination of a second set of four pendulum rods in tension and compression springs between the carbody and the truck bolster.

The basic electrical circuit for both locomotives is shown in Fig. 19. The transformer will receive 11 kV/25 hertz, 12 kV/60 hertz, or 25 kV/60 hertz single-phase power from the catenary via one of the two pantographs and a main circuit breaker. The voltage will be reduced to about 1,300 volts (800 volts for the GM10B) at the transformer secondary and impressed on a thyristor converter which consists of six sets of two series-connected asymmetric diode-thyristor bridges. The oil-cooled converter rectifies and controls the current to each of the six parallel connected DC motor armatures. The separately excited motor fields are fed by individual thyristor field converters. To maintain the rectified current ripple factor at an acceptable level for good communication, an oil-cooled smoothing reactor is placed in series with each motor armature. In addition, a low pass filter is interposed between the transformer and thyristor converter to filter out odd harmonics generated by the thyristor action so as to reduce the possibility of interference with trackside communications and signal circuits.

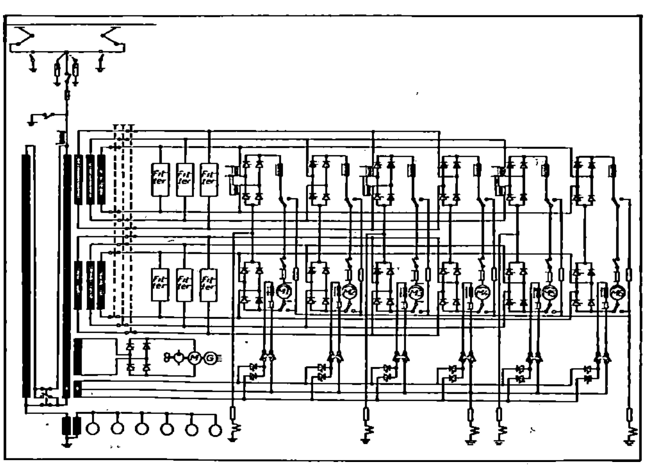


Fig. 19. Basic circuit diagram for GM6C and GM10B locomotives.

The performance of these locomotives is represented in Fig. 20 in relation to the largest single-engine diesel electric model, the SD-45 (3,600 hp. on six axles). The curve for the GM6C illustrates the increased tractive effort available, especially at high speeds. The curve for the GM10B illustrates the further increase in tractive effort of this model, especially at high speeds.

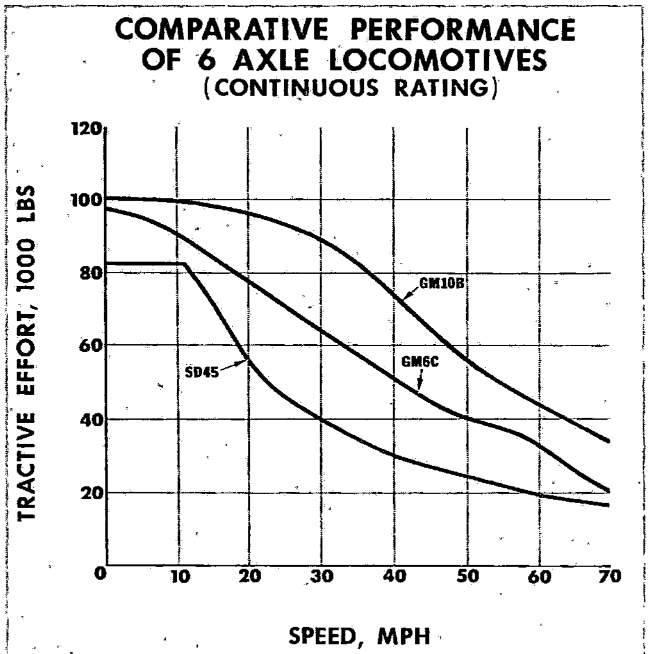


Fig. 20. Comparative performance of 6-axle locomotives.

The GM10B locomotive is expected to have optimum adhesion capabilities, on the order of 26% plus, under adverse rail conditions, by virtue of the use of 50-in. wheels, low weight transfer trucks, and individual axle wheel slip control employing the latest ASEA wheel slip control techniques. This system, known as the Pressductor system, senses the torsional vibration which occurs in the axle at the onset of slip and uses this signal to modulate the current to the driving motor.

The GM6C locomotive also has a low weight transfer truck and individual wheel slip control, but it is equipped with 42-in. wheels and does not utilize the Pressductor wheel slip detection system.

Therefore, the expected adhesion capabilities are slightly lower, nominally 24% under adverse rail conditions.

The first of these locomotives, the GM6C, will be ready for tests and subsequent demonstration on the Penn Central 12-kV, 25-hertz system in freight operations in the spring of 1975. The second locomotive, the GM10B, will follow the first in approximately six months. Although both locomotives will be tested at 12-kV, they can be applied on 25-kV, 60-hertz systems and, with change in the transformer, to 50-kV, 60-hertz systems.

Concluding Remarks

The recent additions to the Electro-Motive product line—namely, the SDP40F passenger, F-40-C commuter, and multipurpose locomotives which have been described—make available to the American railroads a wide choice of modern diesel electric motive power.

Improvements relating to the effect of the diesel locomotive on the environment continue at Electro-Motive, and significant gains have been made in the area of exhaust emissions.

The operational safety of the locomotive is under constant review, and changes in the locomotive cab to promote the safety of railroad personnel are being implemented.

Development of the GM6C and GM10B electric locomotives, to be demonstrated in 1975, will make available to American railroads the most modern electric motive power to cover future applications in the heavy drag freight and high-speed manifest freight operations.

Moderator Loftis: Thank you. Our next speaker is Mr. Werner Siemens of International Engineering Co.

Railroad Electrification: A System Design Project

Werner H. Siemens
Principal Electrical Engineer-Transportation
International Engineering Company, Inc.

Werner H. Siemens is Principal Electrical Engineer-Transportation for the International Engineering Company, Inc., San Francisco. In this position he is involved principally in project engineering and management of electrical and transportation projects, particularly railroad electrification.

Siemens received his education at the Technical Institute of Berlin, Paulsen College, Berlin, and in the Signaling Training Course of the Canadian National Railways. He formerly served as Manager of Electrification Control Systems for General Electric's Railroad Electrification Section. Major projects in which he has been involved include the design or installation of CTC signaling on the Canadian National Railways system and train control systems for the Massachusetts Bay Transit Authority. He is a member of the American Association of Railroads and the American Railway Engineering Association.

Note: The numbers and values used in this presentation are not actual values but are for illustrative purposes only.

Many railroads, nationally as well as internationally, are today seriously looking at the potential opportunities that railroad electrification can bring to their operations. In this discussion I would like to outline briefly why a project such as the planning, design, and construction of an electrified railroad requires detailed system design, engineering, and coordination. This is important not only when constructing a totally new railroad, but even more emphasis needs to be placed upon system engineering when converting an existing railroad to an electrified operation.

To best illustrate this point, let's start at the beginning. A modern railroad electrification system is made up of a number of subsystems, as shown in Fig. 1. The two most obvious ones are the electric locomotives and the overhead contact, or catenary system. But to make an electric railroad operate also requires:

1. Traction power substations.
2. Electric utility coordination and supply.
3. A signal and communication system.
4. Clearance considerations and modifications.

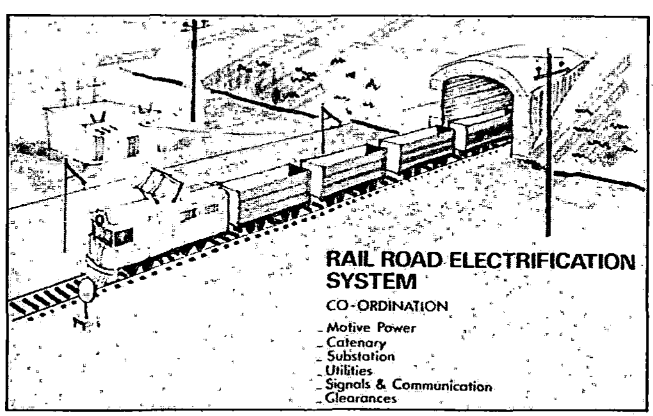


Fig. 1. Railroad electrification subsystem coordination.

Much can be said about the economics and savings that are normally identified with railroad electrification, but that is a subject by itself which needs to be studied for each case individually rather than being generalized. Instead, let me show how a foreign railroad looks at the total cost of electrification vs. traffic volume. Fig. 2 shows a composite curve that expresses both the capital cost and the maintenance cost of an electrified railroad over a given number of years, expressed in cost of electrification vs. unit cost per million tons per annum. What is interesting to note is that once a certain traffic level is reached, no substantial unit cost reduction is expected. This certainly may be the reason why so many foreign railroads are continuously converting their railroads to electrified operations.

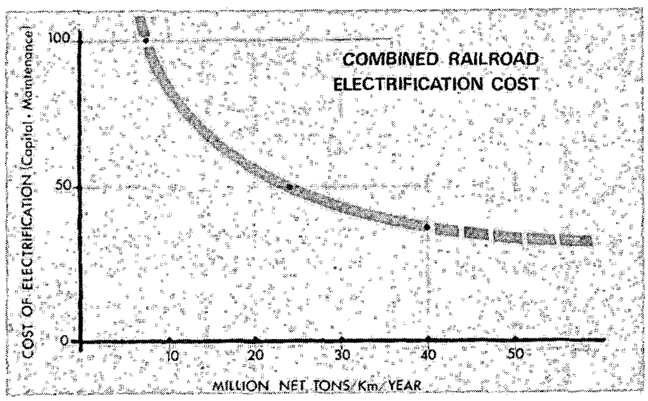


Fig. 2. Combined railroad electrification costs.

Let me give a brief review, not only as to how the various subsystems of a railroad electrification are interrelated, but also as regards the relationship that exists between electrification and the actual railroad operation. The product of a railroad is moving trains, and all that a railroad is looking for is to provide service to its customers, with the best possible operation. Therefore, in establishing the basic criteria for railroad electrification, the present and future railroad traffic patterns, traffic growth, and operational practices have to be considered.

For example, it is an established fact that electric locomotives can be manufactured to provide more horsepower and tractive effort than today's diesel electric locomotives. (Figs. 3, 4, and

Fig. 3. 50 cycle group. CC 21000 electric locomotive.

5 show modern electric locomotives.) However, the maximum train size for a specific route should be established by railroad considerations, rather than the locomotive's capabilities. These railroad considerations as regards ideal train size (see Fig. 6) should include:

1. Optimum train size for departure and receiving and classification yards.
2. Size of passing sidings.
3. Locations of crew change terminals.
4. Maximum speeds.
5. Axle loading limitations.
6. Curves and general alignment.
7. And so forth.

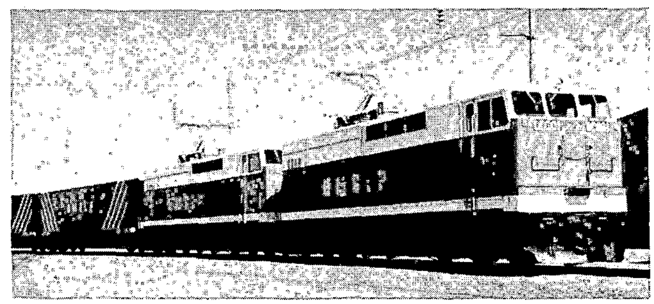


Fig. 4. General Electric E60C 50 kV locomotive.

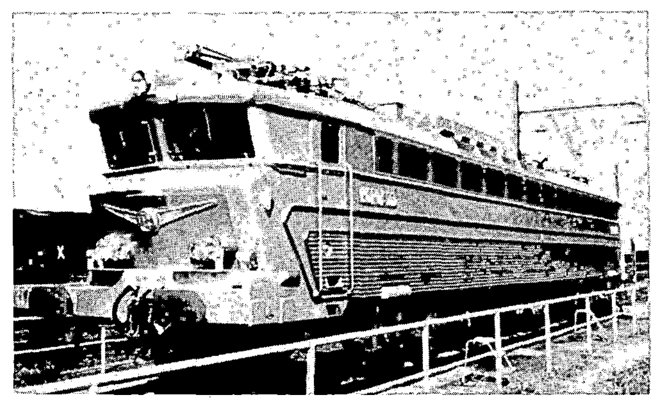


Fig. 5. 50 cycle group, BB 15000 electric locomotive.

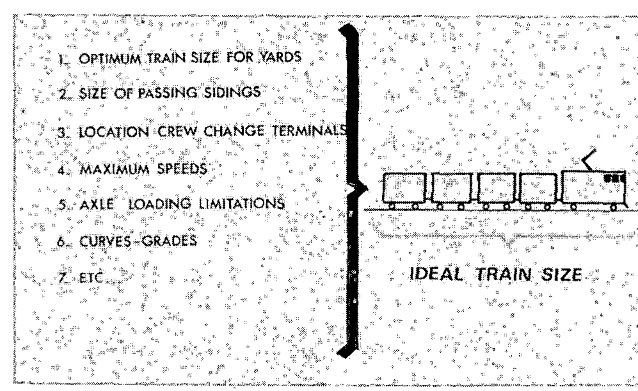


Fig. 6 Factors determining ideal train size.

Once the optimum train size for a specific route has been established, the size of the locomotive or locomotive consist should be determined (see Fig. 7). Locomotive size is based upon:

1. Train size.
2. Ruling grades.
3. Length of ruling grades.

(cont'd.)

4. Maximum continuous tractive effort requirements.
5. Weight limitations.
6. Curve limitations.
7. Maximum speed.
8. Maintenance facilities.
9. And so forth.

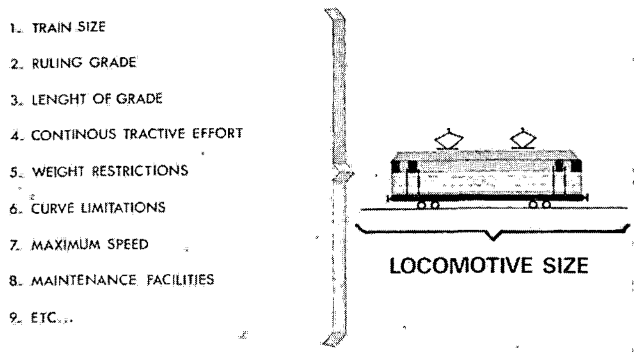


Fig. 7. Factors determining locomotive size.

This now gives us the size of the locomotives required to do the job for the specified railroad operation. Of course, this size may need to be analyzed to assure that we have selected a locomotive that is commercially available.

Having identified the optimum train size and locomotive size, we need to determine, based on present and future railroad traffic, for which condition or year the electrification system should be designed (see Fig. 8). This is a very important point, as undersizing the electrical system will limit future railroad flexibility and growth, and of course oversizing requires a larger investment than necessary. It is in this area that a detailed engineering and operational analysis should be made to assure future success of the electrification project. Sound advice and an understanding of the alternatives at this time are essential.

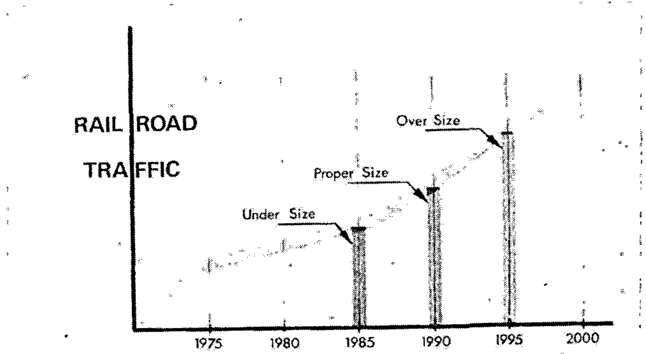


Fig. 8. Projected railroad traffic and size of electrification system.

Having arrived at a practical and economical solution to the problem of size for the railroad electrification system, we can develop the electric requirements that will be imposed upon the catenary system and substations. It is necessary first to investigate the most suitable catenary system voltage for the specific application (see Fig. 9). The availability of high-voltage utility network power plays an important role. Because the electrification system is essentially a single-phase system, it is desirable, for utility system stability, to have a supply voltage that is two to three times greater than the proposed catenary system voltage. After establishing what, if any, limiting factors there are for a 50-kV, 25-kV or other voltage system, a detailed investigation of clearance requirements is necessary. Before this can be done, a preliminary design of the catenary system must be made. This establishes the necessary clearance envelope for the proposed catenary voltage, but the actual height of the contact wire above the rail is determined by the maximum load height established by the railroad.

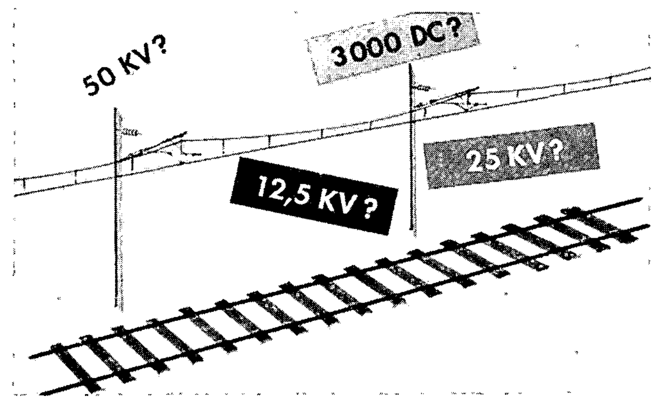


Fig. 9. Contact wire voltages.

With the preliminary catenary design and the established dimensions for passing and static clearance to grounded structures, a detail survey should be made of the route to determine what modifications may be necessary. This detail survey is, of course, especially important on existing routes. But the results of this survey should not be discouraging, as some clearance obstructions can be overcome by different approaches (see Fig. 10).

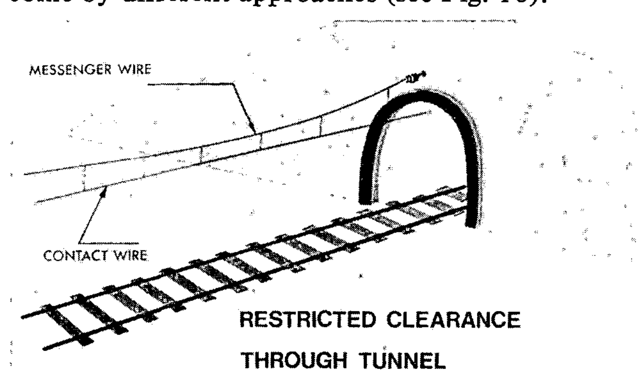


Fig. 10. Restricted catenary system clearance through tunnel.

Having identified the preliminary catenary system voltage, we can now proceed to establish the traction power substation sizes and spacing, as well as the required current-carrying capacity for the catenary. The sizing and spacing of these items must consider not only the electrical loads, losses, and efficiencies of the various apparatus, but, more important, railroad traffic conditions.

For example, assume a typical electrification system with a normal traffic of three trains in a catenary section. This may require a substation with a capacity of 10 MVA and a catenary current of 300 amperes at 50 kV (Fig. 11). Under a contingency condition, such as one substation off line, the adjacent substation has to be able to supply electrical energy to the catenary section normally supplied from the failing substation. This will have to be done within the permissible voltage fluctuation of both the serving utility and the locomotive. For a 50-kV system this voltage may be 10 kV, and the substation transformer and catenary system have to be sized to provide enough voltage and current at the far end of the catenary to start a train. This is necessary because the railroad will want to continue operating even with a substation off line. The requirement to start a train at the far end and to maintain normal traffic may increase the substation capacity to 22 MVA and increase the catenary current to 500 amperes.

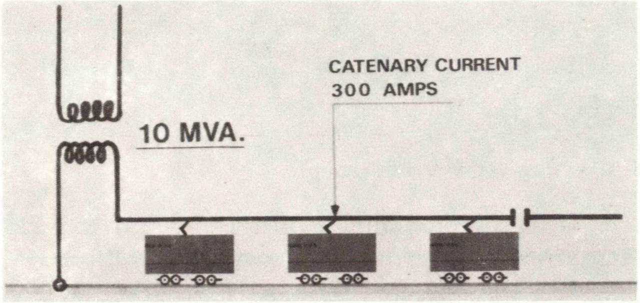


Fig. 11. Voltage requirements for typical electrification system with normal traffic of three trains in a catenary section.

At this time an economic decision must be made. As maintaining full traffic requires a 22-MVA substation, the decision to reduce traffic under contingency conditions to two-thirds could result in a substation size of 15 MVA (see Fig. 12). This represents a substantial saving, especially when one considers that the normal expected outage of a substation due to transformer and transmission line failures may be less than eight hours annually.

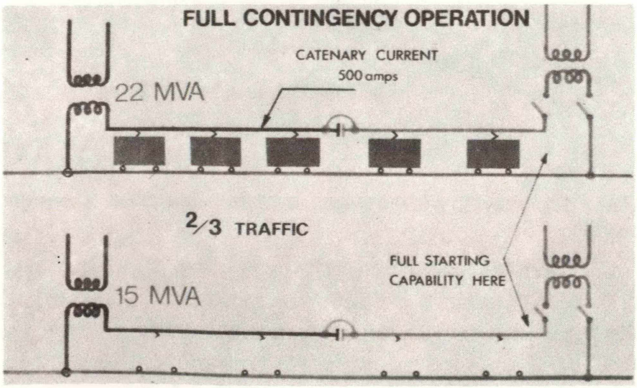


Fig. 12. Full contingency operation, providing full power into adjacent catenary section.

This leaves us with a substation capacity of 15 MVA and a catenary current of 500 amperes. However, one more railroad criterion needs to be investigated, the signal system.

Although it may be unusual, there may be occasions when the trains are separated only by the permissible spacing of the signal or train control system. This may permit as many as six trains into a catenary section, which can result in a catenary current of 800 amperes at 50 kV (Fig. 13). Of course, the system needs to be designed to be able to support any and all conditions that may occur. Therefore, in this example the suggested substation capacity could be 15 MVA, with a catenary system capable of supporting 800-ampere current.

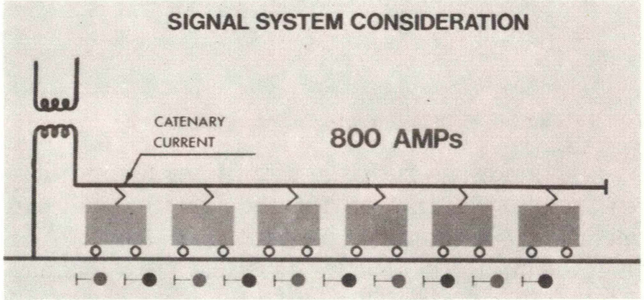


Fig. 13. Signal system considerations for catenary system.

Once the substation locations have been established, the supply of electrical energy from the utilities must be assured. This is done by coordination and cooperation with the electrical utility companies involved. To do this, it may be necessary to perform kW demand studies, estimate the annual and monthly KWH requirements, and investigate system stability and unbalance (see Fig. 14).

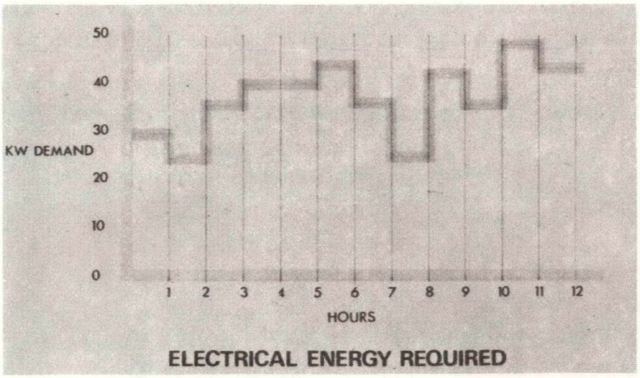


Fig. 14. kW demand study to determine electrical energy required.

Close cooperation with the electrical utilities at this point is very imporant, as it may be necessary to provide some dedicated transmission lines to connect the traction power substations with the electrical distribution network. A proper understanding of the railroad's present and anticipated energy requirements and demands is needed to assist the utilities in planning and providing the power requirements for the electrified railroad, as well as all their other customers.

In some cases it may even be desirable to change the proposed location of the railroad substation. But changing the established location can affect the proposed locations for the other substations involved. This must be carefully studied in order to arrive at the most practical and economical substation sites that suit both the railroad and the serving utility.

With the catenary current established, it is now possible to design the overhead contact wire system to suit the anticipated or established railroad operation (Fig. 15). The maximum speed, number of locomotives per train, and climatic conditions have a great influence on catenary system configurations. We believe that today's catenary systems should be built and designed to last for the duration of the electrification project. This may sound strange, but consider that most overhead contact wire systems built 30-40 years ago still have an estimated life of up to 50 years left. Nevertheless, many of these catenary systems that had an anticipated total life of up to 90 years are now being replaced by different voltage and frequency systems because they are now obsolete. In my opinion it is quite adequate to develop a design that has an expected life of 30-50 years. No doubt even our most modern transportation systems today will look like model T's in the year 2001.

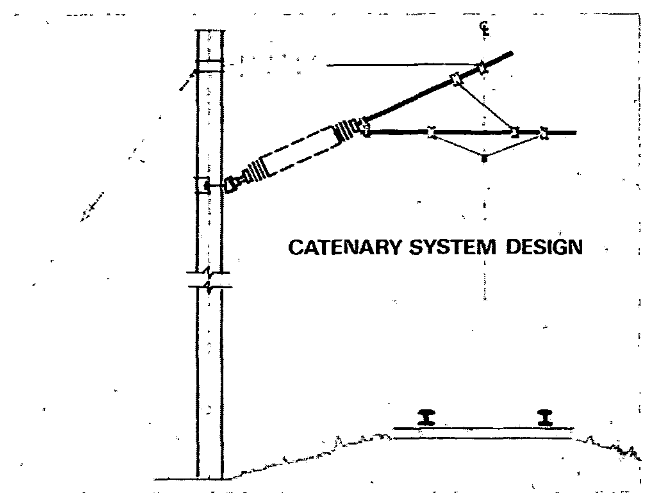


Fig. 15. Catenary system design.

The catenary system provides the path for the electrical energy from the substation to the locomotives, but the electrical current will have to return to the substations to complete the circuit. The current will leave the locomotive through the wheels and return to the substation through the rails and the ground. This requires a continuous path for the electric current through the rails. However, this is the exact opposite of the requirements of most railroad signal and train control systems. A signal system normally requires the railroad track to be divided into blocks and track circuits that are carefully insulated from each other by the use of insulated rail joints. In order to maintain the integrity of the signal system and also fulfill the requirements of the electrification system, a compromise, which usually requires modifications of the signal track circuits, has to be developed.

In many cases this means changing the DC track circuit to an AC track circuit at a frequency different from the traction power supply. The means to bypass the insulated rail joints can be accomplished with impedance bonds (Fig. 16). Sizing of these bonds depends entirely upon the current expected and its duration. However, one should not overlook the fact that some of these return currents travel in the ground and need not be considered when sizing the impedance bond. This is important, as no doubt the most economical solution is desired.

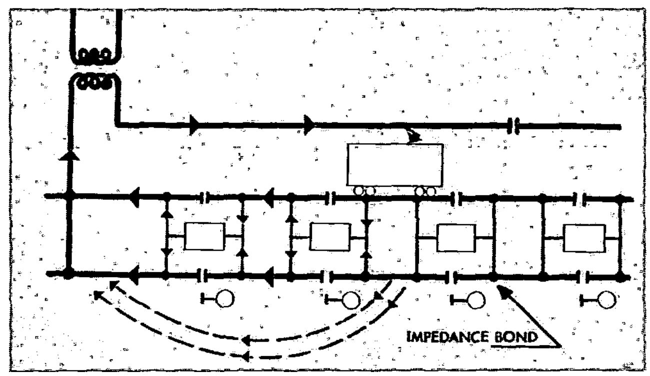


Fig. 16. Impedance bonds and return current distribution.

One side effect of railroad electrification is interference with neighboring parallel electrical conductors (Fig. 17). This can affect both the signal system and the communications systems. This interference phenomenon is the inevitable transfer of energy by induction from one circuit to another neighboring one. Railroad electrification is in essence a single-phase transmission circuit. The magnetic and electric field created by this single-line transmission circuit can induce various types of interference in parallel conductors.

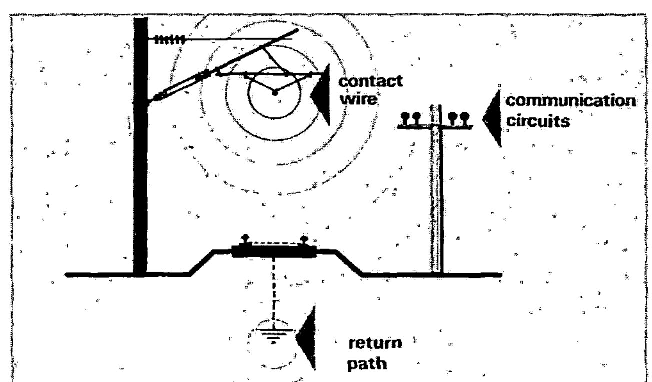


Fig. 17. Interference of railroad electrification system with parallel electrical conductors.

There are many proven solutions to what can be done to eliminate or protect against the interference produced by an AC electrified railroad. Many factors, such as conductivity of the soil, single-track or double-track railroad, distance between catenary and parallel wire circuits, length of circuits, mutual inductance, current and frequency in the track circuit, as well as the catenary design, play the controlling roles in creating, reducing, or eliminating the interference phenomena. Each individual case will have to be studied on its own merits to establish what means and methods should be applied to overcome this unwanted side effect.

When some protective measure for the existing circuitry is necessary, the engineer can take full advantage of this opportunity to improve and enhance the system at the same time. This, alone, could in many instances justify any necessary expenditures involved.

Finally, the total electrification system must be designed and constructed to meet all necessary safety standards for the type of equipment involved. Metallic structures within the vicinity will have to be adequately bonded and grounded to assure personnel safety at all times (Fig. 18). At selected locations, such as substation sites and highway crossings, some additional grounding protection or grounding mats may be required. This is necessary to provide absolute protection to all personnel under fault current conditions. But whether this is required or not greatly depends upon the kind of soil resistivity and the location in respect to the energy supply sources and anticipated current levels.

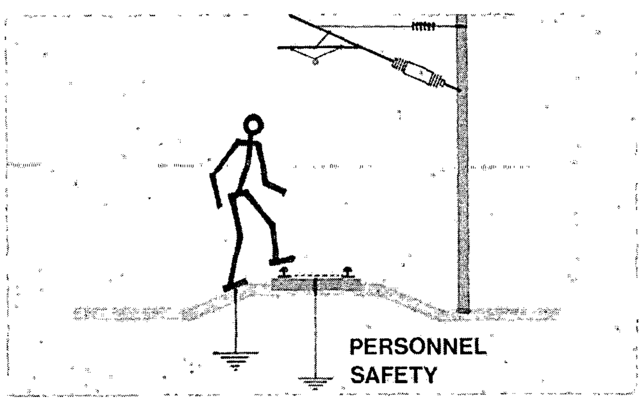


Fig. 18. Assuring personnel safety (step potential).

A railroad electrification system is made up of many independent subsystems that are interrelated and dependent upon one another (Fig. 19). Many additional items that I did not have time to mention play an important role in determining the success of an electrification project. I hope that this brief presentation has given you some understanding of why electrification needs to become a system project. A building-block approach of selecting individual components without consideration of the impact they may have on other components and subsystems leads only to an unsatisfactory operation, and possibly even a costly failure.

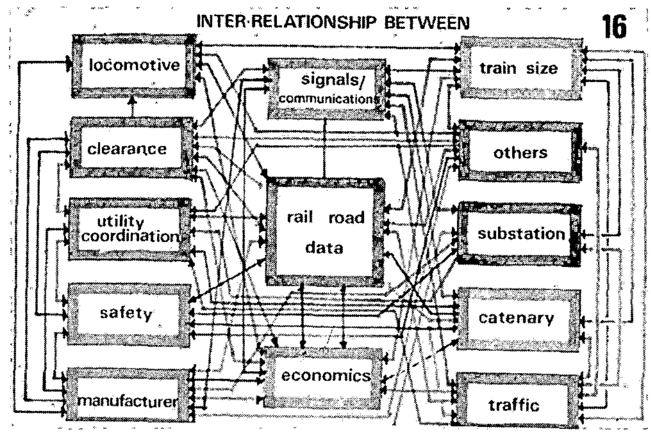


Fig. 19. Interrelationship of subsystems in a railroad electrification system.

The International Engineering Company has over the years gained substantial experience in the planning and design of railroad facilities, including electrified railroads such as the one shown in Fig. 20. This can be evidenced by the Black Mesa & Lake Powell Railroad, the world's first 50-kV electrified railroad operation (Fig. 21), which without too much fanfare was placed into service earlier this year and has been operating satisfactorily since. This 50-kV railroad was designed by IECO in cooperation with the General Electric Company. A close working relationship between the designer of an electrification system and the manufacturers of the major components is essential. Only the manufacturer understands completely the limitations of its equipment, and by working together the designer can introduce the necessary adjustments to arrive at a completely successful project.

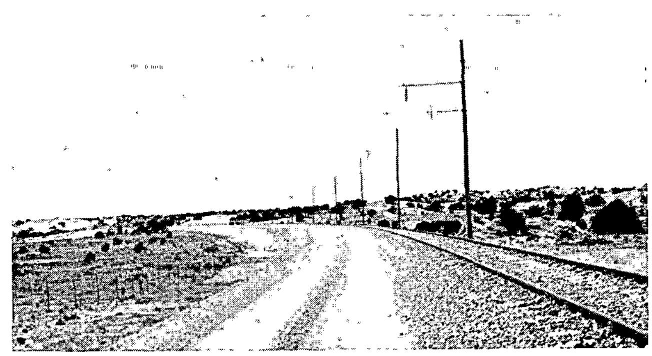


Fig. 20. Electrified railroad facility, Black Mesa and Lake Powell Railroad, 50kV, 60 HZ.

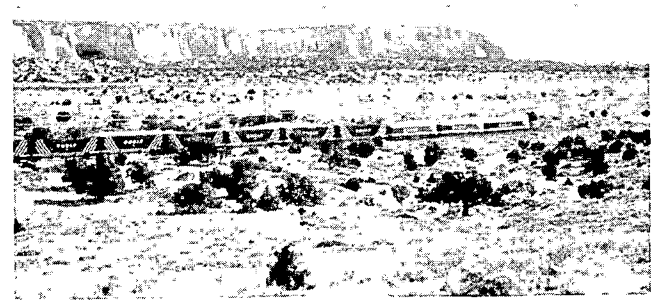


Fig. 21. Black Mesa and Lake Powell electric railroad, 3E60C electric locomotives.

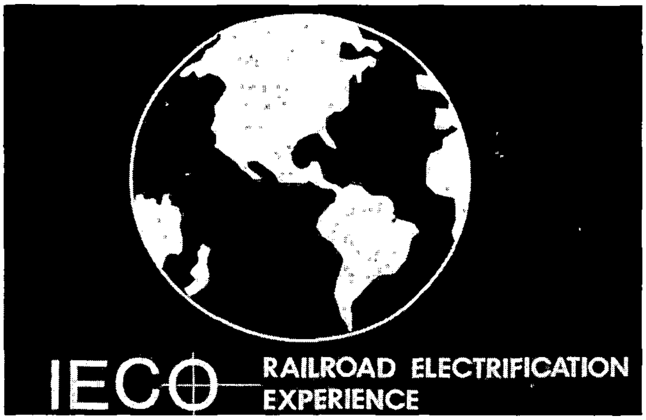


Fig. 22. International Engineering Company, Inc. has worldwide railroad electrification experience.

IECO has been and is working with domestic and international railroads on railroad electrification projects. This has given us the opportunity to maintain and increase our experienced staff, and we are today ready to serve the American railroads in their desire to achieve economy in operation through railroad electrification.

Moderator Loftis: Thank you. John Hawthorne from Seaboard Coast Line will now serve as Discussion Leader for your comments.

DISCUSSION LEADER
John W. Hawthorne
Assistant Vice President-Equipment
Seaboard Coast Line Railroad Company

John Wesley Hawthorne is Assistant Vice President–Equipment of the Seaboard Coast Line Railroad Company, Jacksonville, Florida. He received the BS degree in Mechanical Engineering in 1933 at Purdue University.

His railroad-related experience began that same year at the New York Air Brake Company. This was followed by motive power and equipment management positions with the Central of Georgia Railway and the Atlantic Coast Line Railroad.

Hawthorne is Past President of the Locomotive Maintenance Officers Association and has served the Association of American Railroads as a member of the General Committee and the Executive Committee and as Chairman of the Mechanical Division. He is a fellow of the American Society of Mechanical Engineers and a Registered Professional Engineer.

Discussion Leader Hawthorne: All right, we have had several papers here and I don't know that there is any need to outline anything at all, although I did as we went along. Let's start in with some questions.

Delegate Comment: Are there any design parameter limitations which would be required in electrification relative to catenaries, pantographs, transformers, and so on which would permit run-through operations such as we have now with our diesel electric locomotives and would provide the same possibilities for electric locomotives?

Speaker Response: I will only respond in terms of the fixed components such as substations and catenary. The answer to your question is yes, a system can be designed to provide the type of service, run-through operation, you are looking for. As a matter of fact, when electrification takes place, there will always be a need for some diesel operation. This means that the catenary system will have to be designed that can operate with the type of environmental contamination it might experience from the diesel exhaust. But in terms of electrical sizing, the system can be designed to provide run-through operation, as you have mentioned.

Speaker Response: I would just like to say that if you are interpreting run-through operation as going from one railroad property to another railroad property, it would be very desirable for both catenary systems to be at the same voltage level. This is not absolutely necessary, however. European railroads have as many as three voltage changes, and not always are they AC. Some of them are DC, and this greatly complicates the system. Also, I would think the problem of any differences in signaling practices between two areas would have to be given careful consideration.

Speaker Response: On the same comment, we are building a locomotive now that has three power systems, and one of the changeovers is intended to be manual because we don't expect it will happen in the near future. You can take care of the voltage changes, but the signal changes are going to have to be coordinated among the railroads.

Delegate Comment: I would like to comment that Mr. Siemens is absolutely correct in the need for doing a complete system-planning exercise before you embark on electrification. In the early days of the electrification in the United Kingdom, we made the mistake of trying to electrify the system as it stood, and as a result we had a lot of redundancies in equipment once we started to operate an electrified railroad. Another thing is that it is necessary for the operator, the man who provides the train service, to understand the benefits he will get from electrification.

The second thing I would like to comment on is the suggestion that you should tolerate a reduction in train service if you lose a substation. Now, if a line merits electrification, it implies that it is going to have pretty intensive traffic, and the cost of individual supply points for 25 Kv or 50 Kv, unless you are in very remote country where part supply and transmission lines are expensive, is an insignificant part of the total cost of electrification. We in the UK would certainly never tolerate the situation where you had to curtail the train service past one supply point just because you have gone to electrification.

We have no problems about running from one system to another in the UK. We do operate at the moment at 25 Kv AC on certain parts of the route and come down to 6.2 Kv in the areas around London where low-bridge codes are applied. I would recommend, unless there are very exceptional circumstances, that 25 Kv on the AC system appears to be the optimum, with the possibility of going to higher voltages if you have longer distances and open terrain to pass through.

On the design of cabs, one of the most important things we find at high-speed running is damage through the windscreens due to vandalism. Here we are now having to fit high-impact-resistance glass capable of withstanding missiles weighing 4½ lbs. up to 200 mi. impact levels, because we have children who drop rocks over bridge parapets when trains are coming along—pretty gruesome. But this is the kind of thing we had to go to, so we no longer favor curved windscreens in these driver compartment window fronts. We prefer to go to smaller windows.

Delegate Comment: I might comment that vandalism is not common to your country alone. We replace something like 25 to 30 windowpanes a day in passenger trains.

Delegate Comment: To put this in perspective, would you tell us your peak traffic on the Southeast line in the UK, in trains per hour?

Delegate Comment: Well, if we can talk about the overhead system, we now on the west coast main line, from London to Glasgow and to Manchester, Liverpool, and Birmingham, run a train to Birmingham, which is 105 miles away, every half hour and to Manchester, run an hourly service. So the train service is running around about a train every five minutes. Departures are in groups; we have to flight them so we can fit the lowest speed train in between. We are considerably embarrassed now that our freight trains, running at 45 and 60 mph, are just not comparable over the routes with the high-speed trains.

Speaker Response: I was talking more of the commuter area out in the Southeast.

Delegate Comment: This is a third-rail system. I am afraid I am being terribly forgetful in this; I can't think of the number of trains that, every minute, go out to London Bridge in the rush hour.

Speaker Response: I was gratified to learn that you, in principle, agree with what was presented. In response to your comment as to the suggestion that a railroad should accept reduced traffic, my point was that an economic decision should be made, which should be the railroad's decision and not mine or somebody else's. The railroad can decide whether they could afford to reduce traffic for a limited time at the savings they may incur by not investing in additional capacity.

Delegate Comment: In answer to the question about the possible interchange of electrical equipment, I would like to point out that approximately 20 years ago, on the New Haven Railroad, there was an animal called the FL-9 which ran on catenary, on 600-volt AC, and also operated on diesel.

Delegate Comment: Someone showed a slide of a temperature transducer used in monitoring main bearing temperatures. Is this a fairly complex system, or is it something that could be adapted in a railroad shop to use in road testing or new engine break-in?

Speaker Response: That was shown just as a test kind of operation. Really the purpose in showing it was to show that you get a fantastic amount of data to be reduced. It was not intended to be an operating device. About that final slide of the high-temperature transducer—I think the most indicative of all those conditions on a locomotive is the preturbine temperature, and I would dearly love to be able to continuously monitor preturbine temperature.

Delegate Comment: I have a question in regard to the locked-wheel detector system that was pictured. Will this require retrofitting of motors at the time of rewinding?

Speaker Response: Yes, it would require modifications to the traction motor to apply that pickup and amplifier on older locomotives. What I think would probably happen, after we determine that the system is fully reliable (and that's most important to the application), we would offer this as an option. And I am sure that we would attempt to make a retrofit package available if the railroads would like to have it.

Delegate Comment: There are about 100,000 motors that would have to be retrofitted, and it seems to me that it is going to pose quite a burden to go that route.

Speaker Response: We are not necessarily advocating that you go this route, but we are developing the equipment so that it will be available.

Delegate Comment: Do I understand that on the electric locomotives which you are working on now, the AMTRAK and the prototype EMD's, you automatically change from, say 11,000 volts, 25 cycles to 25,000 volts, 60 cycles?

Speaker Response: In the EMD prototypes, we would not make that automatic change at this moment. It could certainly be done automatically, but we are not building the automatic changeover into the prototype locomotive.

Speaker Response: It's the same with ours, we just don't put it on. And that pretty much follows the idea that you don't put on something you don't need, because it is something else that gets in trouble.

Delegate Comment: I have a question on the miniquad equipment. Could you give us some idea of how often it is necessary to separate cars with the fixed drawbar connections in between shoppings?

Delegate Comment: It has been very seldom except when we bring the cars in for an annual inspection. We do have these cars computer controlled; they come in at least once a year because of the mileage. The system is designed so that if we do have a failure, say a broken yoke in the field, we can go up with a truck and apply the old "E" coupler because we have not changed our draft connection. We can remove the drawbar and reapply the "E" coupler on location and recouple the unit. We have spare hoses on our cabooses and locomotives that can be used to repair the break. Normally the entire four-car unit would be set out. We send a repair crew out by truck, and they make the temporary repairs. The following train, usually a local, brings it into the shop. We don't try to make on-line repairs other than to get it ready to move. There has been very, very little of this; as I recall, two or three occasions of a broken yoke has been about it.

Delegate Comment: Just one more question though. What is the average mileage now on these cars, per year?

Speaker Response: They run about 35,000.

Delegate Comment: I have one general comment about the presentation on the electric locomotive development. It was not brought out that it is very important that any new locomotives developed be compatible with one another so they can be multipled. Our experience as electric locomotive users is that we have five or six different classes, and none of them will MU with another. This is a tremendous burden, and it is only because we acquired the GG1 locomotive from the former Penn, and the EP5 from the former New Haven, the E33 from the former Virginian Railroad, and the E44's, which were built new by General Electric. These classes will MU with each other or within themselves, but they will not MU with other classes. This is very important in the development of a new generation of electric locomotives.

Delegate Comment: I have wondered why, when from both of your talks it seems as if we are getting ready to go into electrification, and it seems very likely we will be getting ready to do so, we shouldn't be getting some standards together. This could be not only from you two fellow's standpoint, but from Mr. Siemens's.

Speaker Response: Well, I can say this, that the two locomotives that we are making prototypes of will, of course, be able to MU with each other, and they will be able to MU with other like units. We will also be able to MU them with our diesel electric units. Now, we have not, at this moment, attempted to make them MU with say, an E60C, but I am not sure that that is an insurmountable problem. We both MU in the area of diesel electric locomotives now, but it might be an insurmountable task to be able to MU with all of the electric locomotives that have been built.

Panel Response: The thing that will really save the day, I think, is that both General Motors and General Electric are making the electric locomotives MU with the diesels. Then it should follow that the electric locomotives MU with each other. We are also making the new Penn Centrals to MU with the last E44's, if we sell some new to Penn Central. That's quite a task in that case, but it won't be a task from here on out because we have adopted the principle of MU with the diesels. Both companies now do this with the diesels we have.

Moderator: I would like to direct the discussion and ask, through our translators, if the gentlemen from overseas—Brazil, France, and Spain—would like to ask any questions.

Delegate Comment: You will excuse me, because I don't speak a sufficient amount of English to ask you questions. I would like to say a few words on the electrification problem. You know that in Europe, electrification has been developed to quite a large extent. In France, about 35% of the lines are electrified, and on this 35% of electrified lines, the electric represents approximately 75% of the total traffic.

In making the economic analysis of the electrification of lines in financial statements, the problem of traffic, of course, is a most important element.

Among the economies which you saw can be gained through electrification, there is one which is very important, and which I don't think was really touched on too greatly. These are the economies which are effected in the maintenance cost of locomotives. The maintenance of electrified locomotives is far less costly than is diesel locomotive maintenance, and its availability is usually far superior to maintenance for the diesel locomotive. Therefore, as this economy factor is far greater, and if to this we add the economy of the fuel costs which are increasing today, we can economize through electrification. In Europe, we are far more prone to go into electrification than we have been in the past because of the savings on fuel. Another advantage that perhaps it might be well to note pertains to the greater speed, particularly in regards to heavier trains. In Europe we have some trains that can go as fast as 160 km. per hour, but we don't have any locomotives that have the speed of 200 km. per hour. Certainly it will be far easier to build trains which are electrified that can go at faster speeds than we can achieve with diesel locomotives. Thank you, Mr. Chairman.

Delegate Comment: When you referred to the increase of adhesion, no mention was made of the possibility of use of monomotor locomotives, which on the other hand have an advantage which is quite great in stability. And, it does much less harm to the rails. We in Spain, as in France, have gotten efficient adhesion on dry rails of around 0.37, which is not possible with locomotives that have individual wheel action. Aside, I would like to ask if the six-axle bogie which is being built by General Electric or General Motors has a connection between the bogies for curve manipulation. Locomotives with three bogies without connections, as we see it, have little stability and cause a wearage of the wheels which is quite great, in comparison with locomotives with a short bogie.

Speaker Response: With regard to the comments of the first gentleman from France, I would like to say that the availability for service of diesel electric locomotives in the United States ranges on the order of .85 to .95, an average figure of .9. Now, if you admit that an electric locomotive could have an availability factor of .95, you must admit that there is not much to be gained here. Another point that I would like to point out is that in our studies of electrification thus far, considering the escalating costs of energy, we find that the energy costs of running a high-traffic-density railroad quite overshadow the maintenance costs. Although I agree that diesel locomotives have higher maintenance costs than electric locomotives, I think that the energy costs in the whole economic study will greatly exceed the cost of maintenance.

Now, another point that is quite different in the United States than it is in France is that here our emphasis is on freight, and in France, of course, there are many passenger trains. I believe that they have mixed traffic, so freight trains must run at a much higher speed to get out of the way of passenger trains. We don't have that situation in the United States, and so we don't have the need to go at the extremely high speeds that were discussed for freight trains. Furthermore, I am sure you people who listened to the discussions yesterday realize the problems that exist in pulling freight trains at some of these very high speeds.

The EMD prototype electric locomotives will not be provided with the interbogie control, and we do not anticipate serious wear problems. Now, in regard to the adhesion question, I would like to say that EMD has done a lot of adhesion testing in the last two years. We have operated with independent, separately-excited motors under our diesel locomotives, and we have obtained, on dry rail, adhesion values up to 40% and sometimes even higher. But that really means nothing. What is most important is the adhesion that you can obtain under adverse conditions. We have found that although 25 or 26% adhesion is attainable under very adverse conditions, there is a penalty to pay. To get this good adhesion requires that the wheel must creep and sometimes creep substantially, and when this is so, then we have additional wheel wear and also rail wear. This must be evaluated before one opts for a very high adhesion condition. Also, there is a big difference between the requirements of adhesion in Europe and in the United States. We have long grades, and if we were to slip on those grades, the train would come to a halt and we would have to double the hill. In Europe, the trains are not as long, and they run faster. If they slip, it is a matter of reducing the acceleration rate, not a matter of doubling the hill, and there is the big difference.

Edward Ward: I would just like to thank the speakers and the moderators for making this such a good meeting and such a worthwhile exchange of information—I think the speakers, each and every one, deserve our thanks, and the moderators likewise. I would like to personally thank them all.

I hope you have a good visit at the Test Center this afternoon. I want you to particularly look at the freight activity that is going on out there now.

Moderator Loftis: Thank you, Ed. Just briefly, my impression of the Conference is that we have focused in on knowing more about equipment, knowing more about it from an economic standpoint, knowing more about maintaining it properly so it will be available for utilization, and with special emphasis on economics. Gentlemen, I thank you. You have been a great cooperative group, the speakers have been fine, and I thoroughly enjoyed myself. Meeting is adjourned.

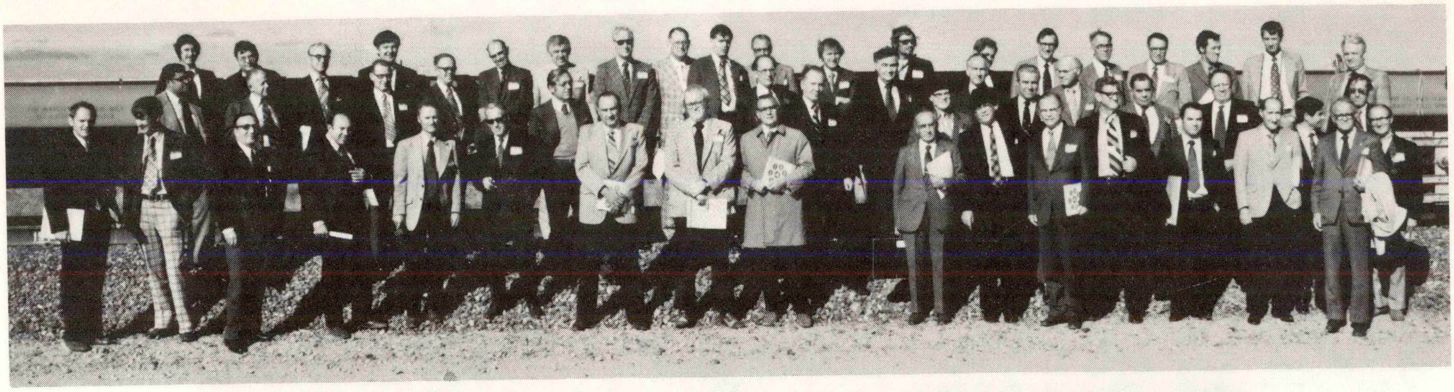
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
ELEVENTH ANNUAL RAILROAD ENGINEERING CONFERENCE

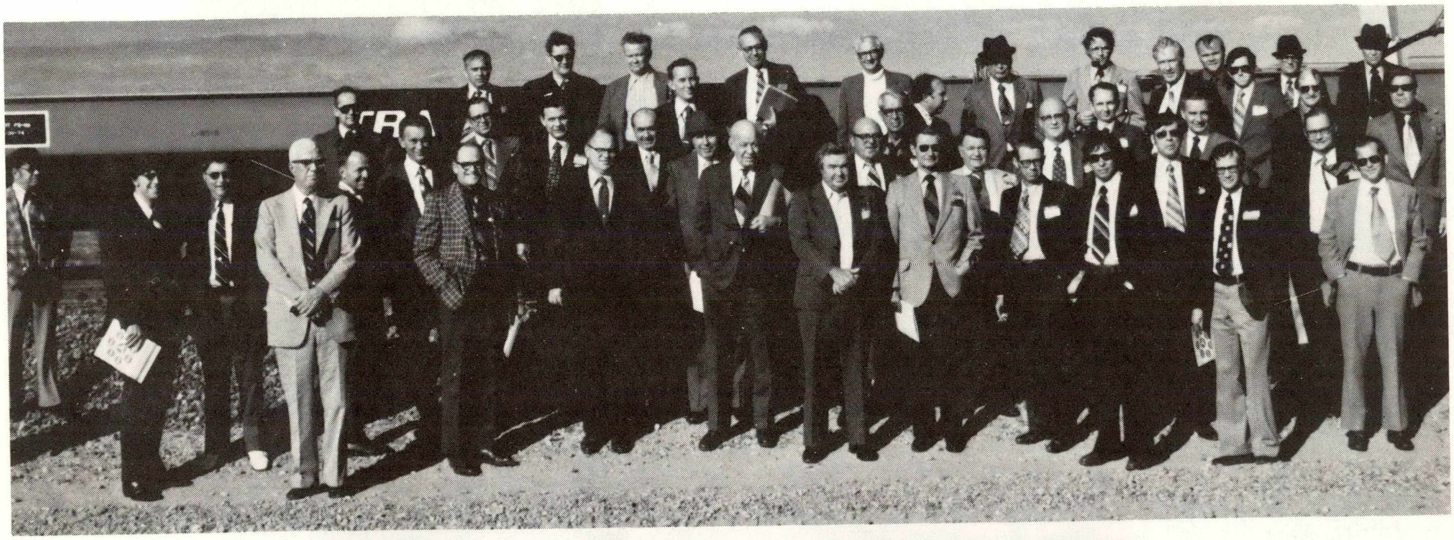
LIST OF DELEGATES IN ATTENDANCE

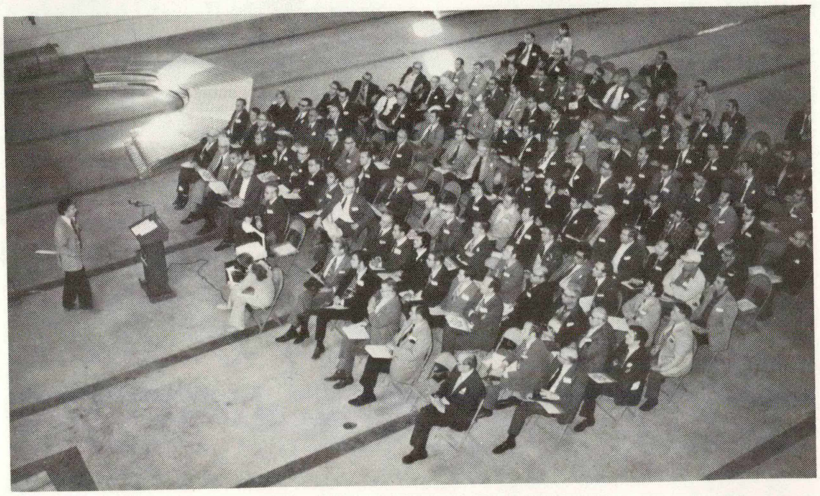
Abramson, J. E.	Shop Supt.	Duluth, Missabe & Iron Range Rwy. Co.
Accord, F. D.	C.M.O.	Union Pacific R.R.
Adams, M. B.	Asst. C.M.O.	Atchinson, Topeka & Sante Fe Rwy. Co.
Addie, A. N.	Mgr.-Adv. Eng.	Electro-Motive Div., G.M.C.
Adler, F. P.	V.P.-Eng.	Pullman Transportation Leasing Co.
Ahnquist, E. T.	President	Pullman-Standard Div., Pullman, Inc.
Aitken, J. A.	V.P.-Eng.	National Steel Car Corp.
Alexandre, D. A.	Dir. Adjunto	Spanish National Railway
Aydelott, G. B.	Chairman/President	Rio Grande Industries
Allen, O. F.	Asst. C.M.O.	Bangor & Aroostook R.R. Co.
Baier, J. H.	Transp. Eng.	P.U.C. of Colorado
Bang, A.	Freight Sys. Program Mgr.	F.R.A.
Baughman, D. L.	Mgr.-Eng.	McConway & Torley
Bellis, M. W.	Mgr.-Loco. Eng.	General Electric Co.
Bernieri, U.	President	Italian State Railways
Bexon, J. H.	Mgr.-Prod. Eng.	DOFASCO
Billingsley, R. H.	Dir.-Eng.	AMCAR Div., A.C.F. Industries, Inc.
Birk, J. N.	Dir.-Eng. Svcs.	Duluth, Missabe & Iron Range Rwy. Co.
Boerke, R. A.	V.P.-Eng.	North American Car Co.
Bridge, P. H.	Eng.-Equip.	British Columbia Railway Co.
Brotherton, R.	Chief Eng.	U.S. Railway Leasing Co.
Bullock, R. L.	Proj. Eng.	Standard Car Truck Co.
Bussman, F. A.	Dist. Sales Mgr.	Dresser T.E.D., Dresser Ind., Inc.
Byrne, R.	Mgr.-Res.	Southern Pacific Transportation Co.
Chinn, R. J.	Mech. Eng.	Illinois-Central-Gulf R.R. Co.
Cleubis de Campos, A.	Tech. Dir.	F.N.V., Brazil
Comiskey, C. E.	Chief Eng.	Hawker-Siddeley, Canada, Ltd.
Cooke, T. S., Jr.	Asst. V.P.	Ortner Freight Car Co.
Cope, G. W.	Dir.-Eng.	Dresser T.E.D., Dresser Ind., Inc.
Cunningham, F. E.	Gen. Supt.-Car Dept.	Chicago & North Western Transportation Co.
Cyr, W. H.	Chief-M.P.&C.E.	Canadian National Rwy. Co.
Danahy, F. A.	Exec. Dir.-Mech. Div.	A.A.R.
Dancu, T. E.	Dir.-Eng.	Thrall Car Manufacturing Co.
Davis, L. D.	V.P.-Prod. Eng./Mfg.	American Steel Foundries
Drinka, J. J.	Asst. C.M.O.	Chicago, Milwaukee, St. Paul & Pacific R.R. Co.
Dunham, M. G.	Eng.-Car Des.	Fruit Growers Express
Dyson, R. L.	Asst. G.M.-Eng.	Union Pacific R.R.
Eck, B. J.	Dir.-Proj. Eng.	Griffin Wheel Co.
Edson, W.	Mechanical Engineer	F.R.A.
Eggleton, P. L.	Dir.-Rwy. Branch	Transport Development Agency, Canada
Elms, J. C.	Director-T.S.C.	D.O.T.
Eyrich, R. R.	C.M.O.	Reading Co.
Fillion, S. H.	Consultant	Dresser T.E.D., Dresser Ind., Inc.
Findling, F. B.	Asst. V.P.-Mech.	Chicago, Rock Island & Pacific R.R. Co.
German, J. G.	Asst. V.P.-Eng.	Missouri Pacific System
Green, J. H.	Asst. Dir.-Oper. Branch	Canadian Transport Commission
Greenfield, L.	Mgr.-Res.	Trailer Train Co.
Greenwood, W. F.	Dir.-Mktg.	Dresser T.E.D., Dresser Ind., Inc.
Guarino, M.	Engineer/Interpreter	F.R.A.
Gutman, P. F., Jr.	V.P.-Eng.	Scullin Steel

Hackney, T. P.	Asst. V.P.-Mech.	Chessie System
Hahn, P.	Exec. V.P.	Southern Iron & Equipment
Harris, W. J.	V.P.-Res. & Test	A.A.R.
Hart, C. E.	Chief Eng.	New York Airbrake Co.
Hawthorne, J. W.	Asst. V.P.-Mech.	Seaboard Coast Line R.R.
Hawthorne, V. T.	Vice President	Keystone Railway Equipment
Hobbs, S. B.	Act. Assoc. Dir.-Plans & Program Dev.-T.S.C.	D.O.T.
Holabeck, G. D.	Chief Eng.	Bethlehem Steel Co.
Housman, R. J.	V.P.-Eng.	Cardwell-Westinghouse
Ingram, J. W.	Administrator	F.R.A.
Johnson, L.	Staff Eng.	F.M.C. Corporation
Johnson, R. E.	Dir.-M.E.	Burlington-Northern
Johnston, W. S.	Gen. Mgr.	Alaska R.R.
Jones, R. D.	Dir.-Sales/Dev.	Canadian Steel Foundries
Jones, W. J.	Eng.-M.W.&S.	Southern Pacific Transportation Co.
Kelsall, J. P.	Mgr.-Oper. Dev.	Canadian Pacific, Ltd.
Kessler, R.	Sec. Rep.	D.O.T.
Kinnecom, P. G.	Supt.-Des. Eng.	Berwick Forge & Fabricating Co.
Knapton, C.	Public Affairs	F.R.A.
Lewis, B. E.	S.M.P.&C.	Duluth, Missabe & Iron Range Rwy. Co.
Lewis, R. G.	Publisher	Railway Age
Lich, R. L.	President	Dresser T.E.D., Dresser Ind., Inc.
Lind, E. F.	Proj. Dir.-Res. Program T/T Dynamics	A.A.R.
Loftis, J. D.	Consultant	
Love, R. B.	Asst. V.P.-Prod. Eng.	American Steel Foundries
Love, W. J.	Chief-Sec. R.R.s	I.C.C.
Lockridge, P.	P.R. Officer-H.S.G.T.C.	F.R.A.
Lovelace, W. S.	Mgr.-Res. & Test	Southern Railway
MacDermott, C. G.	Supt.-Motive Power	Delaware & Hudson R.R.
Manos, W. P.	Vice President	Pullman-Standard Div., Pullman, Inc.
Martin, A. E.	Chief Prod. Eng.	Dresser T.E.D., Dresser Ind., Inc.
McCracken, W. M.	Chief Eng.	Pittsburgh & Lake Erie R.R. Co.
McDaniel, R. R.	Mgr.-M.P.&E.-Car	Norfolk & Western Rwy. Co.
McHenry, F. H.	C.M.O.	Pittsburgh & Lake Erie R.R. Co.
McKee, R. F.	Gen. Mech. & Eng. Officer	Pacific Fruit Express
Melcher, C. H.	Chief Res. Eng.	AMCAR Div., A.C.F. Industries, Inc.
Messimer, R. P.	Dist. Sales Mgr.	Dresser T.E.D., Dresser Ind., Inc.
Minshull, T. R.	Chief Eng.	Greenville Steel Car Co.
Molitoris, M.	Dist. Sales Mgr.	Dresser T.E.D., Dresser Ind., Inc.
Morella, N. A.	Act. Mgr.-Tech. Ctr.	National Castings
Mowatt-Larssen, R.	Office of Safety	F.R.A.
Mustard, R. W.	C.M.O.	Western Pacific R.R. Co.
Oberlechner, G.	Mgr.-Track Recording, Car Div.	A.A.R.
Ojard, D. R.	Elec. Eng.	Duluth, Missabe & Iron Range Rwy. Co.
Olson, C. L.	Supt.-C.D.	Denver & Rio Grande Western
Orr, D. G.	Eng.-Test & Res.	Louisville & Nashville R.R. Co.
Parker, C. W.	Asst. C.M.P.&R.S.	Canadian Pacific, Ltd.
Parker, J. C.	Chief-Equip. Maint.	Seaboard Coast Line R.R.
Pendy, O. R.	Dir.-Equip. Eng.	Penn Central Transportation Co.
Peterson, L. A.	Chief-Rail Sys. Div.	F.R.A.
Phillips, E. A.	Vice President	Union Tank Car Co.
Phipps, G. H.	President	Gerald H. Phipps, Inc.
Pinnes, R. W.	Chief-Multi-Modal Sys. Projects	D.O.T.
Price, A. E.	Chief Eng.	General American Transportation Co.
Prud'Homme, M.	Gen. Eng.-Equip.	S.N.C.F., France
Punwani, S. K.	Sr. Eng.-Res. & Test	A.A.R.

Richter, F.	Publisher	Progressive Railroading
Roberts, L. N.	Eng.-Gr. M.&R.	Buckeye Steel Castings
Roland, R. S.	Asst. G.M.	Pacific Car & Foundry Co.
Rousseau, G. L.	Vice President	Pullman-Standard Div., Pullman, Inc.
Ruprecht, W. J.	Dir.-Eng.	Shippers Car Line Div., A.C.F. Industries, Inc.
Salathe, J., Jr.	Gen. Mgr.	Pacific Car & Foundry Co.
Sayer, G. G.	Dist. Transp. Officer	Canadian Transport Commission
Scheffel, H.	Chief Mech. Eng.	South African Railways
Schoenwald, W. H.	Acct. Exec.	Mandabach & Simms, Inc.
Schrotberger, K.	Office of Research & Experimentation	U.I.C.
Schultz, H. E., Jr.	Asst. Chief Eng.-Staff	Delaware & Hudson R.R.
Seay, O. E.	Mgr.-Eng.	Freightmaster
Shaffer, F. E.	Assoc. Editor	Modern Railroad/Rail Transit
Shannon, W. R.	Vice President	Trailer Train Co.
Sharpe, J. J.	Mech. Eng.	F.R.A.
Siemens, W. H.	Prin. Elec. Eng.	Int'l. Engineering Co., Inc.
Silien, J.	Chief-Rail Prog.	Urban Mass Transportation Administration
Silverberg, B.	Public Affairs	F.R.A.
Smith, L. W.	Mgr.-Eng. & Res. (Retired)	Dresser T.E.D., Dresser Ind., Inc.
Solomon, J. E.	Eng. Grp. Mgr.	Buckeye Steel Castings
Solomonson, G. L.	Vice President	U.S. Railway Leasing Co.
Souter, T. T.	Asst. G.M.	Kansas City-Southern Rwy.
Spaine, L. F.	Eng.-Design	Nat'l. Research Council
Starr, P. D.	C.M.O.	Denver & Rio Grande Western
Stauffer, J.	Director-H.S.G.T.C.	F.R.A.
Stenzinger, R. E.	R.R. Coord.	Int'l. Assoc. Machine & Aerospace Workers
Sundberg, C. O.	President	American Steel Foundries
Sutliff, D.	Res. Eng.-Safety	A.A.R.
Sutton, R. L.	Mech. Supt.-Cars	Union Pacific R.R.
Taliaferro, L. K.	Supt.-Special Equip.	Louisville & Nashville R.R. Co.
Taylor, K.	Traction Eng.	British Railways Board
Taylor, T. M.	Industry Exchange Fellow	F.R.A.
Thomas, W. B.	Vice President	Stucki Co.
Trau, F. G.	Mgr.-Eng.	St. Louis-San Francisco Rwy. Co.
Ullman, K. B.	Office of N.E. Corridor Development	F.R.A.
Upton, F. A.	Asst. V.P.-Mech.	Chicago, Milwaukee, St. Paul & Pacific R.R. Co.
Van Der Sluys, W.	V.P. & G.M.	Pullman-Standard Div., Pullman, Inc.
Wallace, W. D.	Exec. V.P.	W.H. Miner Co.
Ward, E. J.	Act. Assoc. Admin.-Res., Dev. & Demon.	F.R.A.
Weisenbach, C. O.	V.P.-Eng.	New York Airbrake Co.
Widell, G. W.	Exec. Asst.	Chicago, Rock Island & Pacific R.R. Co.
Wiebe, D.	Mgr.-R.&E.	Stucki Co.
Wilhite, D. L.	Dist. Sales Mgr.	Dresser T.E.D., Dresser Ind., Inc.
Wolverton, W. B.	Mech. Eng.	Western Pacific R.R. Co.
Wright, C. D.	V.P.-Eng.	WABCO-WAB







DEPARTMENT OF TRANSPORTATION

FEDERAL RAILROAD ADMINISTRATION