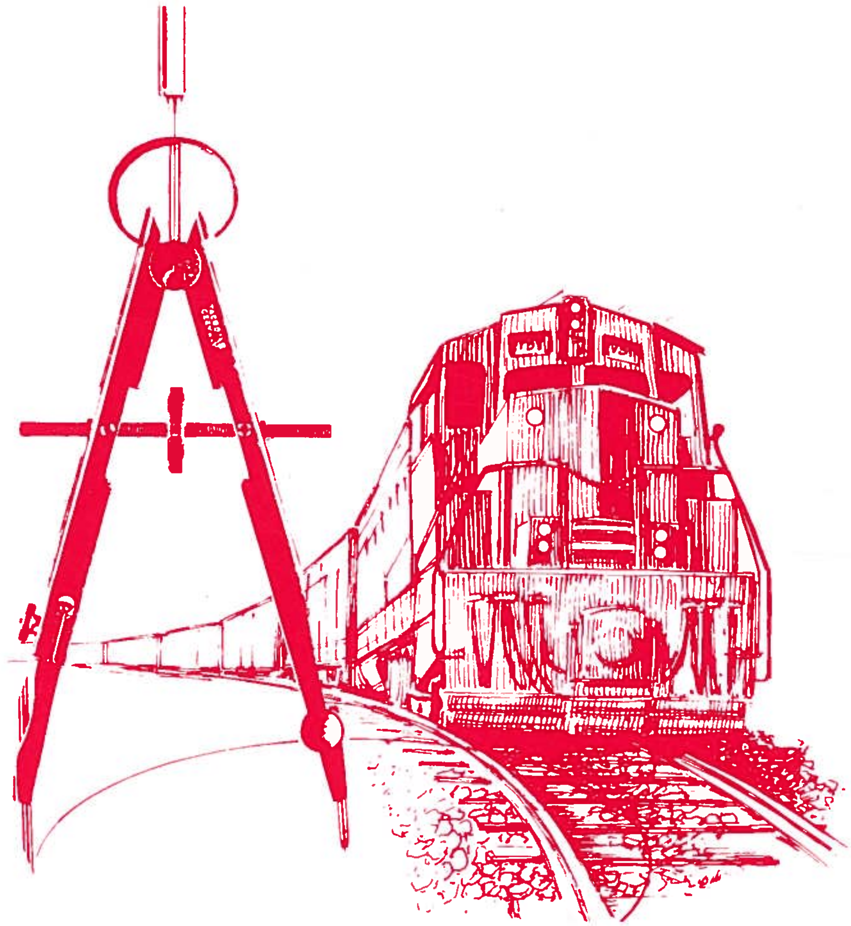
REPORT NO. FRA/ORD - 80/35

15th RAILROAD ENGINEERING CONFERENCE PROCEEDINGS

RAILROAD R & D CHALLENGES OF THE 80's: OPPORTUNITIES & OBSTACLES



June 1980

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16. Abstract

This report constitutes the proceedings of the 15th Railroad Engineering Conference held at TSC on October 21-23, 1979. Conference papers were delivered by various industry and Government officials and centered on three topic areas: The Status of the Northeast Corridor Improvement Project and Passenger R&D; An Overview of Freight Technology Advancements, Obstacles, and Future Opportunities; and Major R&D Opportunities of the 80's. A tour of the Sante Fe-San-Vel concrete crosstie plant in Littleton, Massachusetts, was included as part of the conference program.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
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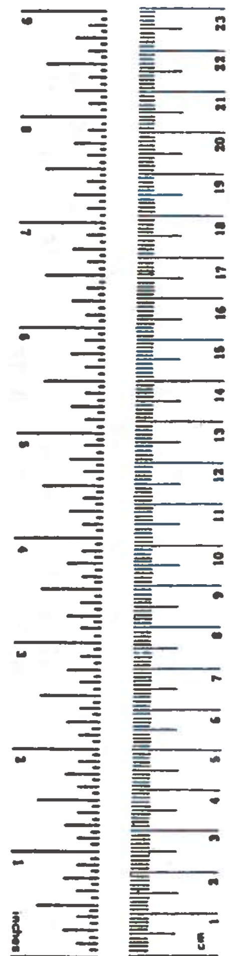

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
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l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
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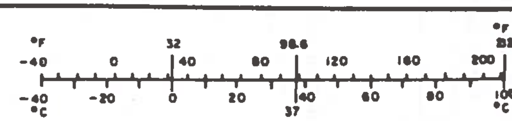
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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MONDAY, OCTOBER 22, 1979

WELCOME

Dr. James Costantino, Director
Transportation Systems Center
RSPA

WELCOME

BY

DR. JAMES COSTANTINO

I want to welcome you to this conference and to the Transportation Systems Center. I want to give a special welcome to our international friends who have joined us here today. Roughly 20 percent of the work that we do here at the Transportation Systems Center is on railroad issues, so we take those issues very seriously. It's a topic of special interest to us, and we are delighted to have this opportunity to host this conference.

This Center is DOT's research, analysis and development facility for the air, rail, auto, energy, highway, pipeline and marine transportation. With an annual budget of almost $80 million and a staff of about 1000 people - 635 Federal employees and the rest made up of support contractors in-house, we carry out major R&D programs for the Office of the Secretary and all of the major agencies within the Department of Transportation. We provide technical and analytical support to the entire department with a professional staff of engineers, scientists, economists, researchers, mathematicians, community planners and so forth. We're engaged currently in about 150 different R&D projects here at TSC.

TSC railroad-related projects cover both the engineering aspects of railroad operation as well as the economic and institutional analysis supporting Federal policy initiatives. Projects span the spectrum from improved track safety standards, track inspection vehicles, yard design techniques, safety improvement options analyses and studies of the Federal impact of initiatives outside the railroad sector.

New and expanding projects at TSC are being implemented with increased contractual support. Today, with a smaller Federal work force than we had 3 or 4 years ago, about 60 percent of our funding goes to private industry and universities compared to about 40 percent 3 years ago. I hope this trend will allay any fears that any of you have that we're trying to compete with private industry. Our interest here is in building a strong government/industry/academic team to address high priority national transportation problems. I hope you all understand that that requires people in the Federal Government smart enough to write specifications to monitor the work and to integrate that work. Our job is to do enough research here at TSC to stay on top of problems, not to compete with you, but to facilitate the diffusion of Federal funds and knowledge into the private sector. I think that our record over the past several years shows that we're making good progress in that area.

This annual conference is sponsored by the Federal Railroad Administration, Office of Research and Development. It will attempt to look into the future of railroad research and development opportunities for the 80's. The spreading awareness and understanding of the railroad's problems of the 70's will hopefully develop into the concensus and action for the 1980's. The modernization and streamlining of the regulatory environment for the railroads has already reached the stage of a specific proposal to Congress. Attempts at equalizing the direct and indirect Federal subsidization of the various freight modes are being actively pursued. If these changes achieve the desired improvement in the financial condition of the railroad industry, a substantially different and better environment may come to pass for railroad R&D in the next decade.

In addition to these activities and the rail projects I mentioned, all of which are worthwhile and offer the promise of significant payoff, particularly in the short term, the potential exists for the railroad industry to develop an expanded role in the nation's long-range energy program. The railroad's energy efficiency in freight transportation is one of their primary advantages over their competitors and yet such an advantage has not been parlayed strongly enough into any substantial participation in Federal energy-related R&D funding. In contrast, the President has set aside $800 million over a 10-year period out of the energy security fund for a new automotive research program, including trucks.

The solution to the energy problem must include, but cannot be limited to the "re-invention" of the automobile. A viable program in the development and adaption of new technology for railroads could provide the balance required to meet our country's energy needs. As a matter of fact, the President's message on science and technology that he sent to the Congress last March said that mission agencies, like the Department of Transportation, should be doing research for their constituents.

I suggest this issue should be foremost in your minds as you participate in the formulation of your respective research and development programs. We at TSC would welcome the opportunity to sit and talk to you about what we're doing for the automotive industry to be supported by the energy security fund.

Again, let me tell you that it's a pleasure to have you here at the Transportation Systems Center. We're delighted with the international participation and with the large turnout. I would like to turn you over to your chairman, Bob Parsons.

James Costantino is Director of the Transportation Systems Center, the U.S. Department of Transportation's multi-modal research, analysis and development facility. He was appointed to this office by the Secretary of Transportation in January 1976.

Prior to his current position, Dr. Costantino served as Executive Assistant to the Deputy Secretary of Transportation in Washington, DC. Before joining DOT, he worked for 9 years with the National Aeronautics and Space Administration as an aerospace engineer in NASA's launch vehicle and propulsion program and as the Director of Technical Support, Office of Manned Space Flight. He also worked as a mechanical engineer with the Federal Aviation Administration.

Dr. Costantino holds a B.S. in Mechanical Engineering from the University of Massachusetts, a Master of Engineering Administration from George Washington University and a Ph.D in Transportation Policy and Economics from American University, Washington, DC.

He is a member of the National and Massachusetts Societies of Professional Engineers, the American Astronautical Society, a member of the Technical Board of the Society of Automotive Engineers, the Advisory Council of Boston State College, Chairman of the Technology Commercialization Committee of the Boston Federal Executive Board and other professional and public service organizations.

CONFERENCE OVERVIEW

Robert E. Parsons, Associate Administrator for R&D
Federal Railroad Administration

CONFERENCE OVERVIEW

BY

ROBERT E. PARSONS

Today, we kick off the 15th Railroad Engineering Conference - "Railroad R&D Challenges of the 80's: Opportunities and Obstacles." But first, before we start with the formal presentation of technical papers, I would like to spend a few minutes assessing the railroad situation of the 70's here in the United States. Looking back one can see that the last 10 years have been pretty rough on our industry. Essentially, private sector passenger rail service has virtually disappeared. We've created Amtrak, and they have the difficult job of turning that situation around. For energy and other social reasons, Amtrak is charged to rejuvenate our passenger network. On the freight side, the nation's private railroad's return on investment has been very poor, reaching as low as 1 percent. The U.S. Government, having recognized that to some extent it has been a contributor of the past railroad woes in this country, has gone through two or three recent legislative attempts which were to assist the railroads. To date, however, we have not found the right answer. Hopefully, the Carter Administration's bill now before the Congress will survive in sufficient form to allow the railroads to free themselves of excessive Government regulation and get their ship in financial shape. Once they are financially healthy, their safety record should also improve.

In the meantime, research activities in this country during the last decade have been considerably expanded in order to help the railroads. As Dr. James Costantino, Director, TSC, has just indicated, we still may not have enough of that going on. Much of this success in railroad R&D can be attributed to Dr. Harris' work in getting the private roads to work together through the AAR research and test programs. We've been fairly fortunate in the Department to steer the resources available to us in a more productive fashion for helping the railroads, suppliers, and our own FRA regulators.

The nature of most of our research is cooperative, as most of you know, and it is basically aimed at providing a knowledge base. We are trying to determine the cause and effect relationships of the different variables available to management so that as a more flexible business environment is created through regulatory reform, those in charge of redirecting this industry will have a feel for the technical consequences of the decisions they are going to be making in the future.

Hopefully, Jack Cann, in Sessions III and IV tomorrow, can focus the discussion as to where the railroads ought to go without excessive continued Government regulation and, thus, overcome some of the obstacles and exploit the opportunities available to them.

Today, Lou Thompson's session will focus attention on the passenger rail side, where there is heavy Government involvement, both through its funding of Amtrak and our own Northeast Corridor Improvement Project. Hopefully, these front-end investments will make the passenger sector also more viable in the future. With that, I would now like to introduce Lou Thompson, Director of FRA's Northeast Corridor Project Office and turn over the morning session to him.

Robert Parsons is the Associate Administrator for Research and Development in the Federal Railroad Administration. He was appointed to this position in March 1975.

Prior to his current position, Mr. Parsons served as Director of the R&D Plans & Resources Program for OST. Before joining OST, he worked from 1964-1971 for the Federal Aviation Administration, serving as an SST Value Engineering Specialist in 1964, the Acting Chief, Analysis & Control Division, from 1964-1966, and as Chief, Analysis & Control Division, from 1966-1969. In 1969, Mr. Parsons was appointed Acting Deputy Director, Office of SST Development, and served in that capacity until 1971.

Mr. Parsons holds a B.S. in Mechanical Engineering from the University of Cincinnati, and Masters in Mechanical Engineering for the Drexel Institute of Technology.

Among his recognitions and awards, Mr. Parsons has received the Distinguished Engineering Alumnus Award from the University of Cincinnati, the Secretary of Transportation's Award, and the Department of Transportation's Meritorious Achievement Award. He was also an Arthur S. Flemming Semifinalist.

SESSION I: THE STATUS OF NORTHEAST CORRIDOR IMPROVEMENT PROJECT AND PASSENGER R&D

Chairman: Louis S. Thompson, Director
Northeast Corridor Project
Federal Railroad Administration

INTRODUCTORY REMARKS ON THE NORTHEAST CORRIDOR PROJECT

BY

LOUIS S. THOMPSON

Holding a session this morning that deals with both the Northeast Corridor Improvement Project (NECIP) and rail passenger R&D points up the close relationships that have developed in FRA within the past few years between the offices involved in all aspects of rail passenger service. This integration of effort has been advanced significantly within the past year with the proposed reorganization and merger of the Amtrak monitoring function within the Northeast Corridor Project, and the passage of the Surface Transportation Act of 1979, PL 95-421, which authorizes the development of equipment compatible with the improvements being made under the NECIP. Both of these moves have strengthened the ability of the FRA to treat nationwide rail passenger requirements as well as meet our obligation to carry out specific projects such as the NECIP in a total system context.

Although not always fully appreciated, an intimate relationship exists between R&D and understanding the rail passenger market and its needs. Of primary concern are the requirements for reliable, attractive, comfortable service; demand-generating speed; and safety in a complex, if not hostile, traffic environment. Many of these needs will not require extensive, if any, research and development, but will be satisfied by sound engineering using proven advanced technology. As we on the NECIP have found, it is difficult to adopt an R&D oriented viewpoint where a large investment in fixed plant exists. The papers which follow will deal for the most part with applications of state-of-the-art technology to the NECIP and other passenger systems.

I hope this does not give the impression that the NECIP is a simple prosaic project. It is probably, by far, the most complex railroad development ever undertaken; not only involving extensive reconstruction and upgrading of physical plant while it is in operation, but done under the pressures of conflicting interests and tight budgets. The NECIP is not just a glorified track maintenance program. It encompasses a variety of activities in keeping with the total system consideration being given to the project. This diversity ranges from the analysis of future demand and socioeconomic environments to automated track-laying of concrete ties, and from training of welders to replacement of major moveable bridges, a blend of abstract and concrete disciplines. As you can appreciate, we will only be able to offer a brief overview and touch on a few of the many aspects of the project this morning.

The NECIP was initiated in 1976 with passage of the Railroad Revitalization and Regulatory Reform Act of 1976, commonly known as the 4R Act. It's goals were: a 2-hour 40-minute trip time between Washington and New York; a 3-hour, 40-minute trip time between New York and Boston; $1.25 billion in project costs; and 5 years completion time. The project has seen many changes in direction during the past 3-1/2 years and a great part of that time has been devoted to engineering and design with the primary construction work during this period being performed by Amtrak. Although productivity has not been up to initial expectations, improvements have been steady and forecasts now take into account the realities of working on a very complex operating railroad. The cost per unit of production has decreased for major activities such as operation of the track-laying system, installation of CWR, joint elimination, ballast cleaning, and tie and surfacing. Although some criticism has been raised about productivity, the evidence so far from this year's production shows further improvements. In 1977, for example, we (and Amtrak) completed about 70 percent of the planned work for about 148 percent of the budget, a cost efficiency of 47 percent. In 1978 this rose to 69 percent, and as of October 1, 1979, this year's performance showed a cost efficiency of 106 percent. Our projections show, however, that for 1979 overall we should achieve a cost efficiency of about 93 percent. These production efficiency measures deal primarily with track-oriented work. Other major areas being covered include:

1) Bridges - Amtrak's bridge program began in 1977. Through 1979, 100 bridges have been scheduled for rehabilitation and repairs. To date Amtrak has completed 42, has 23 underway, and has not yet begun construction on 35 bridges. Rehabilitation of the Connecticut River Bridge will start soon under an FRA contract.

2) Communications and Signaling - Amtrak has cleared 1323 man holes to enable installation of the new signaling system. The reverse signal system has been installed between Bell and Landlith, Wilmington, Delaware. Additional work includes installation of detectors and switches, rehabilitation of the interim signal system, and installation of communications and fire alarms.

3) Electrification - Amtrak's electric traction program this year includes the installation of loop hangers in support of the catenary, the checkup and correction of wire tension, the rehabilitation of signal cut sections, and the repair of worn trolley wire.

4) Station - Amtrak's station program includes the replacement of the roof at Wilmington Station, renovation of the chandeliers and repair of the parapets at 30th Street Station in Philadelphia, and platform painting at Newark Station. Other construction includes replacement of the roofs at Boston South, Baltimore, and New Haven stations, and installation of additional escalators at Newark Station.

5) Grade Crossing - Of the 49 public crossing eliminations involved, 9 have been completed, 7 are under construction, 18 are in final design, and 15 are in the preliminary engineering stage.

If I could leave you with one thought from this initial overview, I would stress the need to avoid viewing the NECIP as purely a railroad engineering problem. Technology is important, of course: that is the reason we are here today. The NECIP does not face technological challenges. In fact, as some of the following speakers will discuss, NECIP is very much in the forefront of United States rail engineering. Our use of concrete ties, the Track Laying System, two panel exchange track or interlocking replacement systems, a dual frequency cab signal with automatic speed control, perhaps a fiber optic communications system - all of these establish a real engineering leadership role for the NECIP. Despite some of our well-reported false starts, I am firmly convinced the day will come when Amtrak, FRA, or DCP experts will be consulting with other United States railroads on the application of these techniques.

But little of this would impress Buck Rogers. Most of these innovations, alone, are good, solid, well-proven industrial engineering. The real challenge is organization, and I mean organization on two levels. The first challenge, of course, is how to fit all these pieces together to make a coherent program. DeLeuw, Cather/Parsons as consultants to FRA have been instrumental in helping FRA and Amtrak keep technology in balance across all the program elements. I would also like to mention the role played by the assistance team from the Japanese National Railways as well as our work with British Rail.

The second organizational challenge is unique to the NECIP and is rooted in the diversity of interests. We traverse eight states and the District of Columbia, each with slightly different objectives. The Corridor has five different owners. It serves Amtrak, seven commuter authorities, and three freight railroads of which Conrail is the largest. Measured by gross tons, about two-thirds of the Corridor traffic is freight - but measured by trains, two-thirds is passenger traffic. Measuring passengers only, about two-thirds of Corridor traffic is commuters, while two-thirds of passenger revenue is Amtrak intercity.

This is not a simple beast we have because of the complexity of purposes and users. Technology, or management, which might be apropos for a single user can be totally unsuitable for others. Clearly, our design or methods would change dramatically if freight, or commuters, were not involved.

The outcome of all of this is technical and political balance and compromise. I think it makes the NECIP the most fascinating and difficult engineering and management challenge in the United States railroading industry today. I know it makes the discussions of the ensuing speakers more interesting. I hope you enjoy them.

Louis S. Thompson, an experienced transportation budget and policy planning analyst, was appointed Director of the U.S. Department of Transportation's Northeast Corridor railroad improvement project May 1978.

Prior to joining DOT, Mr. Thompson was a senior analyst with the Washington consulting firm of Richard J. Barber Associates, Inc., consulting on railroad matters of interest to the Association of American Railroads, Federal Railroad Administration, Senate Commerce Committee, Burlington Northern, Atchison, Topeka and Santa Fe, Southern Pacific, Missouri Pacific, Chesapeake and Ohio, Baltimore and Ohio, Southern, Chicago, Rock Island and Pacific, among others.

Mr. Thompson previously worked for DOT from 1968 to 1973 as one of the senior planning analysts in the policy and budget offices involved with the establishment of Amtrak and the writing of the Regional Rail Reorganization Act of 1973 (3-R Act), as well as review of early Northeast Corridor studies.

Mr. Thompson, as project engineer and manager for the Badger Co., Inc. in Cambridge, Massachusetts, the Hague, the Netherlands, and Antwerp, Belgium from 1965 to 1968, supervised the design, procurement, and construction of large chemical plants.

Mr. Thompson received his BS in engineering from the Massachusetts Institute of Technology in Cambridge, Massachusetts and his MBA from Harfard University. Mr. Thompson is married, has two children, and resides in Washington, D.C.

AN OVERVIEW OF THE NORTHEAST CORRIDOR IMPROVEMENT PROJECT

BY

RICHARD P. HOWELL

Upgrading the Northeast Corridor (NEC) rail system is the most comprehensive railroad program ever attempted in the United States. The Northeast Corridor Improvement Project (NECIP) will provide the U.S. with its first facility-integrated high-speed intercity rail passenger service.

In the last decade, many studies have been made concerning transportation problems in the NEC region. Rail travel is considered a viable solution to some of the problems; therefore, the NECIP has been implemented. This overview of the events leading to the project and the complexities of the project itself will illustrate the magnitude of this monumental undertaking.

EVENTS LEADING TO THE NECIP

The NEC is the 456-mile railroad system between Boston, Massachusetts, and Washington, D.C., serving the most densely populated area in the United States. Approximately 20 percent of the nation's population is concentrated here, on 2 percent of the nation's land.

This great concentration of people has made transportation a major concern in the NEC region. The highways and air corridors have become increasingly congested, resulting in increased travel time and decreased reliability. Rail travel is the only transportation mode presently under-utilized.

Recognizing the potential benefits of improved passenger rail service on the Corridor, a Northeast Corridor Project was established in 1963 by the Department of Commerce. In 1965, the High-Speed Ground Transportation Act was passed authorizing the Secretary of Commerce to sponsor demonstration projects to determine the contributions high-speed rail transportation could make toward more efficient and economical intercity transportation systems. The responsibility for the high-speed demonstration projects was transferred to the Federal Railroad Administration of the Department of Transportation when it was established on April 1, 1967.

Two demonstration projects were developed on the Corridor in response to the 1965 Act. Between Washington and New York, high-speed, self-propelled, electric passenger cars (Metroliners) were put into operation. Experimental service using new gas turbine-powered trains (Turbotrains) was provided between New York and Boston. These two projects rekindled interest in rail passenger travel. Increased patronage proved that given clean, comfortable, and fast trains, people would again utilize the service.

In 1971, the Secretary of Transportation issued a report that recommended implementing improved high-speed rail service with nonstop running times of about 2 hours between Washington and New York and 2 hours and 45 minutes between New York and Boston.

The Regional Rail Reorganization Act of 1973 (3R Act) was indicative of Congress' concern over the railroads. This act required the Department of Transportation to improve high-speed rail passenger service on the NEC and authorized preliminary engineering work. The United States Railway Association was established by the 3R Act, and in July 1975, the Association expressed support of the recommendations made by the Secretary of Transportation in 1971.

Based on the planning efforts specified in the 1973 act, the Department of Transportation issued a report in September 1976 making further recommendations for improvements to the NEC. Recommended trip times in this report were 2 hours and 30 minutes between Washington and New York and 3 hours between New York and Boston.

The 4R Act

The culmination of these years of studies and recommendations came in the form of the Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act). This act called for implementation of the Northeast Corridor Improvement Project (NECIP) and required that within 5 years of the date of enactment (February 5, 1976), regularly scheduled and dependable 120 mph rail passenger service be established on the NEC. The maximum trip times between Washington and New York and New York and Boston were specified as 2 hours and 40 minutes and 3 hours and 40 minutes, respectively, including appropriate intermediate stops.

Other requirements of the 4R Act include improving facilities on feeder line routes to make them compatible with improved high-speed service on the Corridor mainline; improving nonoperational portions of stations; ensuring that improvements are compatible with future improvements in service levels; expanding the use of rail commuter services, rapid rail transit, and local public transportation; and maintaining an improved rail freight service.

Organizational Structure

Based on this legislation, the NECIP was launched by the Department of Transportation through the Federal Railroad Administration (FRA). A Northeast Corridor Project office (NECP), established by the FRA to execute the project, is responsible for project direction and control, congressional reporting, intergovernmental coordination, system specifications and standards, and program definition and development planning.

In August of 1976, the FRA signed a contract with Amtrak under which Amtrak has a dual role. As owner of most of the NEC and operator of the intercity passenger service on the Corridor, Amtrak participates in program and individual project development, and provides the force account construction management and labor for much of the work on the NECIP.

Organizational plans for the NECIP also called for an architect-engineer (A-E) contractor to assist in the execution of the project. The selected joint venture, De Leuw, Cather/Parsons, (DCP) provides systems engineering functions to ensure that the system design specifications result in a completed system achieving the legislated goals, and extends the planning and engineering through detail final design by A-E subcontractors. Work packages can then be established for construction activities of Amtrak work forces and general contractors.

DCP also supervises and inspects construction activities and maintains liaison with various jurisdictional bodies to secure approvals for various phases of the overall program effort. Twelve other firms having architectural, engineering, design, or management expertise are associated with the joint venture.

In January 1978, primarily because of increasing concern expressed by Corridor commuter and freight users, former Secretary of Transportation Brock Adams called for reexamination of the project goals around four main issues: Amtrak service and operations, Amtrak equipment, commuter and freight coordination, and a realistic scope of work, budget, and schedule for project implementation.

The results of this Department of Transportation Northeast Corridor Improvement Project Redirection Study (published in January 1979) concluded that the NECIP could not be accomplished as it was originally conceived within the present budget, and that additional time and money would be required to satisfy the goals of the 4R Act. The study recommended that Congress extend the project completion time to 1984, and that an additional $654 million be authorized for the project. While Congress is currently considering this request, total project implementation is directed towards the $2.404 billion scope.

PROJECT FEATURES

The overall project is broken down into 11 major subsystems. Track improvements, curve realignments, and bridge and tunnel work account for more than half the total program cost. A detailing of the scope of improvements in each subsystem follows.

Route Realignments

Each of the 415 curves between Washington and Boston has been evaluated by project engineers according to degree of curvature, length of spiral, amount of superelevation, existing speed limit, proposed design speed, and impact on train schedules. Between 30 and 40 curves were selected for improvement to provide higher speeds and increased passenger comfort.

Route modifications will be slight in most cases; however, a few curves shift up to 100 feet. Tracks will be shifted to lengthen the spiral transition between curved and tangent sections, and rail superelevation will be adjusted to improve track speed. Fifty-five interlockings will be reconfigured, and switch and signaling improvements will be interfaced accordingly, to provide greater operational flexibility and higher speeds. These improvements along with the curve realignments and improved track structure provide for the trip-time goal and reliability achievements.

Track Structures

The track improvements are perhaps the most important and certainly the most costly of the construction tasks. A major decision affecting work in this area concerned the type of tie to be used. Extensive studies and evaluations were conducted and it was decided that concrete ties would be used on about 420 track-miles in designated high-speed areas. The 800-pound ties are being built according to rigorous specifications. Also, more than 600 miles of conventional wood ties are to be installed.

Innovative use of concrete ties on the Corridor is directly related to another major "first" for American railroading. A mechanized track-laying system (TLS) is being used to install the ties and continuous welded rail. The TLS is a system of machines that can replace all ties and both rails in one pass. The main feature of the system is a machine with an overhead gantry and conveyor system that shuttles new ties to and old ties from the roadbed. The front wheels of the track-laying machine ride on the old track while the rear wheels travel on the newly installed track. About 230 people are required to operate the TLS. As of June 1979, 554 ties were being laid per productive hour; the average being attained was about 6/10 of 1 mile of track per day.

Other work in the track structures effort includes undercutting of 600 miles of designated or alternate track, installation of approximately 500 miles of continuous welded rail, improvements to existing interlockings, and tunnel trackwork. More than 400 worn turnouts will be repaired or replaced to promote fast, safe train operations. Improvements to track geometry - alignment, gauge, and cross level — are essential to the track program.

During the 1979 construction season, interlocking reconfiguration and many rehabilitations will be accomplished through the installation of preconstructed switch and turnout panels. For this innovative procedure, the work force is organized so that in a minimum interval of track usage, the old turnout is removed, old ballast excavated, new ballast dumped and graded, and the new switch and frog panels placed and connected. The old and newly built panels are handled by new self-propelled exchange equipment.

Use of the TLS, panel exchange machinery, and mechanized undercutting are new techniques adopted to overcome the most difficult factor of the project: construction under traffic conditions of the busiest intercity, commuter, and freight train route in North America.

Bridges

There are 1300 undergrade and overhead bridges along the NEC, some of which were constructed in the late 1800's. Major improvements are slated for many undergrade bridges. Several are scheduled for complete replacement and more than 200 will be rehabilitated. Overhead bridges are to be improved only as required to provide increased clearance for the upgraded catenary system or to accommodate proposed curve realignments.

Three movable bridges will be completely replaced. Ten major drawbridges are scheduled for major strengthening, and extensive work will be done on the mechanical and electrical opening systems to improve their reliability and maintainability.

Tunnels

Operations through the New York area Corridor tunnels are to be improved through total track structure replacement and reestablishing efficient drainage. Moisture problems in the tunnel track structure have impacted tunnel signal systems over the past decade. A clean, well-drained, and stable track structure will eliminate these problems. Other improvements in the East and North River Tunnels will include ventilation, structural repairs, and fire protection.

In the Baltimore area, intercity passenger traffic is impacted because the B&P Tunnel structure does not provide the necessary clearance for operational flexibility of freight trains. Additionally, the tunnel track and drainage system conditions impact optimized train speed and other operating conditions. An extensive rehabilitation project utilizing newer polymer-concretes and direct-fixation track concepts is programmed to rectify this latter situation.

Electrification

Electrification ranks third in terms of cost. The program calls for the entire NEC to be electrified which requires new electrification to be installed between New Haven and Boston.

New substations are being designed and procurement is complete on traction 25 kV transformers and switchgear. The new substations, switching stations, and transmission lines will be linked to commercial power sources. North of New Haven, the substations will be 14 to 18 miles apart, with switching stations in between. Low-profile catenary poles about half the size of the existing ones in the south Corridor will be erected. The poles will have cantilever wire supports with galvanized fittings and components to resist the corrosion damages caused by salt-water proximity.

South of New Rochelle, the supports, transmission systems, power-supply substations, wire arrangements, and insulators of the present catenary system will be rehabilitated.

Signaling and Traffic Control

The entire signal system between Washington and Boston will either be completely replaced or rehabilitated. New features include the installation of centralized traffic control (CTC) systems between Washington and Ragan interlocking near Wilmington, and between New Haven and Boston, with corresponding control centers in Philadelphia and New Haven. The computer-operated control centers will provide for remote control of switches and signals, and will be equipped with CRT displays showing the location of all trains in their territory. These CTC systems will improve dispatching efficiency and reduce operating costs.

All designated tracks will have reverse signaling. This, in conjunction with new interlocking configurations, will increase traffic capacity and operating flexibility.

Onboard cab signals will be supplemented by wayside signals located at the approach to and at interlocking signals located at the approach to the engineer at all times providing the appropriate authorized speed regardless of varying weather conditions and track visibility.

Automatic train control (ATC) will also be an integral part of the onboard signal system. When a cab signal aspect changes to a more restrictive speed, an audible signal is heard in the cab. If the engineer fails to acknowledge the warning signal within 5 seconds, the train speed is reduced automatically.

Also included in the signaling program is replacement of cables and installation, modification, and general repairs of switch machines, signal masts, dragging equipment detectors, switch heaters, and hot journal detectors.

A $77.9 million signaling contract has recently been signed with the General Railway Signal Company of Rochester, New York, to design and furnish the hardware for the systems between Washington and New York. This is the largest such contract let to date on the Corridor project.

Communications

A systemwide communications backbone transmission network is to be installed. The leading technology candidate is a fiber optic cable system with electronic repeaters. Proposals will soon be received by Amtrak from several common carriers to install such a system. Electrification supervisory control, centralized traffic control, security surveillance, station operations, and maintenance communication will all utilize this communications system.

A new telephone system will enhance exchange of information throughout the Corridor facilities. It will be linked to the off-Corridor public telephone network. There will also be three radio systems functioning on assigned VHF frequencies. One will be used by police and security personnel, one by maintenance forces, and the third by train control and vehicle operators.

Grade Crossing Elimination

At-grade highway crossings are being eliminated along the Corridor, with the exception of a few in Connecticut. These grade crossings pose a safety hazard in populated areas of high-speed train operations. Elimination of grade crossings will be accomplished through acquisition of property and construction of grade separations. The states in conjunction with the Federal Highway Administration will handle most of this work.

Stations

The stations projects include improvements and rehabilitation work at 13 existing stations, completion of a joint Washington Metro-Amtrak station, and construction of one new station. Improvements directly related to intercity passenger travel, such as work on building structures and utilities, waiting areas, platforms, and escalators will be fully funded by the Federal Government. The cost of nonoperational improvements, such as commuter ticketing facilities, station access and site work, parking, and landscaping, will be shared on a 50-50 basis by the Federal Government and state and local sources.

Seven of the Corridor stations are included on the National Register of Historic Places. An effort is therefore being made in the architectural planning for stations to ensure that exterior and structural improvements are consonant with the historical character of the stations.

Service Facilities

Two basic types of maintenance activities are required on the Corridor: maintenance of fixed plant (track, signals, catenary, and bridges) and maintenance of rolling stock. Five maintenance-of-way (MOW) bases and five maintenance-of-equipment facilities will be provided to accommodate these needs.

Complete MOW bases are to be built at Odenton and Perryville, Maryland; Philadelphia; Adams, New Jersey; and Providence, Rhode Island. These bases will also serve as staging areas for NECIP construction crews. A Readville, Massachusetts MOW site has been equipped with a self-powered gantry crane that loads concrete ties onto tie cars for transportation to sites where they will be installed by the TLS.

The maintenance-of-equipment facilities are to be built at Ivy City Yard, Washington; Wilmington; Philadelphia; will provide services ranging from locomotive servicing and train washing to wheel truing and change-out of defective components. All of the facilities will be new except the Wilmington complex.

Fencing and Barriers

Fencing and barriers will be installed at overhead bridges and along selected portions of the right-of-way. This program will reduce train-delays due to encroachment of people, animals, and foreign objects; will protect the public; and will deter vandalism and theft.

Safety-related fencing is to be funded entirely by the Federal Government from the NECIP budget. Other fencing may be provided if state and local authorities match Federal funds dollar for dollar. This participation is minimal in most states; however, the State of Massachusetts is sharing in a fencing program throughout its entire Corridor right-of-way.

PROGRESS

Since the fall of 1976, most of the FRA and DCP resources have been focused on general and financial program management, systems planning and engineering, scope of work definition, project cost estimating and scheduling, and final design management and review. Involved in this latter endeavor are 79 design subcontracts involving 185 A-E firms who will produce in excess of 100,000 plan sheets through the completion of the engineering and design phase. Specification preparation and procurement of over $100 million worth of new track, bridge, signal, and electrification equipment for use by Amtrak forces has also been accomplished.

Amtrack, while participating in much of the above work, has directed its primary effort toward trackwork construction during the 1977, 1978, and this year's season. During this interval, the following selected highlighted items of trackwork have been accomplished:

1) 103 miles of concrete ties installed between New Haven and Boston
2) 212 miles of continuous welded rail laid
3) 541,000 conventional wood ties installed
4) 7000 joints eliminated through field welding
5) 70 undergrade bridges repaired.

In 1980 and 1981, the TLS will be working in the New York to Washington Corridor, almost entirely in 3- and 4-track territory. During these work seasons, interlocking reconfigurations also will be intensively progressed in this area.

Although few FRA contracts have been let to date, many more will be starting up in the 1980 construction season and will further increase in frequency through 1981 and 1982 as the final designs for right-of-way improvements, interlocking reconfigurations, catenary, and signal system installations are completed.

At the peak of construction, scheduled for 1981-1982, there will be a force estimated at around 4000 Amtrak and contractor employees working on the NECIP. Planned improvements, in excess of $400 million annually, will be installed during this peak interval.

CONCLUSION

Many advanced systems and computerized techniques are being utilized in the planning, engineering, and construction of the Corridor. The latest tested technologies are currently being designed into the various subsystems. Most of these innovations have resulted from rail-oriented R&D programs, and the application of these new technologies will provide the Northeast Corridor Improvement Project with the best of reliable, maintainable, and safe rail facilities.

EQUIPMENT AND TECHNIQUES FOR TRACK LAYING IN THE NORTHEAST CORRIDOR IMPROVEMENT PROJECT

BY

DAVID S. GEDNEY

INTRODUCTION

Under the Railroad Revitalization and Regulatory Reform (4R) Act of 1976, the Secretary of Transportation was authorized to undertake the Northeast Corridor Improvement Project (NECIP). The project will implement the improvements necessary to provide "regularly scheduled and dependable intercity rail passenger service." The Act states that within 5 years of enactment, operating schedules of 3 hours and 40 minutes between Boston and New York and 2 hours and 40 minutes between New York and Washington, DC, shall be established. Achievement of these schedules when coupled with the Corridor's physical characteristics and the time loss associated with station stops, requires a peak operating speed of 120 mph over approximately 30 percent of the 455-mile long route. Clearly, the creation of a high quality, stable and low maintenance track structure is essential to realizing the NECIP goals.

NECIP TRACK PROGRAM

The NECIP track program addresses both the elimination of deferred maintenance which has plagued the Corridor for many years, and the accomplishment of the improvements necessary to provide a 120 mph track structure. The major elements of this track program and the approximate quantities involved are shown in Table 1. It should be noted here that, although enacted as a 5-year project with a projected end date of February, 1981, the first working season was devoted to identification of the necessary improvements, preparation of the overall track program, and the procurement of the necessary track machinery and materials, which Amtrak lacked when they assumed ownership of the Corridor. Thus, the track program became a 4-year effort with a total of approximately 22 months of available working season in which to complete the work.

Completion of this ambitious track program in such a short period of time, concurrently with other NECIP improvements such as bridge, signaling and electrification work, while still maintaining acceptable train service, represented a significant challenge. It became apparent at the outset, that the NECIP must adopt track renewal techniques which combined several operations into one and minimized track outages. The gamut of international track renewal techniques was examined, both through reports and first-hand observations under actual operating conditions. With rail, tie and turnout renewal

TABLE 1. 4-YEAR TRACK PROGRAM (APPROXIMATE QUANTITIES)

- INSTALL 1,100,000 CONCRETE TIES
- INSTALL 765,000 WOOD TIES
- INSTALL 500 TRACK MILES CWR (NEW & RELAY)
- RENEW OR REHABILITATE 640 TURNOUTS
- UNDERCUT 960 TRACK MILES
- SURFACE 1020 MILES OF TRACK
- CLEAN 235 TRACK MILES OF BALLAST SHOULDERS
- SURFACE GRIND 1120 TRACK MILES OF RAIL
- INSTALL 1300 BONDED INSULATED JOINTS
- CONSTRUCT 155 MILES OF DITCHES

representing a major portion of the program, attention was focused on equipment and techniques available for these operations. Several types of mechanized systems which combine rail and tie renewal into one operation were identified. Additionally, other mechanized systems for turnout renewal were also identified. Each system or device was evaluated for applicability to the Northeast Corridor Improvement Project on the basis of operating principle, amount and type of work performed within the machine, degree of automation and required support functions. The following describes the systems selected for track laying and for turnout renewal.

TRACK LAYING SYSTEM

The term "track laying system," (TLS) as used on the Northeast Corridor Improvement Project encompasses all of the operations and equipment necessary for the transition from an existing track in-place to a completely renewed track in-place. Specific TLS operations include improving track drainage, tie and rail renewal, ballast cleaning, and surfacing and lining the track. The order in which these operations are performed is shown in Figure 1. (Circled numbers refer to operations listed in Table 3.)

Those items of track work identified in the track program which could be performed simultaneously by the TLS were assembled into a TLS Program, shown in Table 2. Given the 22 months

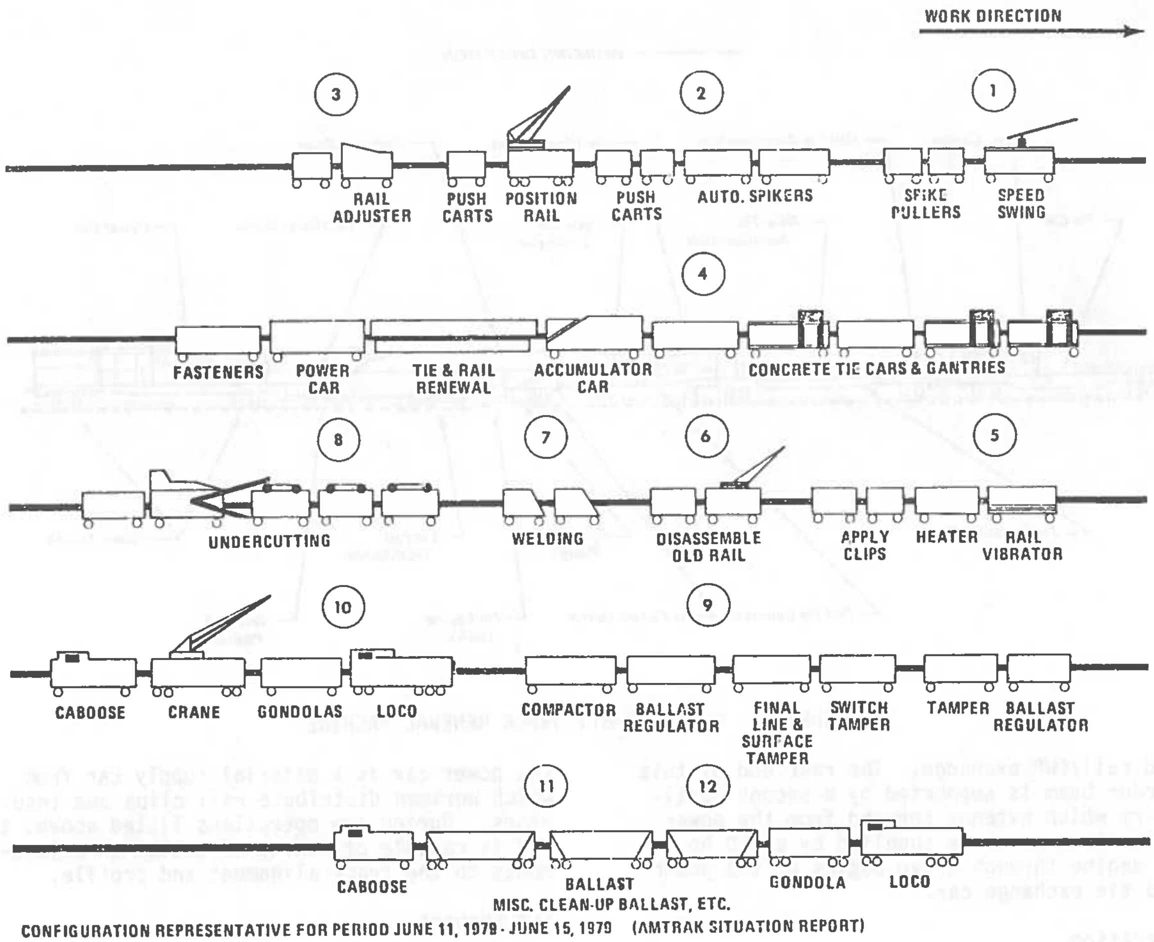

FIGURE 1. TLS COMPONENT OPERATIONS

of available working season, the objective was to average 1 mile of track rehabilitation per day.

TABLE 2. TLS PROGRAM

- RENEW 417 MILES OF TRACK
- INSTALL 1.1 MILLION CONCRETE TIES
- LAY 233 TRACK MILES OF CWR (USE EXISTING CWR FOR 184 MILES)
- CLEAN 2.52 MILLION CUBIC YARDS OF BALLAST
- ADD 420,000 CUBIC YARDS OF NEW BALLAST
- REMOVE 1.3 MILLION WOOD TIES
- REMOVE 63,250 39-FOOT RAILS
- REMOVE 35,500 TONS OTM (OTHER TRACK MATERIAL)

Track Laying Machine

The track laying machine (TLM) is the key component in the overall TLS equipment consist. The piece of equipment chosen to perform this function was the P-811 Track Renewal Machine manufactured by Canron Rail Group, Columbia, South Carolina. This machine weighs 346,000 lbs, is 221 feet 9 inches long, with a width of 10 feet 4 inches and a height of 13 feet 1 inch. The TLM performs the functions of replacing the old wood ties and rail with new concrete ties and continuous welded rail (CWR).

Each concrete tie weighs approximately 760 lbs, and is of the RT 7SS2 design. This is a third generation concrete tie, designed and produced for the Northeast Corridor Improvement Project by Sante Fe/San Vel, a joint venture of Santa Fe Pomeroy of Petaluma, California, and San-Vel Concrete Industries of Littleton, Massachusetts. The tie is 8 feet 6 inches long with a bottom width of 11 inches, top width of 9 inches, maximum height of 10 inches and minimum height of 7 inches. The new CWR being installed between New Haven and Boston is 132 RE rail. However, 140 RE rail will be installed at all other locations.

The main elements of the P-811 are shown on Figure 2 and include the tie exchange car, with a cantilever arm to the rear, connected to a 72-foot renewal beam which supports the operational mechanisms for wood tie pick-up, ballast plowing and roadbed compaction, concrete tie placement

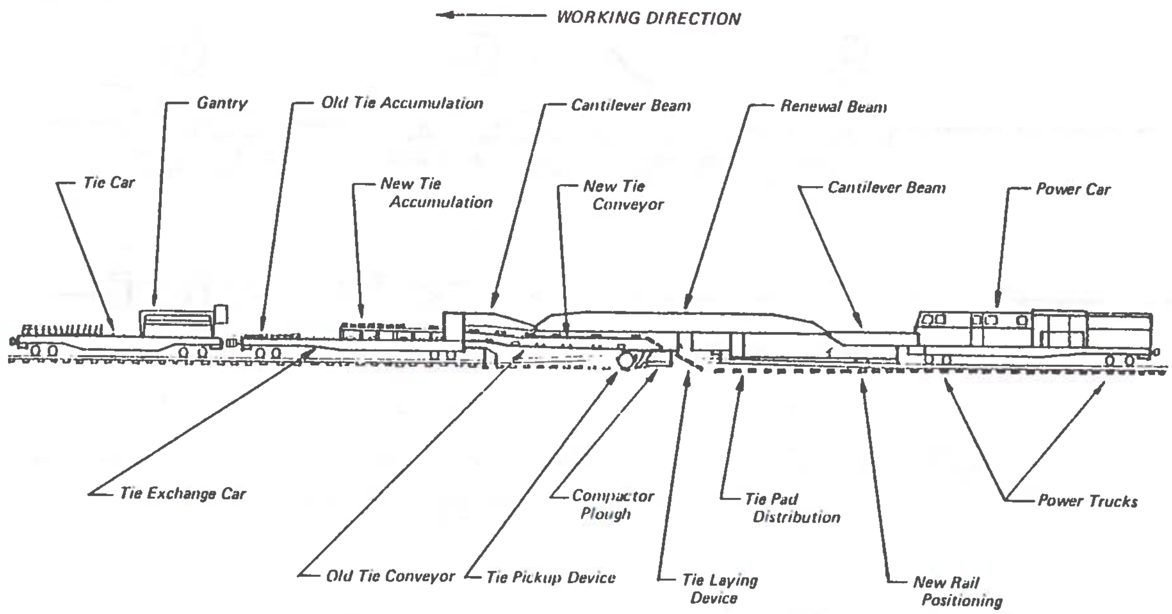

FIGURE 2. CANRON P-811 TRACK RENEWAL MACHINE

and old rail/CWR exchange. The rear end of this box girder beam is supported by a second cantilever arm which extends forward from the power car. Tractive power is supplied by a 420 hp diesel engine through drive bogies on the power car and tie exchange car.

TLM Operation

During operation, approximately 15 tie cars are pushed ahead of the TLM carrying enough concrete ties to cover 1 mile of track. Each tie car carries 168 concrete ties. Riding on side rails attached to the tie cars are three traveling gantry cranes which continuously charge the new tie conveyor on the tie exchange car with concrete ties and transport the replaced wood ties to the forward end of the tie car consist. Each gantry has the capacity to carry 21 concrete ties or 24 wood ties at one time. Actual tie and rail rehabilitation by the TLM occurs in this sequence: (1) old rails are spread apart and guided through leads to the track shoulder; (2) old wood ties are removed and flipped on to the old tie conveyor by the pick-up wheel and wood tie flipper; (3) the ballast plow smooths the existing ballast; (4) new concrete ties advance down the tie chute and are placed on 24-inch centers; (5) as concrete ties are placed, two workmen riding below the beam place tie pads on the ties in the rail seat area; and (6) simultaneously, new CWR is picked up from the track shoulder and guided into place on the new concrete ties. All of these operations occur in the area beneath the TLM's suspended beam. The front portion of the TLM, through the tie exchange car, rides on the old rail prior to its removal. The rear portion of the TLM, through the power car, rides on the new concrete ties and CWR. Trailing the power car is a material supply car from which workmen distribute rail clips and insuators. During the operations listed above, the TLM is capable of making some limited adjustments to the track alignment and profile.

TLM Support

Two major support operations must occur prior to TLM performing its tie and rail rehabilitation. New CWR in 1440-foot sections is distributed along the track shoulders in the areas designated for rehabilitation. On the NECIP, the attempt is made to perform this operation as part of the winter work program.

The second major advance operation is the preparation of the old track. This operation consists of removing rail anchors and spikes from the existing track structure and driving tie plate hold down spikes. On the NECIP, tie plates are secured to the old ties and picked up together with the ties by the TLM. This spiking operation is performed directly ahead of the TLM and must keep pace with the progress of the machine to avoid delay.

Concrete ties, produced at the Santa Fe-San-Vel plant in Littleton, Massachusetts, are transported to staging bases near the work site. The ties are delivered to the TLM by train as needed during construction.

The additional TLS operations of undercutting, surfacing, application of rail clips, welding, ballasting, material cleanup and undercutter spoil removal, as well as other miscellaneous support functions, follow the TLM.

A typical manpower breakdown for the TLS is given in Table 3. The 213-man labor force includes all support gangs as well as the major TLS work crews. Table 4 provides a summary of the rolling stock necessary to support the TLS program.

TABLE 3. TLS OPERATION SEQUENCE (FROM SITUATION REPORT JUNE 11, 1979)

OPERATION NO.	DESCRIPTION	AUTHORIZED LABOR FORCE
1	ROAD SUPPORT	14
2	HEAD END GANG - SPIKING, BALLAST PREP., RAIL POSITIONING	38
3	CORRECT NEW RAIL ALIGNMENT	4
4	T.L.M.	36
5	DESTRESS RAIL & INSTALL CLIPS	12
6	DISASSEMBLE RELEASED RAIL	5
7	WELDING-CONNECT RAIL, INSTALL FBJ's	18
8	UNDERCUTTING	14
9	RAISE, LINE & SURFACE	26
10	CLEAN-UP RAIL & OTM	13
		180 SUB TOTAL
11	WORK TRAIN - GEN'L SERVICE	6
12	WORK TRAIN - SPOIL DISPOSAL	2
13	TRAIN PROTECTION - WATCHMEN	1
14	MISC. GANG SUPPORT (YARD)	6
15	MECHANICS - MAINTENANCE (YARD)	18
		33 SUB TOTAL
		213 TOTAL TLS

TABLE 4. SUMMARY OF TLS ROLLING STOCK

TYPE	TLS
LOCOMOTIVES	14
CABOOSES	7
BALLAST CARS	100
FLAT CARS (TIES)	95
FLAT CARS (EQUIPMENT)	3
DUMP CARS	33
RAIL TRAINS	3

Operating Experience

The track laying system began NECIP operation on June 26, 1978. During the 1978 work season, 41.3 miles of track structure were rehabilitated. This amounted to 39 percent of the initially planned 1978 target of 107.2 track miles. Lack of proper advance planning and field coordination accounted for a portion of the program shortfall. As a result, Amtrak established a planning branch to support the TLS field operations beginning with the 1979 season. This group is responsible for generating site specific work documents that define work elements, schedules, and coordination of all track construction. To date, these documents have been utilized with some degree of benefit. In the early part of 1979, the flow of survey information for track alignment and profile lagged behind anticipated schedules. By mid-season, however, alignment data was made available to field construction crews on a more timely basis.

Throughout the TLS operation, there have been several recurring problems with equipment and coordination. Lack of traction on the TLM has been a continual source of lost production. Experiments with additional sanding devices have not improved the condition and presently additional power trucks are being considered. Wood tie jams have been a source of production delay, accounting for an average of 18 percent of all delay through April, May, and June, 1979. Some adjustments to the wood tie pick-up wheel and tie flipper decreased wood tie jams during July, 1979, but apparently caused an offsetting increase in delay due to repair and adjustments of these two mechanisms.

Unforeseen underground obstacles have been encountered by both the TLM and undercutting operations. Several times, obstacles have caused damage to equipment. Availability of spare parts for the Canron P-811, although not a frequent cause of production delay, has been a costly one. Two full days of production were lost this July when, for want of a voltage regulator, the machine could not operate.

Causes of lost production time become more meaningful when analyzed from the perspective of total production potential. In addition, it should be emphasized that delays caused by the TLM operation impact all other TLS operations because the TLM is the key production unit in the overall system.

During the 1979 work season, the average number of concrete ties placed per hour of production has increased from 476 ties/hour to 606 ties/hour as shown in Figure 3. This steady increase in the hourly production rate, however, is not reflected in the overall performance of the track laying system. A recent study of TLM delay through July 31, 1979, reveals that of an average daily shift time of 8.8 hours, only 2.7 hours of production have been realized. This results in a daily concrete tie average for 1979 of 1600 ties per day, or 60.6 percent of the 2640 ties, 1 mile a day, programmed average. The mile a day goal, however, has been met and exceeded on eight occasions so far in 1979 with the best production to date being 3116 ties on July 11, 1979.

With the 1 mile per day production goal having been achieved, along with a rate of 600 plus ties per hour, the target area for management attention and improvement is clearly a reduction of TLM delay time. From April 2, when the TLM began work on the 1979 Trackwork Program,

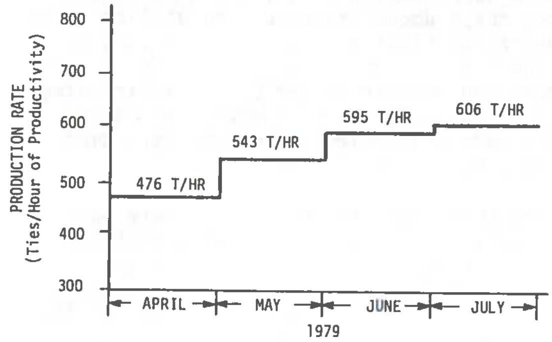

FIGURE 3. TLM PRODUCTION RATE, 1979, NECIP BOSTON DIVISION

through July 31, 1979, approximately 52.2 miles of track have been renewed, using 131,213 concrete ties. From the start of the NECIP to date, 93.6 miles of track have been rehabilitated with the Canron P-811.

Undercutting and Surfacing

Track undercutting and surfacing are the other two major elements of the track laying system. During the 1978 construction season, the undercutting operation was initially performed ahead of the TLM. Poor track conditions, loose spikes, split ties, missing anchors, etc., greatly hindered undercutter production and caused system delays. At times, undercutting ahead of the TLM also necessitated a surfacing operation preceding the TLM to restore track configuration for trailing equipment.

The 1979 track program began with the undercutting operation behind the TLM. The TLM, therefore, was in the position of setting the production pace for the other TLS operations. In May, 1979, a second undercutter was added to the TLS consist in tandem with the initial machine. These undercutters worked in "measuring worm" fashion: as the lead machine advanced, it left behind an area to be worked by the second undercutter. Initially, undercutting production picked up, but ultimately was controlled by the TLM progress and overall TLS production. In time it was shown that the second machine was not required to keep undercutting up with TLM progress.

Undercutter spoil disposal has been a continual problem due to right-of-way space limitations, drainage considerations and efforts to avoid despoiling wetland areas. In addition, mechanical problems with the side-dump conveyor cars procured for transporting undercutter spoil have further hampered undercutter operations.

Throughout the 1979 season, the undercutting operation has been approximately 3.7 miles behind the TLM. In an effort to improve TLS production and prepare for the 1980 work season, areas scheduled for TLS work will be undercut in advance.

Surfacing is performed in a series of raising, tamping and lining operations. Both production tampers and switch tampers are utilized to adjust the new track to its design profile. Ballast is distributed, compacted, and dressed as raising progresses to insure specified track section. Surfacing has progressed at a somewhat slower rate than the undercutting and TLM operations and by July 31, 1979, there were 10.3 fewer miles of track surface than had been renewed by the TLM. Based on the TLM location when surfacing began in April of 1979, these operations should be no more than 3 miles apart.

Changes in NECIP track alignment and elevation are being effected by the TLM and undercutters as well as the surfacing operation. Where major curve realignments are incorporated, the TLM has the ability to move track up to 4 inches laterally. Changes in elevation are accomplished by undercutting and raising and surfacing track. Where tracks must be lowered considerably, at various overhead bridges, manual labor must be utilized. Such confined areas prohibit the use of mechanized undercutting, and particular care must be given to developing a well drained roadbed beneath the bridge.

TURNOUT RENEWAL

Turnout renewal was the second area of NECIP trackwork in which advanced technology was employed. As shown in Table 1, some 640 turnouts along the Northeast Corridor were identified for complete renewal or rehabilitation through replacement of components. Included in the category of renewal are those turnouts which are being relocated as a result of interlocking reconfiguration. While turnout component replacement is suited to conventional methods, it was determined that complete renewal or relocation of turnouts could be most effectively done using preassembled panels. Although panelized turnouts are not new to the railroad industry, the added challenge or working in 3-, 4-, and even 6-track territory with live catenary overhead presented serious material handling problems. Conventional cranes can not be readily used to handle fully assembled panelized turnouts, up to 195 feet in length, across multiple tracks under the existing catenary. An alternate method was sought.

The equipment selected to perform this task is the Geismar Panel Renewal System (PRS). The system consists of two basic types of units: a carrying trolley with a 10-ton load capacity, and a hydraulic lifting machine (PUM) having two hydraulic rams with a 51-inch stroke and total lifting capacity of 16 tons. The number of trolleys and PUMs used varies with the size of the panel being moved.

Under the general operating concept of the Geismar system, a turnout panel is lifted vertically using several PUMs. Each PUM also has the capability to move the suspended panel horizontally to permit "walking" a panel across tracks. For movement parallel to the track, the panel is lowered onto a set of carrying trolleys and rolled along the track. The system is complete with 525 track feet of auxiliary rails in 16 foot lengths, for use where existing track has been removed. A total of 12 trolleys and 12 PUMs were purchased to permit handling of up to a No. 20 crossover in three panels.

The first four units were received in early June and a panelized No. 10 turnout was installed near Baltimore on June 21, 1979. The remainder of the PRS units were received in August 16, 1979, and as of this writing, no attempt has yet been made at installing a No. 20 turnout. With such limited experience, it is difficult to evaluate the success of the system; however, two minor problems have arisen.

The first involves the auxiliary rails which are relatively heavy and difficult for two men to handle. A partial solution to this problem will be the addition of handles to the rails making them easier to carry. The second minor problem is that the PUM control area is exposed and accessible to vandalism. Hopefully this will be resolved through the addition of a cover which may be locked over the controls.

SUMMARY

The Northeast Corridor Improvement Project is utilizing some of the most advanced innovations in track equipment and techniques available. The ambitious scope of work, and large geographical area encompassed by the project create complex logistical problems. These problems are magnified by the need to concurrently perform other work and maintain train operations.

As stated, a number of problems with work planning and field construction coordination are being encountered and dealt with at all levels.

Experience gained thus far with the track laying machine indicates that the 1 mile a day production goal can be met. The extensive improvements to the Corridor's interlockings are expected to be greatly facilitated by the newly acquired panel renewal equipment.

Efforts to seek out and utilize, where possible, recent developments in railroad construction and maintenance techniques will continue by all those involved with the Northeast Corridor Improvement Project. It is anticipitated that the knowledge and experience gained on the Corridor will be beneficial to the rail industry and will stimulate needed efforts to continue improvements in track laying technology and equipment.

A REVIEW OF RECENT FOREIGN PASSENGER EQUIPMENT DEVELOPMENT

BY

ROBERT B. WATSON

The Federal Railroad Administration's Improved Passenger Equipment Evaluation Program (IPEEP) over the past 2-1/2 years has investigated a number of foreign high-performance passenger trains for possible application in the United States. It was, of course, recognized that modifications would be required to any foreign equipment in order to meet U.S. requirements in general, as well as the particular requirements of a specific service in this country. It was soon apparent that each of the trains selected for review had been designed for specific service requirements within each of the respective foreign countries. For the most part, the representatives of the foreign railroads and manufacturers emphasized this point to the FRA team: direct application of any of the foreign trains to a specific U.S. market would be almost impossible without major changes in the configuration or construction of the train. It was then decided that specific components and philosophies of design and operation would be reviewed.

In all, eight trains were reviewed representing the most advanced high-performance designs committed to hardware: the British HST and APT, the Swedish Experimental X15, the French TGV, the German ET403, the Swiss Type III cars, the Italian ETR401, and the Japanese 961/962. Recent North American entries in the high-performance vehicle market were not reviewed because interest in these vehicles had already been expressed by Amtrak. Specifically, these trains were the SPV 2000 and the LRC, both of which are now in production for use in this country.

It must be pointed out that comparison of the various trains was nearly impossible and perhaps even meaningless since each of the trains reviewed had been designed and built for a specific application. Each features design and operating principles which were dictated by the operating philosophy of the country and were required to address the market and service. It should also be noted that none of these matched exactly the requirements of the Northeast Corridor or any other American Corridor per se.

Another general but very important observation with respect to all of the foreign equipment was that the operating environment was generally better than any found in the United States, and that the level of maintenance required and provided for the trains was much higher than any which might now be found in this country. In Japan, France and parts of Italy, separate rights-of-way have been constructed for new high-speed service. Thus, there is no mix of traffic and the operating environment is relatively pure. In other countries where separate rights-of-way have not been constructed, the traffic patterns are such as to permit high-speed operation on existing rights-of-way after major reconstruction. Track conditions are considerably better than those in the United States, thus allowing higher speeds with less detrimental effect to the equipment. In many cases, signal spacings have been adjusted to accommodate the new high-speed trains without adverse effect on other services.

With these differences in mind, some of the major features of each of the trains examined are discussed in the following sections. Table 1 lists, for comparison, the major features of seven of the foreign trains.

HST

The HST (Figure 1) was developed by British Rail initially as a stop-gap to provide improved and higher speed passenger service over non-electrified lines until the general electrification program was completed and until the more sophisticated APT train could be developed and put into service. It has become a very popular train with a total of 90 trainsets now on order or in service. HST is particularly appealing due to its simplicity. It has taken advantage of the latest conventional British equipment design in order to attain higher speeds and higher performance with a fixed consist. Standard Mark III coaches are used as the cars, along with lightweight diesel power cars at each end.

The power cars use 4-cycle, V12, turbocharged Paxman Valenta diesel engines developing 2250 gross hp each. Four traction motors are used on each power car. The engine is a key contributor to the light weight (77 tons) of the locomotive, which has a specific weight of about 7 lbs per horsepower. It should also be noted that head end auxiliary power is developed from the same engine thus reducing the power available for traction. The estimated auxiliary power load of the train can be as high as 550 hp.

Both power cars and the coaches have cheek-mounted disc brakes and a tread brake for wheel cleaning purposes only. There is no dynamic brake.

Power cars employ fabricated steel trucks with coil springs in the primary suspension and a flexicoil in the secondary suspension. The unpowered cars use a similar fabricated truck

TABLE 1. MAJOR FEATURES OF NEW FOREIGN PASSENGER EQUIPMENT

CONFIGURATION	BRITISH HST	BRITISH APT	FRENCH TGV	GERMAN ET403	SWISS TYPE III	ITALIAN ETR401	JAPANESE 961
Individual Locomotive-Hauled Cars	x				x		
Power Cars	x	x	x				
Multiple-Unit Cars				x		x	x
Married Pairs						x	x
Special Cab Cars				x		x	x
Articulated Cars		x	x				
PROPULSION & PERFORMANCE							
Power	diesel electric	electric 25 kV 50 Hz	electric 25 kV 50 Hz 1.5kV DC	electric 15 kV 16 2/3 Hz	n.a.	electric 3kV dc	electric 25 kV 50 or 60 Hz
Horsepower-continuous	2250	4000	4120	1280	n.a.	820	1470
Speed-MPH	125	150	162	125	87	155	162
Horsepower/Ton	10.8 var.	14.1 var.	18.1	19.7	variable	18.2	22.8
BRAKING							
Tread	x	x	x		x		
Disc	x		x	x	x	x	x
Electrodynamic			x	x		x	x
Hydrokinetic		x					
Track				x		x	
CARBODY							
Material, Power Car	steel	steel	steel	n.a.	n.a.	n.a.	n.a.
Cars	steel	alum.	steel	alum.	alum.	alum.	alum.
Buff Strength x 1000 lbs.	441	450	450	330	225	450	220
Collision Posts	none	none	cab end	none	none	cab end	none
SUSPENSION							
Axle Box Location	link	link	rubber	leaf	link	link	leaf
Primary	coil	coil	coil	coil	coil	coil	coil
Secondary, Powered	flexicoil	coil	flexicoil	air	n.a.	coil	air
Non-Powered	air	air	flexicoil	n.a.	flexicoil	n.a.	n.a.
WEIGHTS - U.S. TONS							
Power Car	77.3	76.4	70.9	n.a.	n.a.	n.a.	n.a.
Cars	36.4 to 43	26.2 to 38.1	34.5 to 53.1	63 to 66.9	35.9 to 42.5	44.2 to 45.7	63.9 to 66.1
Axle Load - Powered	19.7	19.1	17.8	16.2	n.a.	12.6	16.8
- Non-Powered	11.6	13.1	17.3	n.a.	12	12.6	n.a.
DIMENSIONS							
Car Length, Max. - Feet	75.5	70.9	72.6	90.1	82	89.7	82.5
Exterior Width - Feet	9	8.92	9.23	9.17	9.35	9	11.11
Max. CG Height - Inches		51.75	54.9	42.3	56.4	42.4	45.3
ACCOMMODATIONS							
Seats/Car	48/1st 72/2nd	47/1st 72/2nd	38/1st 60/2nd	45 cab 51 coach	46/1st 70/2nd	49 coach 24 cafe	68 to 90
No. of Seats Across	3 or 4	3 or 4	3 or 4	3	3 or 4	3	4 or 5
Platform Level	high	high	high/low	low	low	low	high

with a coil spring primary suspension and air springs on a swing hanger as the secondary suspension. Traction motors on the power car trucks are frame-mounted and drive axle-mounted gear boxes by means of Cardan shafts, which pass through hollow pinion quill shafts to avoid severe angularity in alignment.

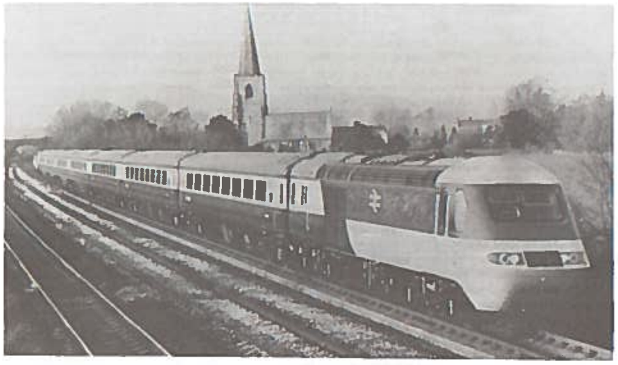

FIGURE 1. THE BRITISH HST

All cars are constructed of mild steel welded in a semi-monocoque construction. Roof sections of the power cars are removable for access to the engine and other heavy equipment. No major collision structure is provided at the ends and the buff strength is only 441,000 lbs. The cars are 75-1/2 feet long and, in keeping with British Rail's restricted clearances, are only 9 feet wide. The unpowered cars weigh on the average about 40 tons. The powered axles rate at 19.7 tons per axle, while unpowered axles carry only 11.6 tons per axle.

HST has a maximum operating speed of 125 mph. The power-to-weight ratio is 10.8 hp per ton, dependent on the number of cars in train, the most usual consist being seven or eight intermediate cars.

APT

The Advanced Passenger Train is to be the train of Britain's future, and is still under development by British Rail (Figure 2). Originally considered for service as a gas turbine powered train, it was later changed to utilize only electric propulsion at the standard 25 kV, 50 Hz power supply. British electrification having slowed somewhat in recent years, development of APT has also lagged. In addition, labor problems involved with the high-speed requirements of the train have caused some difficulty in the development program. The first production train is now under test, and ultimately a fleet of some 80 APT's is envisioned.

The APT is an articulated trainset with tilting body to accommodate curves at higher than normal speeds. Over the years, the configuration of APT has changed with respect to the number of cars and the location of the power cars. As originally planned, APT would have had center-of-train power cars, with an articulated rake of seven cars on either side, including a cab car at each end. Recent changes in marketing predictions have reduced the consist to a single power/cab car at one end of the train and a cab car at the other end with an articulated rake of seven cars between them.

FIGURE 2. THE BRITISH APT

The APT power cars are equipped with a traction control system similar to the ASEA RC class locomotives and operate on 25 kV, 50 Hz electrification. The power car has four body-mounted traction motors which are connected to the axles via transfer gear boxes and Cardan shafts to truck-frame-mounted right-angle gear boxes. The gear units are connected to the axles through concentric quill shafts. Each power car rates at 4000 hp continuous with short-time ratings considerably higher. Auxiliary power is provided by motor alternator sets rated at 430 kVA. Originally two sets would have been provided for the 14-car train. An emergency 200 kW diesel generator is provided as well. Performance of the APT is impressive with a maximum speed of 155 mph.

Braking is provided by a combination of tread brakes and a newly developed hydrokinetic brake. The hydrokinetic brake, although rather complex, is reputed to provide extremely high braking levels. In the case of the power cars, the hydrokinetic brake is coupled into the drive train from the traction motors. For the unpowered cars the hydrokinetic brake is built around each axle. Connected to individual reservoirs of water glycol mixture (as the working fluid) each axle acts independently with its own car-body-mounted radiator. The overall brake system provides for blending between the friction and hydrokinetic brake with pneumatic control.

The power cars of APT are of all-steel, semi-monocoque construction. The unpowered cars, however, are built almost entirely of aluminum extrusions. The underfloor equipment bay has a deep keel type centersill which provides for equipment support as well as car body stiffness. The floor is a composite of longitudinal aluminum sills and plates. End cars have a cab formed from a fiberglass shell.

One of the most unusual features of the APT is its suspension and articulation system.

The articulated trucks under the unpowered cars are of relatively long wheelbase. They have a primary coil spring suspension and an air spring secondary; however, the air springs are at the ends of each truck.

The tilting mechanism utilizes bolster mounted accelerometers to signal hydraulic jacks on the tilting bolster below the air springs. The maximum tilt angle is 9° with a maximum rate of 5° per second. The power car with its greater weight and the need to accommodate the drive train from the body-mounted traction motors has a somewhat more complicated suspension and tilt system. In addition, it is necessary to level the pantograph when tilting the car body by a mechanical linkage to the truck frame through the sides of the power car. In a sense, the pantograph is suspended directly from the truck frame while the car body tilts around it.

The non-powered cars are about 69 feet long, the maximum length being slightly less than 71 feet for the end or cab cars. The power car is 67 feet long. APT is slightly narrower than British Rail equipment at 8 feet 11 inches to accommodate the greater clearances required by the tilting system. The maximum CG height of APT is 51.75 inches. The power cars weigh 76.4 tons, with the other cars in train varying between 26 and 38 tons. Maximum axle loading of the power cars in 19.1 tons.

X15

Swedish Railways has expressed an interest in improving the performance of its intercity passenger trains over existing rights-of-way. The key to high-speed operation in Sweden is felt to be operation at high speeds on curves and reduction of track forces. This has led to an ASEA-conducted development program for an experimental train known as the X15.

X15 is a 3-car, MU trainset of relatively old cars fit-up with new trucks to develop the suspension system and tilting arrangement for a new trainset yet to be built. The end cars of X15 are powered, and the center is an idler. The center car utilizes a hydraulic tilting system, while the end cars have an earlier pneumatic system which is now considered obsolete. The hydraulic tilt system utilizes large rocking bolsters operating on hydrostatic bearings. Air springs are located above the tilting bolster.

The trucks utilize rubber chevrons at the journal boxes with a stiffness designed to give it a degree of radial steering. X-2, the production prototype of X15, has not yet been authorized for construction, and the current status of the X15 development program is not clear.

TGV/PSE

French National Railways, in conjunction with a number of French suppliers, has directed the design of the latest high-speed and high-performance French intercity passenger train (Figure 3). TGV/PSE will be a 160 mph fixed-consist train, operating from a 25 kV, 50 Hz electrification system on the major portion of its route from Paris to Lyon, and into the cities of Paris, Lyon and on other secondary lines at 1500 volts dc. The route for the TGV is completely new and is still under construction. This new line is almost curve-free, but grades will be significant at up to 3.5 percent. The route will be restricted to TGV operation with no mix of traffic and the high maximum speed of the line will prevail for most of the route.

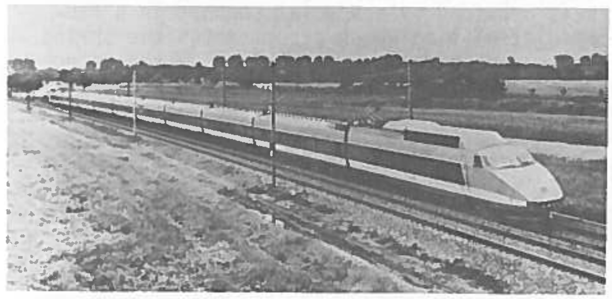

FIGURE 3. THE FRENCH TGV

The trainset is comprised of eight articulated cars plus power cars on each end. Each of the power cars has its own separate power and control system, operating from both the dc and the ac systems. A controlled rectifier is used with the ac system for dc traction motors. Each power car feeds six traction motors, four under the power car itself, and two under the adjacent end of the connecting articulated car set. TGV traction motors are body-mounted below the floor in a very low configuration within the truck frame geometry. A parallel drive to gear units mounted on the trucks is provided by special Cardan shafts.

Dynamic braking is provided by six separate circuits, one for each power truck, each with its own grids and control. All wheels are provided with tread braking (primarily for wheel cleaning). Non-powered axles are each provided with four disc brakes.

1500 volt dc auxiliary power is supplied from either the dc catenary or via a rectifier from the main transformer. Air compressors and train heat operate from this power source. Three-phase power is provided at 220 volts, 50 Hz by two 450 kVA static inverters (which also operate from the 1500 volt dc source) for blowers, air conditioning and battery chargers for the entire train. Car lighting is provided by individual inverter ballasts at each lamp that operate from the battery circuit.

TGV/PSE is of all-steel construction with heavy side sills and no centersill. Coaches have integrated roofs and sides assembled to the underframe while the power cars have removable roof and side panels for access to equipment. A heavy protective structure is provided at the front of the cab extending across the bottom of the windshield for collision protection and a collapsable energy-absorbing nose is applied in front of the structure. The buff strength of TGV is 450,000 lbs.

TGV has an unusual articulation arrangement. The connections between cars are made at the truck pivot point, a fairly conventional center-plate arrangement. However, the suspension at that point is extremely high in the car body. This is provided by a special support in a fabricated steel ring which accommodates the spring seats on each side of the opening for the inter-car walkway. This ring serves as a body bolster for the adjacent cars. This arrangement shock-mounts one car to the ring while the other pivots on it. Suspension of the TGV is by means of coil, primary springs, and flexicoil secondary, of very long travel. Axle boxes are guided by rubber shear mountings.

The TGV power car weighs 70.9 tons and the intermediate cars typically weigh between 35 and 50 tons. Very uniform axle loading has been attained with 17.8 tons per powered axle and 17.3 tons per unpowered axle. The power cars are 72 feet 7 inches long, and the intermediate articulated cars are 61 feet 4 inches long. Exterior width of the car is 9 feet 3 inches, and the maximum CG height is 55 inches.

ET403

Several years ago the German Federal Railways began the development of a new high-speed, high-performance MU trainset which culminated in the construction of three MU sets of ET403 equipment (Figure 4). Since that time, the high-speed, intercity passenger program of DB has diminished somewhat and a greater emphasis has been placed on locomotive-hauled trains. However, there has been a recent resurgence of interest in the high-speed, intercity service but the equipment for this most recent program has not yet been discussed. Thus, the ET403 is not in current development, but its performance and construction were worthy of attention.

ET403 is a 4-car MU trainset operating at 15 kV, 16-2/3 Hz. Each car has its own main transformer and propulsion equipment; a few auxiliary functions are shared with adjacent cars. End cars are streamlined with cabs, and operating controls are provided only on those cars. The propulsion system utilizes a main transformer and controlled rectifiers, feeding the four parallel, separately excited, traction motors. The brake system uses dynamic brakes with roof-mounted resistors and pneumatic disc brakes. In addition, a track brake is also provided for emergencies.

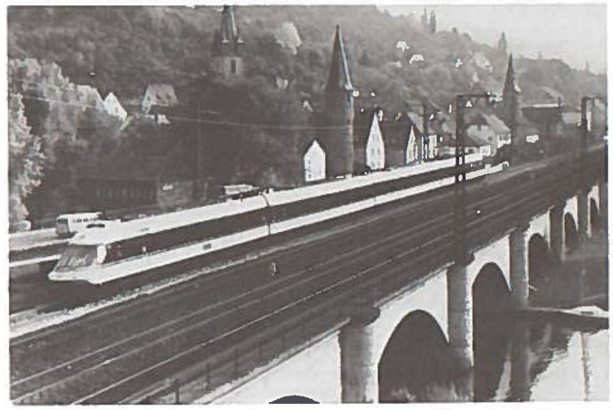

FIGURE 4. THE GERMAN ET403

The maximum speed of ET403 is 125 mph, and this is developed with a relatively high power-to-weight ratio of 19.7 hp per ton.

The motors and gear units are rubber mounted to the truck frame and drive the axles through concentric quill shafts to minimize unsprung mass. Disc brakes are cheek-mounted to the wheel plates, thus overcoming the space restrictions of the motorized truck. An interesting feature of the ET403 is an automatic high-voltage bus connector on the roof of each car, which allows the use of only one or two pantographs per train. Auxiliaries are supplied by a 1000 volt, 16-2/3 Hz tap from the main transformer, with a rectifier used for dc for the air conditioning motors. The 110-volt battery system supplies other loads and 3-phase, 50 Hz power for certain auxiliary loads via a 15 kVA converter.

The ET403 truck frame is fabricated, rigid and non-equalized with a center bolster pivot and end transoms. The primary suspension utilizes hydraulically damped coil springs at each journal box with the Minden Deutz type axle box guidance. Secondary air springs are provided.

Construction of the ET403 is of aluminum with an overall buff strength of 330 tons. No collision posts are provided. Roof and floor sections are of corrugated aluminum sheets, while the sides are large extrusions. The widest is 22.8 inches, and encompasses all of the area between the windows and the side sill.

ET403 cars weigh between 63 and 67 tons each, with an axle loading of only 16.2 tons, with all axles powered. The cars are 90 feet long with a width of 9 feet 2 inches in keeping with the UIC standard clearances. The CG height, because of the large amount of underfloor equipment, is very low at 42.3 inches.

TYPE III COACH

Swiss Federal Railways several years ago began the development of new lightweight, higher-speed passenger equipment. However, they were committed to the use of locomotive-hauled cars so that the emphasis of this program was the development of a lighter weight conventional car to operate at higher speeds. Because of the numerous curves in the SB system, a tilting body concept was considered. In addition, light weight was a primary consideration in order to provide air conditioning at no increase in weight over previous non-air conditioned cars. The maximum speed of SB is 87 mph, so that no major breakthrough in speed was to be accomplished. However, by virtue of the tilting body suspension, it was hoped that intercity times could be reduced by operating on curves at higher speeds.

Thus, the SIG-built Type III cars were developed with all aluminum construction and with four cars temporarily equipped with an experimental tilting system (Figure 5). A total of 64 cars have been built, but apparently, the SB has opted against the tilt system in view of the relatively limited gains in the trip time on most of the SB system. In addition, aluminum construction apparently did not meet with great favor by the operators since new Type IV cars are to be built of steel. The auxiliaries for the Type III trains are supplied by a 1000 volt, 16-2/3 Hz, single-phase trainline from the locomotive. The construction of aluminum is primarily means of extrusions providing for a very light car, its total weight being only 78,000 lbs even though it is fully air conditioned. Buff strength is only 225,000 lbs which does not meet the UIC Standards.

FIGURE 5. THE SWISS TYPE III CAR

However, the tilt mechanism was found to be significant and interesting in that the entire tilt package other than its pumps and controls can be housed within the confines of a very low truck. The truck is fabricated with primary suspension of rubber springs and bell cranks to locate and guide the journal boxes. The secondary suspension is by means of flexicoil springs which shear to accommodate truck rotation. The tilting bolster has a roller pathway with hydraulic cylinders to position the car body.

Actuation of the tilting system in response to an accelerometer is by a hydraulic power unit on each car. Control is arranged so that an accelerometer on the preceding car is used to signal the next car in anticipation of curves. This requires the use of an accelerometer on the locomotive even though the locomotive does not itself tilt. Thus, maximum speeds of trains are limited to the speed that the locomotive can accommodate on curves. The maximum tilt angle of the Type III car is 6°.

The Type III car is equipped with both tread and disc brakes. The tread brake being used primarily for wheel cleaning. It weighs, depending on the interior appointments, between 36 and 42 tons, or a very low 12 tons per axle. The cars are 82 feet long, with a 9 foot 4 inch width, rather unusual in view of the tilting body which might be expected to be narrower to accommodate the swing of the car. Maximum CG height is 56.4 inches.

ETR401

Italian State Railways is building a new higher-speed line from Florence to Rome which is partially completed but moving on a slow and erratic schedule. At the same time, Fiat has developed the ETR401, a high-speed, high-performance, multiple-unit train, better known as the Pendolino (Figure 6). The train does not normally operate on the new high-speed right-of-way and only two trains have been built as demonstrators; one for use in Italy, and another broad gauge version which is on trial in Spain. FS has not yet adopted the ETR401, however, it has been in revenue service for several years. ETR401 attempts to provide a high-performance train for Italy's existing routes with a tilting body and radial trucks.

FIGURE 6. THE ITALIAN ETR401

ETR401 is a multiple-unit train operated at 3 kV dc, the standard voltage of FS. It is made up of two married pairs of cars with special cab cars at each end. Its maximum speed is 155 mph, however, in current service between Rome and Ancona, its speed has been restricted to about 100 mph. The route over which it is currently in service is extremely curvy and the track is not of particularly high quality.

ETR401 has a horsepower per ton ratio of 18.2. The train has dynamic disc and track brakes (the latter for emergencies only). Each of the four cars is powered by two motors which drive the inboard axles of each truck. Motors are body-mounted, driving through Cardan shafts and right-angle drives. Two disc brakes per axle are used and blended with a dynamic brake. One MA set serves each married pair of cars to provide 3-phase, 50 Hz auxiliary power. The Spanish version has a 150 kW inverter for this purpose.

The cars are built of aluminum framing with a stressed aluminum skin. A buff strength of 450,000 lbs is accomplished and a form of collision post is provided at the end cars.

The control of the power tilt system is unique in that it utilizes gyros on each end car to detect changes in track crosslevel as the train progresses into transitions in superelevation. The gyro provides a signal in advance of a curve's actual lateral acceleration. Thus, the lag between the force and the tilting response is reduced. A hydraulic tilt system is used on each car. One truck of each pair of cars has a linkage supporting the pantograph to keep it centered on the wire in spite of the tilting of the car body. The tilting mechanism is quite complex. It is located over each truck and extends well up into the car body, thereby considerably reducing car interior space.

The Pendolino weighs an average of 45 tons per car. Powered and unpowered axles alike are loaded at 12.6 tons. The cars are almost 90 feet long, with an exterior width of 9 feet. The CG height is a very low 42.4 inches. The Pendolino trucks are unique in that there is a provision for a degree of radial steering by virtue of variable pressure, lateral air springs, a system which so far has not been utilized to its expected capacity.

Pendolino is still in its developmental stages and the likelihood of its adoption by the Italian State Railways is unknown at this time, but it does not seem to be well suited for the new high-speed route.

JPANAESE 961

The 961 is a prototype train for the development of the second generation of high-speed bullet trains for Japan's Shinkansen (Figure 7). It is being used for tests to develop the new production trains (of which the 962 is the prototype) for the Tohoku and Joetsu Shinkansen north of Tokyo which are scheduled to open in March of 1981. These new lines are in the more severe, snowy areas of northern Japan with long stretches of steeper grades and numerous tunnels. The older lines are south of Tokyo where the existing Shinkansen equipment operates in a much less severe environment. The major differences between the existing equipment and the newer 961 and 962 are slightly higher power, aluminum construction, and provision for snow protection by higher air intakes and enclosed equipment.

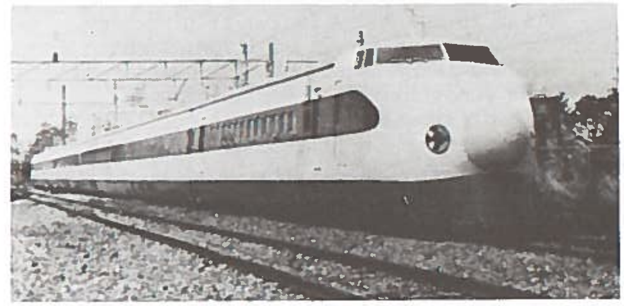

FIGURE 7. THE JAPANESE 961

The propulsion system for the 961 operates at 25 kV on either 50 or 60 Hz. (50 Hz is the commercial frequency in northern Japan.) The 962, which will operate exclusively in the north, is built for only 50 Hz. Five phase-controlled rectifiers are used for the propulsion system. Each axle is powered and each pair of cars shares a main transformer and rectifier. Braking is by means of rheostatic dynamic braking with blended air operated disc brakes. A relatively new feature of the 961 is the use of freon for cooling the solid-state devices.

The all-aluminum car body is new to the Shinkansen; the older equipment has been of all-steel construction. However, the construction of the new aluminum cars is by means of aluminum sheets and framing similar to the original steel cars. For the past 15 years of Shinkansen operation there have been relatively few changes in the design of the equipment. The 962 will be the first major change in the Shinkansen design.

Trucks of the 961 are fabricated with primary suspension by means of coil springs at the journal boxes. Journal box guidance is provided by a leaf spring arrangement and the secondary suspension is by means of air springs. The traction motors and gear units alike are mounted to the truck frame. Parallel drives to concentric quill shafts are connected to the gear units at the axles.

Disc brakes are outboard of the wheels. This results in an unusually wide truck, which can only be accommodated by the unusually wide clearances of the Shinkansen.

The aluminum construction of the car body provides for only 220,000 lbs of buff strength and there are no collision posts. The train will normally operate as a 16-car unit with a cab car at each end. Car weights average 65 tons, with an average axle loading of 16.8 tons per axle. The cars are 82-1/2 feet long, with an unusual exterior width of 11 feet 1 inch. The maximum CG height of the Shinkansen equipment is 45.3 inches.

CONCLUSIONS

Parochial interests and prejudices of each of the railroads and countries involved in the IPEEP assessment appear to have been well served. All have made good arguments for the particular directions which they have taken, and all appear to be well conceived and well designed. Operational and maintenance considerations for the use of any of these vehicles in the United States would require a great deal of study before adopting any of them inasmuch as all of the vehicles surveyed were felt to be beyond the complexity of existing equipment in this country. A radical change in maintenance practices would be required for any of these vehicles to be successful in the U.S. - not that this should be a deterrent.

The British APT is a highly advanced train, and should be observed as it finally becomes operational. Unfortunately, delays in its development have caused some consternation, but it is apparent that when finally delivered it will be a superior vehicle.

The British HST, in the meantime, has provided excellent service with relatively conventional equipment and continues to be the mainstay of British Rail's high-speed service, and is even now is attempting to break the Japanese speed records.

The Swedish X15 also bears watching. A highly sophisticated radial truck and tilting body arrangement may well yet be delivered. However, until SJ makes a decision on future equipment, little more can be expected from the development program.

The French TGV appears to be the best developed train so far. It is a well conceived vehicle integrated to its required service and operation in a relatively pure environment. Lower speed revenue service on existing lines will start next year with the total project in high-speed service by 1983. This service experience bears attention.

The German ET403 is a high-performance vehicle of relatively conventional and proven design at this time. No major innovations are involved in its current state. However, it appears that the Germans are not likely to pursue its development any further and may well opt for locomotive-hauled trains.

The Swiss Type III cars have a most interesting tilting body suspension system because of its compact configuration.

The Pendolino although operational, is still a demonstrator. It features concepts such as a tilting body and radial steering trucks which have been complicated beyond the need of the moment. In addition, as a 3000-volt dc vehicle, it does not appear to offer a great deal for direct adaptability to U.S. service. Further attention to the development of the tilting and radial truck system is in order.

The Japanese 961 and 962, although also under development, will apparently provide the new features required for the next generation of Shinkansen equipment. The size of the 961 and 962 is similar to that required for U.S. service, but changes in the car body would be required.

In summary, it is felt that the U.S. railroad industry would do well to develop its own new equipment geared to its own needs, rather than try to adopt any foreign train in toto. Many of the concepts of the foreign trains are good and may well be adaptable to U.S. practice. However, many changes would be required to put any of those trains in service in the U.S.

RECENT ADVANCEMENTS AND FUTURE TRENDS IN SIGNALING AND CONTROL TECHNOLOGY FOR HIGH SPEED OPERATIONS

BY

STEWART F. TAYLOR

INTRODUCTION

In recent decades advancements in railroad signal technology have taken divergent paths in the United States and other nations of the world. With prospects for the establishment of high speed intercity passenger services, effort is underway in this country toward the development of new signal and control systems. In a reversal of past practice, the new technology is likely to incorporate elements found throughout the world. This paper describes the background, recent developments and future trends for high speed intercity railroad operations.

THE FRA STUDY

Over the past 10 years, the United States has been concerned with dependence on the automobile as the primary means of transportation. Partly as a result of the growing oil crisis, this concern has led to an examination of alternative courses of action, one of which is to upgrade existing Amtrak railroad passenger services to operate at higher speeds and thus offer more attractive schedules to the public. An intensive effort is presently directed to improving service between Boston and Washington under the Northeast Corridor Improvement Program (NECIP). Concurrently with this program, the Federal Railroad Administration initiated a research program to determine the feasibility of upgrading existing signal systems on the 18 railroads over which Amtrak operated. This program, "Evaluation of Signal/Control System Equipment and Technology," is examining the possibility of assembling a signal and control system which could be "overlaid," or superimposed, on the various existing systems to allow Amtrak trains to operate safely at speeds in excess of 100 mph without the disruption of existing freight traffic signals and equipment. If such a system could be identified, a considerable cost saving could be realized and existing rolling stock would not have to be upgraded as is the case with the NECIP. The study program has examined the evolution of railroad signals and control systems throughout the world, has compared the available technologies with the design requirements for an "overlay" system and has recommended several promising implementations.

HISTORICAL BACKGROUND

During the second half of the nineteenth century, as railroading evolved from a novelty into a viable method of moving passengers and freight, the "art" of railway signaling was established. With the advent of two or more trains running on one track, a need to control speed and separation was rapidly recognized. The early control methods were manually operated wayside signals usually in the form of moving paddles or "semaphores," although many other imaginative devices were tried. The basis for signal operation was to insure either safe distance or time interval between trains. The time interval separation method was quickly abandoned because it was not "fail-safe." If the lead train was stopped unexpectedly, the following train did not necessarily receive warning in time to prevent a collision. Initially, the space, or distance, separation method consisted of station-to-station separation based on telegraphic communication of each train's passage from one station to the next. Since this rudimentary signaling system relied almost completely on the performance of operators, it was very costly and subject to human error.

In 1866, the first "automatic block signal" system was installed in the United States. This system used the running rails as conductors and wheel operated treadles as actuators for the signals. In 1872, the use of the train wheel and axle as a shunt between the running rails was implemented to provide a "fail-safe" signal system. The running rails were cut and an insulator placed in the cut at each block was fed by a primary battery with the other end of the block connected to a relay. With this implementation, all failures produced the same indication as the presence of a train in the block. Hence, the circuit was "fail-safe."

As train speeds and volumes increased, the "stop-go" 2-aspect signal display was no longer adequate and additional aspects designating intermediate speeds were required. Initially, multiple aspects were obtained by interwiring adjacent blocks so that the aspect displayed was a function of the number of "clear" or unoccupied blocks ahead. This implementation was costly and difficult to maintain due to the number of wires and relays involved. The development of frequency selective or "code following" relays allowed the signal circuits to be energized with pulsed direct current, the pulse rate being indicative of the aspect within each block. Typical code rates were 75, 120 and 180 pulses per minute (ppm) to indicate one, two and three clear blocks respectively.

The emergence of electric propulsion systems in the early part of the twentieth century presented a new set of constraints on the use of the running rails as signal system elements. Since electric traction systems utilized the running rails for traction power return, steady and coded dc track circuits were no longer practical. This situation led to the use of alternating current track circuits (both steady and coded) at frequencies other than that of the traction power. The insulated joints which defined block boundaries now required "impedance bonds" which effectively shunt the insulation at the traction frequency while providing isolation at the signal system operation frequency. Typically for traction supplies of 25 Hz, signal system track circuits would operate at 60 Hz and for 60 Hz traction current the signal system would operate at 100 Hz.

The rapid increase in passenger train operating speeds during the second and third decades of the twentieth century created a need for signal information inside the locomotive cab rather than at the wayside. The ability of humans to distinguish wayside signal displays at speeds in excess of 80 mph was proven to be marginal at best. Fortunately, the previous development of coded ac track circuits provided most of the solution to this problem. Since the running rails already carried an ac signal denoting the signal aspect, it was only necessary to provide an inductive receiving system onboard the locomotive to decode the signal and activate a cab mounted display. This system was first put into operation in the U.S. in 1923. As the need for cab signals increased during the 1930's, some "intermittent" inductive transponder systems were developed which were installed at wayside signal locations to provide cab signal information, but most systems in the U.S. were continuous ac coded track circuits.

RECENT DEVELOPMENTS

Prior to World War II signal system development was fairly consistent throughout the world. Subsequently, however, the development pattern in the United States differed considerably from that in Europe and Japan. Because of the shift in travel patterns, U.S. practice tended to emphasize freight rather than passenger operations. Europe and Japan, on the other hand, had virtually no operating transportation systems at the end of World War II and concentrated almost exclusively on restoring rail service with the emphasis on passenger service since most freight movement could be accomplished via water.

In the U.S., railroad signal and control technology has been directed almost exclusively toward improved freight operations. This has resulted in emphasis on centralized traffic control and automated freight classification yard control systems. Although these systems are sophisticated and efficient, they are normally interfaced with steady and coded dc and ac track circuits designed prior to World War II. The only significant exception is in commuter rail systems serving the nation's larger cities. Some of these systems have installed audio frequency track circuits which eliminate the need for insulated joints in the running rails; and one city, San Francisco, has developed a new commuter rail system using a totally "new" signal and control technology.

In Europe and Japan, the emphasis on signal and control technology since World War II has been directed toward achieving train speeds in excess of 100 mph and providing maximum train densities. This effort has resulted in the evolution of almost fully automated train control systems using state-of-the-art technology throughout the system. Additionally, in Europe, since trains may run through several countries, signal system design tends to be much more standardized than that in the U.S. In Japan, the deployment of the Shinkansen high speed passenger train system has resulted in the development of a fully computerized signal and control system which is gradually being incorporated as a standard on all Japanese railroads. It is interesting to note that the Shinkansen Line has carried more than one billion, one hundred million passengers without a single fatality.

SIGNAL SYSTEM REQUIREMENTS

As previously described, the intent of the FRA study program was to examine the technologies available for the control of high speed trains, compare them with a set of requirements, and to recommend one or more implementations for further consideration. Since the purpose of such an implementation would be to provide Amtrak with a common system, the 18 railroads over which Amtrak operated were examined.

At the time of the study Amtrak trains were operated over approximately 27,000 miles of railroad. Of this figure, less than 2 percent is owned by Amtrak. The other 17 participating railroads, comprising 26,000 miles of the system, utilize many different signal systems with and without centralized traffic control. It was determined that 95 percent of the rail system used by Amtrak does have some form of automatic block signaling (ABS) and that about 50 percent has some form of centralized traffic control (CTC). The ABS used is predominately coded dc and ac track circuits. An examination of the CTC implementations showed a wide variety of systems ranging from all relay to a proliferation of computers, minicomputers and microprocessors. Based on these data, the decision was made that the overlay systems to be considered would interface with the existing signal system track circuits. Although at one time nearly 50 percent of the U.S. railroad mileage had cab signaling installed, the de-emphasis on high speed passenger trains subsequent to World War II led to the removal of most cab signal systems. Only 2700 miles of the Amtrak system has cab signaling with the vast majority being via ac coded track circuits and confined to the Amtrak-owned Northeast Corridor. From these data plus Amtrak expansion plans, the requirements for an overlay signal system were defined. Specifically, the new system would be required to:

1) Interface with steady dc, coded ac, steady ac, and coded ac track circuits

2) Be compatible with 60 Hz electric traction systems

3) Provide bi-directional operation capability

4) Permit safe operation for passenger train operation at speeds up to 160 mph

5) Provide capability for intermixed passenger and freight operation <u>without</u> requiring modifications to the freight operation signals or rolling stock.

Based on the examinations of all systems and on data received from suppliers and operators, the following additional constraints were imposed:

1) The minimum system satisfactory for operation at the higher speeds (above 80 mph) must provide at least 5-aspect cab signaling.

2) It would be at least desirable for the overlay system to be compatible with continuous welded rail (CWR) (no insulating joints) since upgrading of track to operate at high speeds would utilize CWR.

3) Since Amtrak now utilizes communications between 18 different railroads to determine Amtrak train status, it would also be desirable to provide train status information in real time to one or more Amtrak control centers.

STATE-OF-THE-ART TECHNOLOGY

Since the required separation between trains is primarily related to braking performance, the allowable speed for passenger trains can be higher than that of freight trains with given block lengths. The difference in allowable speeds is dependent on the length and weight of trains as well as their braking efficiency. Typically for a 4-aspect system, the speed limits for freight are 30, 45 and 79 mph while a metroliner Amtrak train could safely operate at 45, 60 and 150 mph based on safe separation distance (usually track and roadbed quality is the major constraint on setting the upper speed limit). The basic design of many existing ABS systems in the U.S. already provides block lengths compatible with high speed passenger train operation. The need for more than four aspects arises to provide intermediate indications between 60 and 150 mph to account for limitations due to track geometry and condition.

Of the many signal and control systems examined in the FRA study program, three of the European systems appear to be attractive from performance and cost standpoints. The Italian State railways have installed an overlay signal system between Florence and Rome which permits intermixed low and high speed traffic operation with the high speed trains operating at speeds up to 170 mph. The basic signal system previously installed is 50 Hz coded ac track circuits with code rates of 75, 120, 180 and 270 ppm. The overlay system is a second ac carrier at 175 Hz coded at 75, 120 and 180 ppm, superimposed on the existing system. The second carrier is detected only by the high speed passenger trains and provides (in combination with the 50 Hz signals) the speed limits peculiar to high speed operation. This system is easily overlaid on any signal system having existing coded ac track circuits but is not cost effective for other track circuit types. The NECIP has planned to install a system of this type for high speed operation.

The most economical overlay system examined is widely used in Europe where high traffic densities are not encountered. This system is comprised of inductive loops installed at block boundaries. The loops are passive devices which are tuned to one of several resonant frequencies by contact closures in the existing wayside signal system. The resonant frequencies vary from 500 to 5000 Hz and as many as eight discrete frequencies can be provided. The train borne equipment provides oscillators driving "fail-safe" frequency detectors in series with an inductive loop mounted in a position to pass over the wayside transponder unit. When the train passes over the wayside transponder, the detector at the frequency of the wayside transponder looses its drive signal due to the transfer of energy from the train borne inductor to the wayside unit. This system is very simple and cost effective, but does have the disadvantage that a train can only receive speed commands at block boundaries. This limitation is only a factor where high traffic densities are present such as in the Amtrak Northeast Corridor.

The most sophisticated system examined is used in Germany on its high speed intercity rail lines as well as the newer subway systems. This system utilizes continuous inductive loops laid between the running rails. The loops are normally 12.5 kilometers in length and transposed every 100 meters. Each loop is controlled by a wayside located microprocessor, and the microprocessors communicate to a single control center (or existing wayside signal system). In addition to two-way data exchange between the microprocessors and the train, the train determines its position and velocity within the loop section by counting the crossovers or loop transpositions via carrier nulls. This system is extremely flexible and provides an inherent capability to achieve completely automatic train control. It also provides the capability via the wayside microprocessor to vary the speed commands within a 12.5-kilometer section.

Another system contributing to the trend in railroad signaling and control technology is the new installation for the Stockholm Commuter Rail Network. Solid state electronics and microprocessors are combined in an automatic train control system for dense, high speed operations. It is separate from, but utilized in conjunction with, an extensive central traffic control system. The system enables trains to operate at speeds up to 125 mph and automatically compensates for such variables as curves, station approaches, required braking, and maximum acceleration. Carbone units are actuated by inert transponders set in the track and programmed for the maximum speed over a particular section of track. The train has an antenna pickup which is, in turn, linked with a processor/control unit. The latter is tied in with a combination indicator/control panel in the cab. As with other state-of-the-art systems, redundancy insures constant operation. For required deceleration, brakes are actuated automatically if the engineer does not respond. Self-checks for speed and direction have been built into the wayside transponders.

CONCLUSION

There are increasing indications throughout the world of a resurgent interest in railroads for the intercity movement of passengers. This can only be accomplished, however, through the establishment of higher speeds and reliability of performance. The emerging state of railroad signal technology will be an important bridge to these objectives. It is technology which is international in character. This is because of two factors: (1) The growing international structure of the signal manufacturing industry; and (2) The rising level of international communication as nations abandon local pride and prejudice.

The developmental trend is toward evolutionary progress, although probably at a faster pace. Because of the high cost of new systems and the tremendous investment in older yet adequate systems, introduction of more advanced technology, exemplified by the systems described above, will be on an overlay, or piecemeal, basis. In any case, the Shinkansen Line demonstrates that ever higher levels of safety and reliability will be reached.

As the railroad industry throughout the world emerges from an era of neglect and decline, it is utilizing the most advanced products of science and technology. Nowhere is this more evident than in the field of signaling and train control where new developments are leading to increased railroad capability and efficiency.

COMMENTS/DISCUSSION PERIOD FOLLOWING SESSION I

(R)* MR. THOMPSON: Thank you and why don't we turn now to the questions. If someone wants to ask a question, please identify yourself and your affiliation, ask the question, and then I will direct the questions among the panel.

(Q) MR. NOVOTNY: Dick Novotny from FRA. I would like to direct a question to Bob Watson. In your investigation of advanced train sets, Bob, did you develop any opinions on a passive tilt system versus active tilt systems?

(R) MR. WATSON: Would you repeat that. I'm sorry.

(Q) MR. NOVOTNY: In reviewing the advanced train systems that you did, a number of them had tilt systems. Most of them, I think, were active tilt systems. I'm wondering, did you have an opportunity to develop an opinion on passive tilt systems versus active?

(R) MR. WATSON: We've had some experience, I guess, in this country with the passive system in the case of the United Air-Craft Turbo trains, and we also looked at one other passive system, the Japanese pendular train. I guess, in answer to the question, Dick, I would have to say that there's an awful lot of complexity involved in the active systems that we've seen, and I have serious questions about our ability to maintain them properly. All of the systems that seem to be coming forth now are hydraulic. The degree of cleanliness required of filtering of the hydraulic fluids to keep the system functioning properly, as well as safely, leaves me with a few doubts as to our ability to handle it.

(Q) MR. LIST: Harold List, Railway Engineering Associates. Along the line you were now just discussing, how much consideration did you give to the relative merits of increasing the lengths of spiral as compared with tilting the car? In other words, I've been thinking about this problem somewhat, and it seems that if the spiral is too short, tilting the car is not going to cure the problem.

(R) MR. WATSON: Right. We did not give any consideration to changing track structure. That was not in our assignment, but certainly, that's recognized as part of the game; the longer the spiral the easier it is to anticipate. Consistency in spirals I think is also important so whatever system is chosen can have the right response and respond uniformly through the route that it is intended to travel. Ideally, all spirals would have the same rate of change of superelevation to simplify the design of the tilt system.

(Q) MR. LIST: Well, is this, perhaps, being considered by the track people because it seems that this is a sort of system consideration that perhaps fell through the cracks in the good old days of overly formalized railroad organization charts, but we ought to make sure it doesn't fall through again?

(R) MR. THOMPSON: Well, let's respond to it this way. Bob is looking generically at tilt body equipment and advanced technology. That means looking at a number of different systems that operate now seeing what kind of responses they have, but following the implications of what you're saying: if Amtrack is going to be operating tilt body equipment anywhere other than the Northeast Corridor, we suddenly start talking about worrying about alignments, spirals, curves, on how many different railroads, all of whom have their own standards and their own approach to life and all of whom have different maintenance standards. Within the Corridor Project, we have some direct control and involvement in controlling the spiral. Outside the Corridor Project I would say the range of variation is probably so large that it would be almost impossible to attack spirals, per se, as being the way to solve the problem rather than in conjunction with, as I think you suggest, tilt body equipment.

(R) MR. LIST: I think, perhaps, a better way to say what you're saying is that there are many railroad companies whose primary interest is not passenger comfort. So, what you have to do is to convince these people that the improvement in the spiral you would like to see is no handicap to the freight operations. You can't expect them to compromise the freight operations in favor of the passenger train. On the other hand, lengthening a spiral ... I can't quite conceive how that could even hurt a freight train. Somebody will have to decide what's a good target for the lengthening of the spiral. In other words, what's required. If you told these people what's required, the chances are they could incorporate this.

(R) MR. THOMPSON: I think, really, the issue more is who comes up with the money to lengthen the spiral and where do you find that, and then, who finds the money to maintain track at a higher and better standard from here on out. There's a coherent argument to be made. I think that you are better

*(R) and (Q) designate the response and question interchange, respectively, between the session panel members and the conference attendees.

off in investing your sophistication in the equipment to handle almost any kind of condition that you meet rather than trying to standardize the conditions of the road bed in the United States.

(Q) MR. LIST: I presume all this equipment is intended primarily for the benefit of the standing passenger? A guy that's sitting in the seat is not really all that much concerned about these things. It's kind of an interesting cosmetic, but it's the guy that's standing up that's got the problem.

(R) MR. THOMPSON: Well, I would say most of the investment I've seen in sophisticated equipment didn't have very many people standing up.

(R) MR. LIST: Well, that may be, but I'm saying that it's the standee that has the problem. Of course, if he's going to get into this curve - it doesn't make any difference whatever the lateral acceleration is we hope to produce in the curve - he's got to come up with the right angle if he's standing up. The roll coupling between this guy that's standing up on the floor is pretty poor. Now the body has a pretty good system for figuring out where straight-up is, but it takes time to react to it. It seems to me this is the most important consideration, and the whole discussion is the length of the spiral. It would, perhaps, be an appropriate activity to decide what really are the requirements for spirals, then when a man is laying a new piece of railroad, he ought to be perfectly happy to put down whatever number needed, but somebody has to decide what that number is.

(Q) MR. SIEMENS: Werner Siemens, Kaiser Engineers. I would like to change the subject. I have two questions, one regarding signaling, the other, concrete ties. Regarding signaling, I understand that in the survey that you have done investigating signaling systems worldwide. My question is that in the past many U.S. railroads have looked at electrification, and the conversion of signaling equipment has always been a horrendous cost in achieving this. Have you found any easy solution on how this could be accomplished based upon what you have learned in looking at European and other signaling systems? That's my signaling question. My concrete tie question is, I have been involved in projects overseas, and I have seen, for instance, a major railroad that had many, many miles of concrete ties. When a single truck on a car derailed and was dragged, it destroyed virtually miles of concrete ties. Have you looked into what the effect of a single truck derailment would have on the type of system you're installing on the Northeast Corridor?

(R) MR. TAYLOR: The signal question first. The answer is we have not found a simple answer to the installation of new signal systems in connection with electrification. As you are well aware, one of the most critical problems is electromagnetic interference. As part of our project, we have carried out considerable research in the area of EMI. We have found, however, that this is a very deep subject. I think you and I attended a meeting just two weeks ago in Annapolis on this very subject. We find that there is a great deal more work required to develop techniques and hardware for shielding the signal system on the vehicle from the interference of electrification.

(R) MR. THOMPSON: Let me introduce, if he needs any introduction, Jack Cann from the V.P. Operations, Canadian National Railways, who has some comments on the derailment.

(R) MR. CANN: Lou, that's your first mistake. Let's have it CN Rail, shall we. Maybe I could answer our questioner here a little about concrete ties. We've got one or two of them in the track up there. The ties, of course, are pretensioned. When that truck hits it, they literally explode. That's exactly what happens. So, you do destroy them. However, if you look at the total effect on it ... number one, we had a very serious derailment here, perhaps, six weeks ago where we did just exactly what you're saying. However, once the tension is released from the wires, it tends to pull the ties, therefore, the gauge, together, probably about a half an inch. What happened in that derailment, where it would have occurred, say, on a wooden tie structure, and therefore you would have substantial cars go off, the only car that went off was that car with the trucks. The gauge, while it was a little tight, was still sufficiently solid that the cars behind were able to, I presume, spread it just a wee bit and stay on the track. So, you stand to gain a substantial amount from not putting your train all over the right-of-way. The other thing is you have less derailments to start with because one of your causes are, in certain instances, rails overturning because of sharp curves and so on and so forth ... wide gauge and other elements of this nature in stable track and what have you. Overall, you're going to blow the ties up, in a figurative sense. I believe that even accepting that penalty reduces better overall operation. I didn't want to get into your thing, but I thought I would give you a little practical aspect.

(R) MR. GEDNEY: You're getting into the thing was welcome, but I think we have to say that we have had a derailment thus far on our ties, and the ties did not explode as everybody has predicted. What we had was the truck was able to ride the outside wheel between the Pandral fastener and the rail itself. It did, of course, destroy the Pandral clips, and in a couple of instances, crush the shoulder itself. Those ties which were damaged beyond leaving them in track were cracked, essentially, longitudinally, parallel to the strains. So, we have not had the explosion that we've all seen and heard about, which surprised us, but that did not happen. In so happening at this particular location in Connecticut where we had the derailment, it was the cause, by the way, of about a six-inch rainfall that washed gravel over the track. The train rode up over it and off the rail. That ability of the wheel to maintain its longitudinal balance kept the train, actually, from going over a steep embankment, so we were extremely fortunate: we, Amtrak.

(R) Mr. CANN: It would also depend on where your truck hit at the time. You were lucky it came down right outside the rail.

(R) MR. GEDNEY: Absolutely.

(Q) DR. KERR: Arnold Kerr, University of Delaware. What is shoulder width, the better shoulder width prescribed for the Corridor on curves and how did you arrive at the numbers?

(R) MR. HOWELL: We're talking about an eighteen-inch shoulder. As far as arriving at it, I can't give you all the calculations. From the standpoint of the resistance, ballast resistance, and all the other factors, we came up with the prescribed shoulder for the concrete ties.

(Q) MR. THOMPSON: Are there any other questions?

[Whereupon the discussion was concluded at 11:30 A.M.]

SESSION II : FIELD TRIP

FIELD TRIP

Session II of the conference consisted of a tour of Sante Fe-San-Vel's concrete crosstie plant in Littleton, Massachusetts, where the initial 1,100,000 concrete crossties are being manufactured for use in the Northeast Corridor Improvement Program.

The concrete ties are cast in four lines as shown in Figure 1. Each line is 600 feet long and has eight sets of parallel forms for producing 70 crossties in a row. At normal production, the plant turns out 2240 crossties per day.

The concrete, which is mixed by computer (Figure 2), is poured automatically and cured overnight. After the curing cycle, the ties are picked up, eight at a time, from the forms by machine (Figure 3) and taken to the storage area.

Quality control includes static rail-seat tests of a specified percentage of ties from each day's production (Figure 4.)

Finished ties are then stockpiled awaiting loadout for shipment.(Figure 5).

FIGURE 1. OVERVIEW OF PLANT

FIGURE 2. COMPUTER ROOM

FIGURE 3. PICKUP MACHINE

FIGURE 4. QUALITY CONTROL CHECK

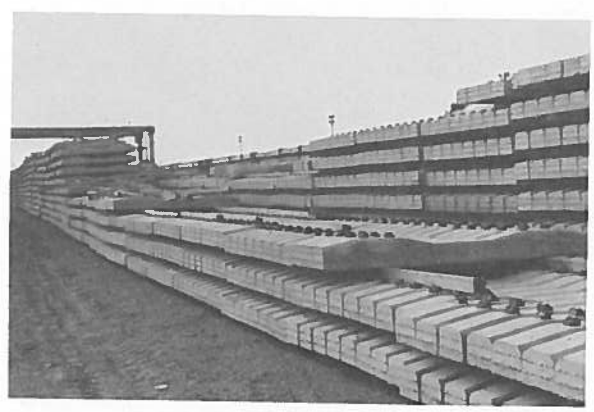

FIGURE 5. STORAGE AREA

EVENING SESSION

KEYNOTE SPEECH

Alan G. Dustin, President
Boston and Maine Corporation

KEYNOTE SPEECH

BY

ALAN G. DUSTIN

I would like to express my sincere gratitude for being invited to address the 15th Railroad Engineering Conference. I consider it a distinct honor and a pleasure to speak before a group who will have so much to do with the success or failure of the railroad industry in the years to come.

Although there are certain disadvantages in operating a railroad in the so-called "railroad ghetto" of the northeast where business is small but headaches are big, we do have one distinct advantage and that's being close to the Transportation Systems Center of the Federal Railroad Administration. We fully recognize the value of the work that's conducted at the Center and hold ourselves out to accommodate their railroad applications for test or other purposes. This arrangement has been helpful to the Boston and Maine and we believe that our location in their "backyard" has been helpful to them too. In my judgment, it has been a good relationship. We are grateful for their help and hope it continues.

Just a few comments about the size and scope of the Boston and Maine so those of you who are not familiar with it will have a better idea of what the Boston and Maine is all about. We operate about 1400 miles of railway which consists of about 2300 miles of track, serve five states and handle about 275,000 carloads of freight a year. Also 250,000 empties. We operate 327 commuter trains a day on a contract basis for the MBTA, serving points north, south and west of Boston, carrying some 33,000 passengers daily. Our employment stands at about 3300, of which one-third is devoted to passenger service. Exclusive of passenger, operating revenues for this year will run about $108 million. Our passenger operations consists of about $40 million a year. We own and operate 150 locomotives, and about 3500 freight cars. And for the MBTA, 45 locomotives and 178 passenger cars.

The Boston and Maine, which is one of the oldest railroads in the country, has had many good years and some very bad ones. Unfortunately, most of the bad years took place during the 50's, 60's and early 70's of this century. The recent history of the Boston and Maine has been mixed with some very bad management problems that took place in the mid-60's at which time a few top officers were convicted and sent to jail for the mishandling of railroad funds.

Although the Boston and Maine may have a checkered past, we do have some singular achievements - some good and some not so good:

1) At the end of 1979, we had achieved the 21st consecutive year experiencing a net loss.

2) We are the oldest bankrupt railroad in the world, having been in bankruptcy for over nine and one-half years.

3) We are the sole surviver of Conrail and the only railroad of the original seven bankrupts that did not become a part of Conrail and survived.

4) Like Lazarus of biblical times, we have virtually risen from the dead.

5) We are one of the few railroads to successfully obtain Title V loans from the Federal Railroad Administration for track rehabilitation which we are presently in the process of carrying out.

6) We have an opportunity to be the first railroad in modern times to effect an income-based reorganization under Section 77 of the Bankruptcy Act.

You see, we are a little bit different, so we have to do things a little differently to survive, and my comments tonight have to be viewed from that particular perspective.

As the clock is fast running out on 1979 and this decade, it is most appropriate to discuss the critical issues that the industry is likely to face in the 80's and what might be done through improvements in rail technology to help address these problems.

First, it might be well to take a quick look back over the past decade to see what the trends have been and in what direction and at what speed we might be moving. I say a quick look only to keep you from becoming discouraged.

Ten years ago, we had a solvent Penn Central, Lehigh Valley, Erie Lackawanna, Reading and Ann Arbor. They have since gone through the throes of bankruptcy and have been eliminated as railroad entities. The New Haven and the CNJ, who were then in bankruptcy, have also ceased to exist. Ten years ago, we had a solvent Boston and Maine (so to speak), Milwaukee and Rock Island. Today we have a bankrupt Boston and Maine, a bankrupt Milwaukee close to eliminating two-thirds of its property in an attempt to survive, and a bankrupt Rock Island that may never see the light of day.

Some might say that what is happening in the midwest is simply a rationalization of the railroad system by the process of eliminating redundant lines not serving any useful purpose. And yet, the fact remains that the Milwaukee and the Rock Island were constructed and operated for many profitable years on the basis of a sufficient volume of traffic to support their operations. That volume of traffic is still being moved, but not by railroad, but by the other modes of transportation.

During the past decade, the average rate of return on net investment for the United States railroad industry was less than 2 percent. Needless to say, the past 10 years have not been good years from a financial standpoint for the railroad industry.

In my judgment, the critical issues that the industry is likely to face in the 1980's are the same basic issues that the railroads have had to face during the past 10 and even 20 years and I view them as follows in their order of importance:

1) Unfair subsidized competition in the form of highway trucking and waterway barge lines which reap increasing benefits from the Federal and state governments and continue to cause a diversion of traffic from the railroads.

2) Failure to improve labor productivity.

3) Excessive and strangulating Federal and state regulation. Not just the type of ICC regulation that is presently being addressed in Congress, but the myriad of other regulations that continues to impose additional and heavy burdens on the railroad industry.

Advanced technology can do a great deal to help us better cope with these problems and hopefully mitigate them to a large extent.

I believe the railroad industry is embarking on a critical period in which actions that will be taken over the next few years will set the direction and tone for the industry for decades to come. The apparent failure of Conrail to meet up to financial and operating expectations, the recent demise of the Rock Island, the restructuring of the Milwaukee and the financial plight of many of the marginal and so-called profitable railroads in this country are setting the stage for activity and action to be taken by both the Government and the industry. Deregulation, which in one fell swoop could entirely restructure the rules by which all railroads have operated for years, is a major looming issue. One with many positive, but at the same time, negative and potentially detrimental provisions.

The anxieties, conflicts and consequences during this period of time will have either one of two affects on the railroad industry. Either we will adjust to the many faceted problems and survive as a stronger, healthier industry; or, if we fail, I suspect that soon we will be on the way to total nationalization of our railroad systems.

The initial reaction of the industry to these pressing problems has been mixed in my mind. I believe that in many ways railroads tend to act more like railroaders operating and making decisions in a vacuum of independency and less like businessmen recognizing the need for cooperation in an industry of total interdependency. Acting like businessmen, making policy and operating decisions on a business-like basis in a true spirit of unity, will be the route and foundation of any potential survival that the railroad industry might have in the 1980's or beyond. It is primarily from this point of view that I visualize railroad research and development efforts.

As managers of an organization with such a high level of fixed plant and equipment investment together with a high ratio of labor expense, the bottom line of the railroad industry can best be improved from a research and development standpoint.

One good example: Although the price of diesel fuel has doubled since the first of this year and has increased six-fold since the energy crisis in 1973, I view the entire energy situation as a golden opportunity for potential improvement to the railroad industry. The inherent engineering advantage railroads have over its highway competitor in the efficient use of fuel, coupled with the obvious need to become more self-sufficient through the burning of coal when our Government gets its act together, gives us the basic foundation for increasing our volume of traffic and recovering business that has been lost to our highway competition in the past.

In order to exploit this potential and to hold our own against our competition, from a technological standpoint we must do a much better job on improving the fuel efficiency of our diesel locomotives, especially in over-the-road train movements. I recently read a statement that indicated that there was a potential fuel efficiency improvement of 27 percent in the rail industry as compared with an 18 percent potential for highway trucking. I am convinced that we can do a much better job in further improving the fuel efficiency of our mode of transportation.

Certainly, ideas like fuel savers need to be expanded and improved upon, but more importantly, new research should be started immediately into developing new highly-reliable, fuel-efficient motive power for the railroad industry.

There has been very little done in this area to develop new prime movers which are truly fuel-efficient, low maintenance and totally reliable engines. The EMD 645 series engine block and the current GE Bessemer Cooper offerings were designed and developed long before fuel became a major concern to the railroad industry. The economics of fuel, relative to overall operating costs, have changed considerably during the past 6 years and it is time to re-evaluate the type of motive power that is being offered for use in our industry. The fact that we only have two domestic locomotive manufacturers, who usually have a number of locomotives back ordered, really doesn't provide the necessary competitive edge that ordinarily would bring about technological improvements. I think we have suffered as a result of this and continue to suffer. This is not intended to be criticism against the two present locomotive manufacturers, but a realistic evaluation of the present situation.

One of the brightest spots on the railroad horizon is the increasing success and size of the research effort being directed toward the railroad industry and it's a darned good thing too. Heavier wheel loads are crushing our rail, faster trains pound the subgrade, and high horsepower locomotives gulp fuel like steam engines drank water. The problems, or opportunities, are almost endless.

But, the challenges are not all in finding scientific solutions to problems. One of the greatest challenges facing any scientist or researcher is keeping both of his feet firmly on the ground while reaching for elegant solutions to vexing problems. Unless the work done by researchers is practical and the results are timely, support for the effort will be difficult to maintain.

But even practical, timely discoveries do not in themselves ensure a successful research program. The final line, and perhaps the most difficult, is to convey the knowledge gained through research to others and through others to actually eliminate the problem. The challenge has been met only when this last difficult step is complete. All too many pieces of fine research gather dust on a shelf because the author was satisfied to find the solution, but did little else to solve the problem. It is in this area that organizations like the Transportation Systems Center and the Research and Test Department of the Association of American Railroads have great opportunities.

You have probably gathered that I am concerned about the rate at which the industry is assimulating the products of research. I am also concerned about the total amount of research being done. While it is difficult to measure research expenditures from all sources, it appears that railroad external expenditures for research amount to less than 0.1 percent of operating expenses and total railroad research expenditures, including funds from the Government, amount to less than 0.2 percent.

By contrast, annual expenditures for the subjects of research are staggering. Railroads spend $8 billion for maintenance last year. They installed one million tons of rail for $500 million. They installed 27 million cross ties for another $800 million, and gulped 4 billion gallons of fuel worth billions more. These individual items represent only a small portion of the $21 billion railroads spent in operating expenses last year, much of which can be reduced through research to develop better materials, practices and products.

What benefits might be expected from research in only the three areas I just mentioned? It is reasonable to expect the cost of maintaining rail to decline by 5 percent due to the development of harder rails. Value: $25 million a year. Research into various concrete, metal and wood ties and tie fastenings could produce another 5 percent reduction in tie costs. Value: $40 million a year. Fuel economy, through better practices and products, should surely reduce fuel consumption 5 percent. Value: $200 million a year. There is certainly room to speculate about the accuracy of my estimates, but I doubt that many experts would call them unreasonable. In total, the estimated value of research in the three areas I mentioned is $265 million a year, or more than the industry's net income in 1978. However, to obtain these benefits, we must not only find a solution, but we must also actually solve the problem.

The bottom line of research and development efforts of both the railroad industry and the Government should be carefully directed at what needs to be done to improve the overall efficiency of the rail industry. If we are going to survive, we of the railroad industry must begin to act like businessmen and managers of massive fixed plant and rolling stock investments and look to ring every dollar out of what the Government and private industry has to offer in the way of technical and analytical help which will allow the improved efficiency of the assets that we need to run our industry.

Time is of the essence.' If we do not address these problems and address them effectively in the near future, the problems of policy and Government regulation, railroading as we know it today will certainly be short-lived. It must be recognized that we are all an inter-related independent industry and the financial health of any of the one components directly affects that of the whole.

Thank you for your time and interest.

Alan Dustin is President of the Boston and Maine Corporation. He was appointed to this position in 1974 after serving as Executive Vice President from 1973 to 1974.

Prior to his current position, Mr. Dustin worked for the Delaware & Hudson Railway. Except for a 2-year stint with the U.S. Army in 1949-1951, he worked there from 1947 to 1968 serving successively as a baggage clerk, telegraph operator, station agent, train dispatcher, assistant trainmaster, assistant to General Superintendent, trainmaster and assistant to President and General Manager. From 1968-1970, he worked for the Erie Lackawanna Railway as assistant to Vice President of Operations and Maintenance in Cleveland and as Division Superintendent in Scranton, Pennsylvania. From 1970-1973, he worked for the Bangor & Aroostock Railroad as Vice President and Executive Vice President. From 1971-1973, he was Chairman of the Board at the Pittsburgh & Shawmut Railroad.

He is a member of the Association of Railroad Superintendents, the National Freight Traffic Association, the New England Council, the New England Railroad Club, the Transportation Association of America and President of the Massachusetts Railroad Association.

TUESDAY, OCTOBER 23, 1979

SESSION III : AN OVERVIEW OF FREIGHT TECHNOLOGY ADVANCEMENTS, OBSTACLES AND FUTURE OPPORTUNITIES

Chairman: J.L. Cann, Vice President of Operations Canadian National Railways

INTRODUCTORY REMARKS

BY

J.L. CANN

I am particularly pleased to have been asked to chair Sessions III and IV of this conference because the subject of railroad research has long been a key interest of mine.

I must admit there have been times over the years when a very few of us were like the proverbial voice crying in the wilderness. Too many railroads, it seems to me, wanted to benefit from the results of research, but were not prepared to participate in the necessary programs.

Research, by its very nature, is usually a long, arduous and costly business. For that reason, it makes eminent sense that major programs be undertaken jointly. In the past it has been a source of disappointment to many people such as Dr. Harris that a relatively small number of railroads in North America have participated actively in research projects, but this seems to be improving.

Now I don't want to be accused of preaching to the converted, and I think most of the railroads present here have "paid their dues" so to speak, but I do want to say loud and clear that we'll all learn more things more quickly if the various research projects are fully supported by all of the industry.

And let me make it equally plain that the type of research I'm talking about is not pie-in-the-sky, intergalactic time-warp stuff. It's not even linear induction or magnetic levitation. I'm talking about research that solves the problems of the day.

Such as, how big should a rail car really be? And how much usable power can a locomotive generate efficiently? And what will all this weight and power do to the track?

We've come a long way in railroad technology in the past 20 years. We know a lot more about most things that go into and onto a railroad. In fact, there's a school of thought that says our biggest problem today is not so much finding new technology as it is incorporating what we've got smoothly into what is often a traditional and old-fashioned work environment.

There's some truth to that. We tend to be timid about implementing new ideas. We want to wait and see, we need to be sure about every last detail.

Now I'm not suggesting impetuous adoption of every new idea. I'm not saying innovate and to hell with the cost and the consequence. But I am convinced that we need to do a more thorough analysis on each new development and then make a conscious decision about it.

I saw a poster once which had a very good message on this subject. It was very simple, but very deep. Think about it. It said "Not to decide...is to decide."

I think we'll be facing more and more decisions in the future, but let me not get ahead of the game. We have a panel of six very capable speakers here who will address this whole subject, and they'll do it in bite-size chunks so that we can all digest what's being said.

J.L. Cann became a full-time railroader in 1944 after several summer stints on engineering department survey crews of the CN. A westerner, he was born in Winnipeg and graduated from the University of Manitoba with a degree in Civil Engineering.

Still in the engineering department, he served as division and district engineer on the Mountain Division, and as project director on construction of the hump yard and approach lines in Toronto. In 1965 he was loaned to the Ontario Northland Transportation Committee as managing director. On his return he was appointed assistant general manager of the Great Lakes Region, and a year later, became general manager of the Prairie Region in Winnipeg.

For 2 years he was a consultant on World Bank missions to Mexico and for CANAC Consultants Ltd., a CN subsidiary, in St. Lucia, British West Indies, Pakistan and Mexico. In 1972, he was appointed assistant vice-president-Operations at Montreal and assumed his present duties as vice-president-Operations in 1974.

Mr. Cann is the Canadian representative on the operating and transportation general committee of the Association of American Railroads, and is on the executive committee of the Railway Association of Canada; and chairman of its operating committee.

He is a member of the Canadian Railway Club and is a Director of Northern Alberta Railways Co., and The Shawingigan Falls Terminal Railway Company. Mr. Cann was just recently admitted to the Order of St. John.

RECENT ADVANCEMENTS AND FUTURE TRENDS IN TRACK STRUCTURES RESEARCH

BY

WILLIAM J. RUPRECHT

Mr. Ruprecht presented very quickly a number of slides that dealt with the advancement of car design over the years in such areas as flat equipment, box equipment, coal cars, and covered hopper cars. The slides showed on an industry-wide basis how the various cars evolved to fit into the changing railroad environment.*

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*A formal paper was not prepared for this document and therefore could not be included.

RECENT ADVANCEMENTS AND FUTURE TRENDS
IN TRACK STRUCTURES RESEARCH*

BY

H. DAVID REED**

Track research in this country has been experiencing increased emphasis in the past 5-8 years, brought about in part by an ever increasing accident rate largely due to the inevitable deterioration of track conditions resulting from years of deferred maintenance (see Figure 1). The underlying challenge of track research activities is to develop a realistic level of understanding and knowledge base which can lead to the development of improved track structures that can tolerate longer periods of heavier utilization before requiring costly maintenance.

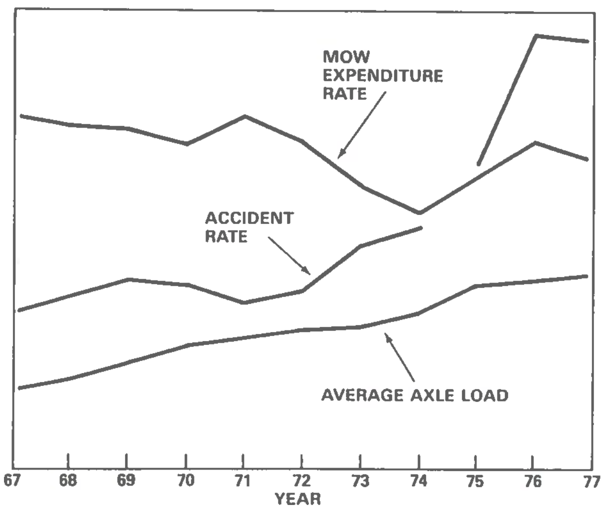

FIGURE 1. TRENDS IN ACCIDENTS, LOADS AND TRACK MAINTENANCE, 1967-1977

The recognition of the need for this research has long been shared by both the Government and the railroad industry as reflected in the joint Government-industry research activities such as Track Train Dynamics (TTD), the creation of the Facility for Accelerated Service Testing (FAST) at Pueblo, and the existence of a wide range of industry-sponsored experiments and testing activities concerning alternative product performance under in-service conditions. A recent survey[1] of industry-sponsored research experiments reveals a wide variety and geographical distribution of field installations covering such components as ties, fasteners, grade crossings, and metallurgies.

The extent of these installations is illustrated in Figures 2, 3, and 4, showing the location of various installations of fasteners, concrete ties, glue laminated ties, and reconstituted ties.***

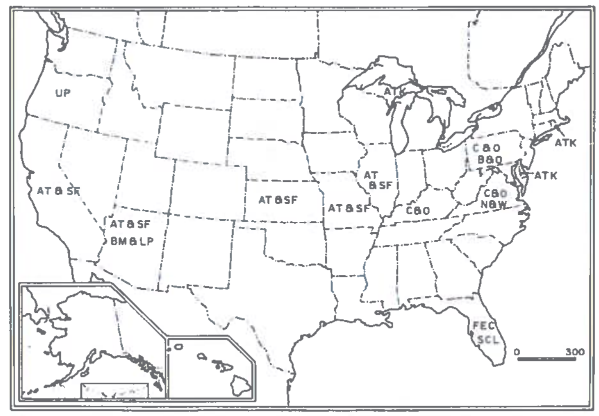

FIGURE 2. GEOGRAPHIC SPREAD OF FASTENERS

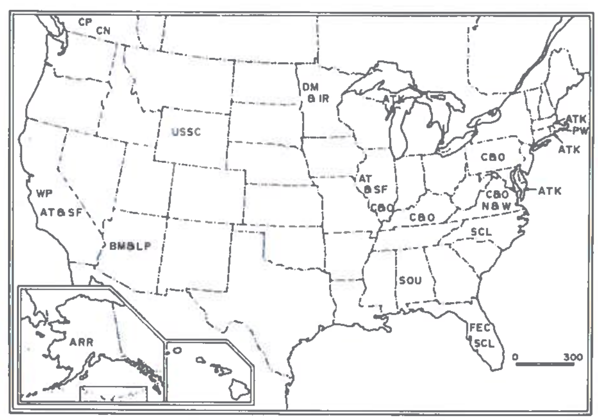

FIGURE 3. GEOGRAPHIC SPREAD OF CONCRETE TIES

*Prepared under sponsorship of the Federal Railroad Administration, Improved Track Structures Research Division.

**Chief, Track Systems Branch, Transportation Systems Center.

***Typical of the observations resulting from these surveys are those from a site on the Conrail system where 94 of the original 99 glue laminated ties in this "experiment" are still in excellent condition after 25 years of service and 1250 MGT.

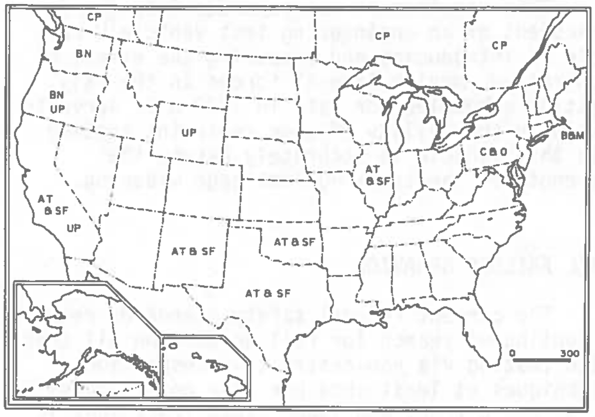

FIGURE 4. GEOGRAPHIC SPREAD OF RECONSTITUTED AND GLUE LAMINATED TIES

Original Federal track research activities were initiated by the Department of Commerce under the High Speed Ground Transportation Act of 1965 and continued under the then newly created (1966) Federal Railroad Administration (FRA). In 1970, the passage of the Rail Safety Act extended the FRA responsibility to establish and enforce track and equipment standards. Initial track standards were promulgated in 1971 and were based on accepted practice as developed over the years by the railroad industry. These standards attempted to specify a practical lower bound, or tolerable level of "good practice," to ensure a uniform level of safety. Clearly, the next challenge then was to understand the physical relationships between good practice and safety which could lead to the development of even more effective measures for increasing rail safety.

A paper by D.P. McConnell,[2] delivered at the 1974 annual ASME winter meeting in New York in November, 1974, suggested that track research should be accelerated to:

1) Develop the analytical and experimental techniques required to predict and measure track behavior under service loads

2) Determine the mechanisms of track degradation and failure and their relation to track behavior

3) Develop cost-effective methods of significantly improving the performance of track while reducing maintenance requirements.

These elements form the core issues in the investigation of the mechanics of track behavior. Research in these areas then would form the foundation for improvements in track safety and performance.

During 1974, the Federal Railroad Administration (FRA) actively embarked on an extensive research program aimed initially at gaining a better understanding of the mechanics of track safety and serviceability. The FRA has been successful in the arduous task of building the necessary knowledge base which now supports a matured research program which is directed at aiding industry efforts in:

1) Improving the safety of train operations by reducing the frequency of track related derailments

2) Improving the serviceability of the track structure through:

   o more effective maintenance techniques, and

   o more durable, yet economic, track structure and component designs.

To date, the major accomplishments in the supporting research have been in the areas of:

1) analyzing service loads and rail capacity

2) understanding rail failure behavior

3) identifying critical vehicle track interaction processes.

ANALYSIS OF SERVICE LOADS AND RAIL CAPACITY

The characterization of the service load environment of the track and the subsequent analysis of the response of the track structure to such loads is fundamental to the development of rational improvements in track performance.

During 1976-1979, a series of investigations and analyses has focused on continued track structures laboratory tests, tests on revenue track, and tests at the Transportation Test Center (TTC) in Pueblo, Colorado. Perhaps the most significant results from these tests have come in the area of improved instrumentation and the ability to accurately relate wheel/rail loads to ultimate track strength for train consist mixes and speeds.

Typical outputs from these analyses[3,4] are shown in Figure 5, where L/V exceedance curves have been developed from the simultaneous measurement of both lateral and vertical loads for various conditions of track and consist configurations. The development of statistically significant data on the probability of simultaneous vertical and lateral load combinations marks the first substantial advancement from rule of thumb allowances for curving forces which came from the earlier efforts of the Talbot Committee over 35 years ago.[5] It is the generation of such data which has enabled the coupling of service environments with track structural behavior that is needed for rationalization of track structural requirements.

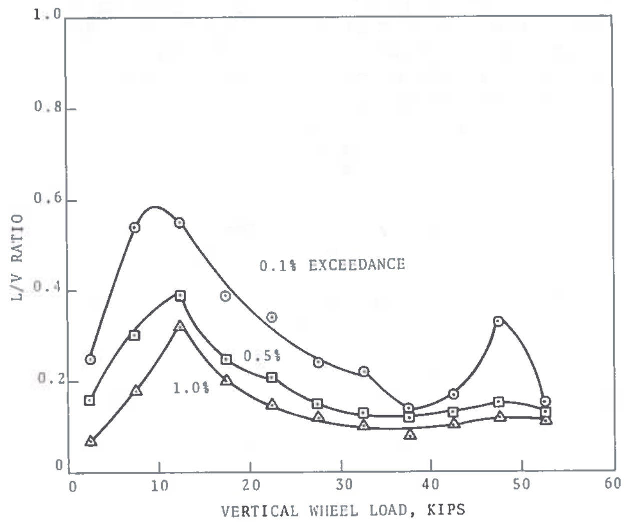

FIGURE 5. FREQUENCY OF EXCEEDANCE CURVES FOR L/V RATIO VERSUS VERTICAL WHEEL LOAD, TANGENT BJR TRACK, ALL TRAFFIC, ALL SPEEDS, ALL MEASUREMENT SITES IN TEST SECTION

The characterization of track response to combined loads has involved numerous analytical and experimental studies and tests. The most recent of these tests are being conducted by the AAR at their track structures laboratory in Chicago. These tests will evaluate the effect of various combinations of static loadings and track conditions on the track stiffness.[6] In addition, recent tests of the response of contemporary locomotives to track irregularities have resulted in comparisons of the static and dynamic gage retention behavior of track. This data[7] suggests that static load response may provide an accurate measure of the response of the track to actual dynamic train loads. This finding has provided corroboration for the earlier analyses of rail restraint behavior which have led to the evaluation of the feasibility of setting performance levels on rail restraint.[8]

RAIL RESTRAINT

Applying the data acquired on the nature of service loads and the response of the track to such loads, a number of advancements have been realized in the ability to predict response/ultimate loading conditions based on non-destructive compliance testing techniques. These advancements have culminated in a preliminary performance based specification for gage restraint.[9] Central to this concept is the utilization of quasi-static measuring of the resistance of a track structure to gage widening to evaluate the capacity of the track to retain gage under train loads. This specification has now reached the stage of gathering field data on non-destructive evaluation techniques.

This requirement has expanded into the development of an engineering test vehicle[10] capable of introducing and measuring the effect of controlled, moving lateral forces in the rail. Testing scheduled for late in 1979 will serve to evaluate the ability of gage restraint testing via this vehicle to accurately assess the strength of the track against gage widening.

RAIL FAILURE BEHAVIOR

The current Federal safety standards require a continuous search for rail defects on all track with testing via non-destructive inspection techniques at least once per year on all class 4, 5, and 6 track and lower class track that is used in passenger service. While this standard provides a uniform requirement on inspection, emerging patterns of defect population statistics, accumulated from railroad experience, have led to a review and evaluation of the possibilities of techniques for adapting rail inspection strategies to monitor the actual behavior of flaws in rails. These approaches increase the potential for improvements in train safety at reduced or equal cost.

One of the promising concepts now under study involves redistributing inspection resources based on previous detection histories. Such a redistribution could be accomplished by decreasing the inspection interval on lines that exceed a maximum allowable defect count. Figure 6 illustrates the application of this "control" concept to a first-order simulation model[11] of a rail line on which defects appear in numbers that increase rapidly with cumulative gross tonnage. Such models derived from actuarial defect data will be used to assess the impacts of strategies that are found to be practical from an operational viewpoint.

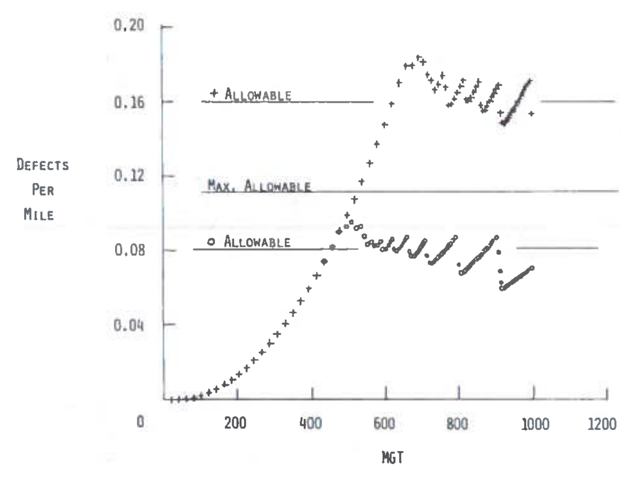

FIGURE 6. BEHAVIOR OF AVERAGE DEFECT RATE

RAIL STRESSES

Extensive studies have been made of the stresses induced in a rail by wheel passage, and procedures are now available for predicting the longitudinal stress for varying combinations of lateral and vertical wheel load.[12] However, such calculations show a broad sensitivity to typical variations in service conditions. This sensitivity results in a wide scatter in the predicted growth rates of such critical defects as transverse defects and compound fissures. Similarly, the critical sizes of these defects which would result in rupture in service show equally wide dispersions.[13] Since these types of defects can cause derailments if left unchecked, it is essential to have some method for predicting their initiation times and growth rates to establish baseline inspection intervals and to evaluate the potential effects of remedial actions.

Low ambient temperature and residual stress buildup can substantially influence crack initiation and growth.[13,14] However, in the case of residual stresses, it is currently beyond the state-of-the-art to accurately predict such stresses by numerical analysis. Therefore, over the past year, a limited number of rail samples in the 80 to 300 accumulated MGT range were collected from the FAST track at Pueblo and from an operating railroad. These samples were analyzed by applying a matrix of strain gages to a cross-sectional slice of rail and then taking measurements as each cell in the matrix was cut free.[15] Figure 7 illustrates the principal in plane residual stresses in the 83 MGT sample, and Figures 8 and 9 are plots of the residual axial stress contours in the 83 and 270 MGT samples.[16]

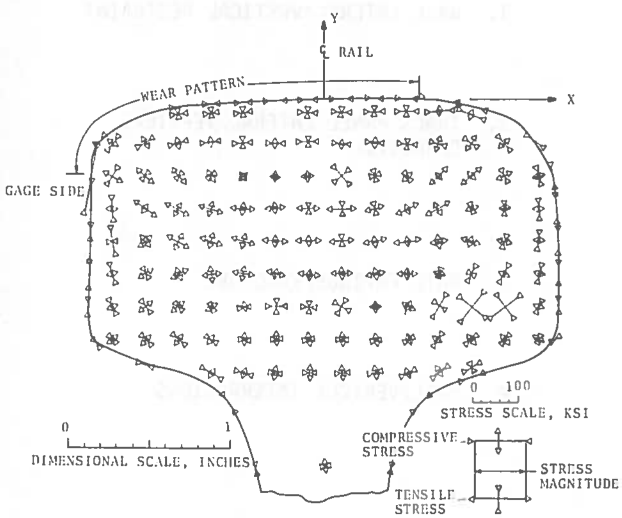

FIGURE 7. IN-PLANE PRINCIPAL STRESSES SPECIMEN NUMBER 1 [83 MGT)

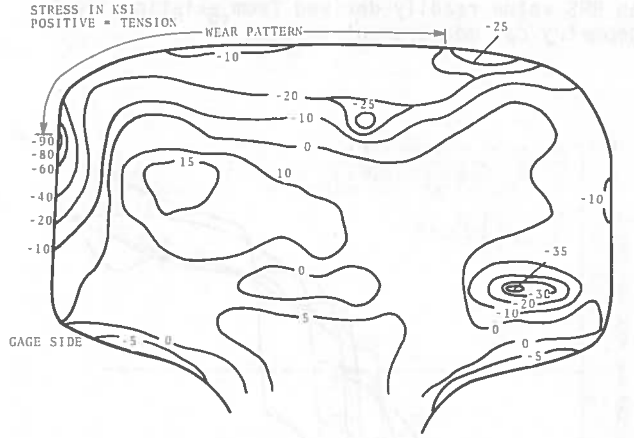

FIGURE 8. AXIAL RESIDUAL STRESS AT 83 MGT

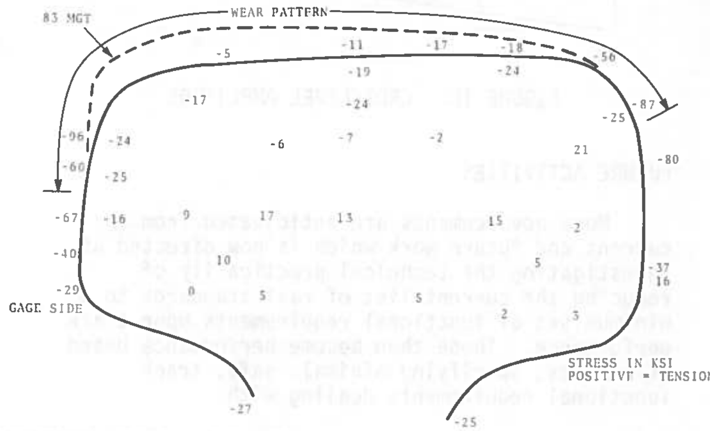

FIGURE 9. AXIAL RESIDUAL STRESS AT 270 MGT

VEHICLE AND TRACK INTERACTIONS

Based on continued analyses of track and train interaction, significant advances have been achieved in understanding modeling, testing, and predicting the response of various vehicle types to a wide variety of operating and track geometry conditions.[17,18,19]

Perhaps most significant among the results of these works is the simplication of the measures needed to identify the critical combinations of track crosslevel descriptors that contribute most heavily to harmonic car body rock-n-roll.[18] To date, excessive crosslevel variations have been cited most often for accidents above 10 mph. (Ninety-five percent of these accidents occurred on classes 1, 2, 3, and 4, and 81 percent of the vehicles involved had center of gravity heights greater than 70 inches.) Shown in Figure 10 is the resulting car body roll angle as a function of periodic crosslevel amplitude variations. An analysis of this type of response under varying conditions of periodicity has shown that a simplified indicator of allowable crosslevel conditions is an RMS value readily derived from existing track geometry car measurement systems.[18]

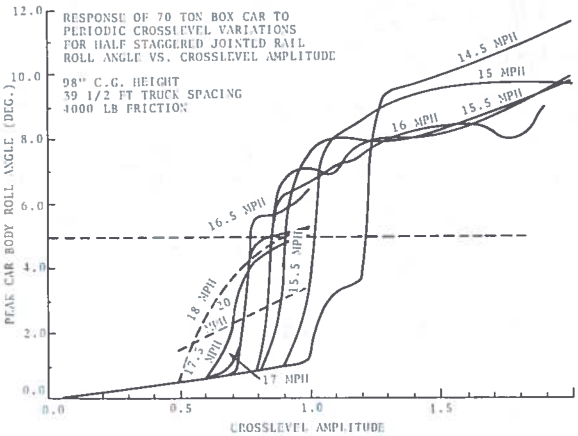

FIGURE 10. CROSSLEVEL AMPLITUDE

FUTURE ACTIVITIES

More advancements are anticipated from the current and future work which is now directed at investigating the technical practicality of reducing the current list of rail standards to a minimum set of functional requirements upon track performance. These then become performance based statements, specifying minimal, safe, track functional requirements dealing with:

1) Rail Restraint
2) Track Panel Restraint
3) Rail Fatigue
4) Track Train Interaction
5) Ballast and Subgrade
6) Track Components.

A cross-mapping of these new statements with current standards is shown in Table 1.

As the understanding and definition of these new performance requirements progresses, it is essential that their implementation and cost impacts be thoroughly understood. This understanding must reflect a careful analysis of the manner in which maintenance-of-way (MOW) expenditures are currently determined by the railroads. Working with the industry through the American Association of Railroads (AAR), the critical elements of the MOW data are being identified and will be analyzed to determine the extent of correlation existing between MOW decisions and operational measures of effectiveness which are relatable to safety, speed, tonnage, etc.

Because these statements represent the technical basis for recommendations of potential new standards, they are being developed jointly with railroad industry researchers. Subsequently, they are reviewed for operational feasibility with the industry through their chief engineering officers. When mutual understandings have been achieved, the research will then turn toward an extended period of field testing to determine and measure the extent of their effectiveness and practicality as viewed from

TABLE 1. TRACK PERFORMANCE SAFETY STANDARDS

FAILURE MODES	EXISTING TRACK SAFETY STD'S	PROPOSED PERFORMANCE STD'S
WIDE GAGE RAIL ROLLOVER SUDDEN WIDE GAGE SINGLE RAIL SHIFT	GAGE CROSSTIE FASTENERS	1. RAIL LATERAL/VERTICAL RESTRAINT
TRACK BUCKLING TRACK SHIFT BALLAST FAILURE SUBGRADE FAILURE	ALIGNMENT CWR BALLAST GENERAL BALLAST DISTRUBED TRACK CROSSTIE TRACK SURFACE	2. TRACK PANEL LATERAL/VERTICAL CAPACITY
INTERNAL FLAWS RAIL RUPTURE	RAIL JOINTS BALLAST GENERAL BALLAST DISTURBED TRACK DEFECTIVE RAILS	3. RAIL FATIGUE/FRACTURE
WHEEL CLIMB WHEEL LIFT RIDE VIBRATIONS CAR/TRACK SEPARATION	CROSS LEVEL SUPER ELEVATION ALIGNMENT RAIL END MISMATCH RAIL END BATTER CURVES RAIL JOINTS	4. RAIL/VEHICLE INTERACTIONS
BROKEN SWITCHES/FROGS WORN SWITCHES WORN FROGS	CROSSINGS TURNOUTS SWITCHES FROGS	5. COMPONENT PERFORMANCE

the standpoint of safety, compliance, and maintenance requirements. The critical point of such tests being that these requirements must demonstrate an improvement in conditions that currently exist. Such evaluations must be based on a comparison of current maintenance needs and compliance requirements as they occur over extended periods of in-service conditions and at high tonnage accumulations.

This process of identifying "standards maintenance requirements" is scheduled to begin in 1980. Test planning for this activity has been initiated through analytical comparisons of the experiences gained at industry field sites (previously mentioned) and information developed at the Industry/Governmental Facility for Accelerated Service Testing (FAST).

FAST will retain its place as a key element in future research, as its unique test environment continues to accumulate tonnage at roughly 10 times the rate experienced in revenue service, thus greatly reducing the extended period of time needed to reach wear-out conditions.

Typical of the key findings from the FAST activities are the in-depth analysis of concrete tie and fastener loads.[20]

This provides a credible means of identifying track structural components that have the highest potential for reducing maintenance needs, and to verify the practicality and in-service effectiveness of the evolving performance requirements.

Track strength measuring devices and research inspection vehicles now being constructed to survey track conditions will supply information for the development of improved criteria for visual inspection and identification of failed track components.

Under the auspices of the TTD Track Strength Committee, a system for applying lateral and vertical loads to the rail to investigate non-destructive methods for predicting rail restraint limitations is being assembled. Field testing is now scheduled to begin in late 1979, and the results will be used to verify the viability of the functional requirements which have been developed to describe and control rail restraint limits.

Work has just begun on the design of a pulsed radar system which can profile sub-ballast conditions to identify potential water table conditions that could affect track vertical stiffness. If a device could be used to give such an advance warning, them immediate, remedial actions could be planned to prevent more serious, and costly degradations.

The ongoing investigation of rail defect occurrence patterns is expected to provide a basis for an improved inspection allocation strategy within the next 2 years. As the statistical analyses of service data are completed and potentially effective strategies are suggested, work will shift to pilot tests which will be guided by extensive rail defect data bases in order to evaluate alternative inspection strategies.

Experimental evaluation of residual stress will be continued to expand the limited samplings achieved over the past year. Parallel experimental efforts will be aimed at collection and metallurgical analysis of service failures to establish critical crack-size ranges. The pilot tests will investigate the rates of growth of defects with and without remedial action taken upon them. All of the information developed by this part of the rail integrity work will be combined to assess the effectiveness of remedial actions, and to determine the period of time and conditions under which various flaws can be expected to reach critical size. The logical final set in this effort will be to test the entire process under operating conditions.

Work in the vehicle dynamics area has seen an exhaustive and comprehensive series of tests both on the Chessie system[21] and at TTC[22] to investigate vehicle responses to known track perturbations. This work is an essential element of the rail vehicle dynamics performance requirements. It has suggested the need for a new, permanent capability dedicated to identifying critical response conditions of existing and new rail vehicles in a controlled environment under representative track conditions. To be known as the Safety Assessment Facility for Equipment, or SAFE, it will be dedicated to supporting the railroad industry for their use in the design, development and improvement of all rail vehicles.

Thus, it can be seen that the immediate thrust of Federal track research today is a coordinated effort directed at the development of an improved understanding and formulation of performance requirements that will directly affect safety, while providing the railroads increased flexibility in planning and selecting maintenance activities to improve the current level of track safety.

REFERENCES

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MANAGING FOR CHANGE IN A COMPLEX OPERATION

BY

HUGH RANDALL

The program agenda indicates that I will be talking about "recent advancements and future trends in intermodal/classification yard technology." I will not. The program also indicates that this is a railroad engineering conference - and I am not an engineer. That is, not in the traditional sense; however, I am a manager whose principal function is engineering change within a complex operation - and that is what I wish to discuss with you this morning.

As most of you are aware, Conrail was created from seven bankrupt railroads on April 1, 1976. The reasons for their bankruptcies are numerous but two of the most important were: (1) the railroads were located in a sector of the country - the northeast - that had been growing at a much slower rate than other sectors of the country (and still is); and (2) with the construction of the Interstate Highway System, rail's share of the intercity transportation market declined significantly.

In taking over seven bankrupt properties, Conrail inherited the responsibility to operate railroads whose track and equipment had been severely undermaintained due to capital scarcity during the preceding decade. Also, many managerial aspects of these properties had been allowed to atrophy. For example, the ratio of line supervisors to employees increased significantly as supervisors were furloughed to conserve funds (to ratios 2-3 times that of profitable railroads); and organizations such as Capital Planning and Construction Management virtually ceased to exist because there were practically no capital funds available.

Another element that made Conrail's turnaround effort more challenging was the size and complexity of the combined properties.

Conrail originates, terminates or carries almost 22 percent of the Nation's rail traffic. It has more than 4000 locomotives, in excess of 200,000 cars on-line at most times and at the time of conveyance had more than 95,000 employees. Conrail's 17,000-mile route structure is also considerably more complicated than the route structure of most other large railroads.

To transform this complex, physically debilitated, financially non-selfsustaining rail operation, Conrail organized and launched a variety of improvement programs.

My comments today will focus on only one aspect of these "turnaround" programs - relating to cost reduction and productivity improvement. Efforts focusing on revenue and contribution improvement have also been launched and are paying significant dividends (or in some cases are expected to begin paying significant dividends in the future). For example, Conrail has been in the forefront of the industry in working to develop an implementable program to modify rail regulatory requirements so that more flexibility in pricing and service patterns can be achieved.

In the area of cost reduction/productivity improvement, we have focused on three principal areas:

1) Improvements that can be obtained through capital expenditures

2) Improvements that can be achieved through the execution of new or revised labor agreements

3) Improvements that can be achieved through more effective management.

In terms of improvements through capital expenditure, or the $2.3 billion drawn down from the Federal Government through June 30, 1979, Conrail has devoted more than $1.9 billion to physical asset improvements (Table 1). The rest has been used to cover operating losses and to provide working capital. Additionally, Conrail has obtained over $550 million in private sector equipment financing through the end of June 1979.

TABLE 1. FEDERAL INVESTMENT IN CONRAIL AS OF JUNE 30, 1979
($ Millions)

Funds Invested in Conrail		$2,298
Funds Used by Conrail for Long-Term Capital Improvements		
Track Rehabilitation	$996	
Additions and Improvements	324	
Equipment Rehabilitation	524	
Equipment Acquisition not Privately Financed	122	(1,966)
Funds Used to Cover Operating Losses		(232)
Cash Required for Working Capital Purposes		$ 100

In terms of specific physical accomplishment in the first 39 months made possible by these capital expenditures (Table 2):

1) Locomotive fleet will be on normalized maintenance basis by end of 1979. More than four-fifths of the active fleet is either new or significantly overhauled since April 1, 1976 (479 new, 2771 overhauled, rebuilt or converted).

2) Car fleet will be on normalized maintenance basis by the end of 1980. More than half of the active fleet is new or upgraded since April 1, 1976 (5920 new, 58,927 rebuilt).

   o As a result, number of cars available for service has consistently exceeded that of the same month of the previous year since last November, although still much to be done to achieve adequate car fleet.

   o Freight car out-of-service ratio now 8.2 percent, compared to 13.3 percent a year ago.

3) Track rehabilitation during 1976-1979 has included installation of 3843 miles of welded rail, more than 18.4 million crossties, and surfacing (ballast and leveling of road bed) of more than 26,800 track miles. In the years 1976-1979, about 90 percent of the total "core route" mileage (5100 miles most heavily travelled) has had some kind of track work done to it (rail, ties, or surfacing).

4) The track maintenance program has given increased attention to yard areas, such as a 3-year, $25 million rebuilding project at DeWitt Yard near Syracuse, New York. Other key locations being rebuilt include:

   o Oak Island, near Newark ($19 million)

   o Allentown, Pennsylvania ($14 million)

   o Elkhart, Indiana ($18 million).

5) Other major improvements to facilities include a $16 million modernization to the Juniata Locomotive Shop in Altoona, including expansion of storehouse facilities, to accommodate expanded operations.

TABLE 2. CONRAIL REHABILITATION PROGRAM ACCOMPLISHMENTS AS OF JUNE 30, 1979

Locomotives -	New Units Acquired	479
	Rebuilds, Conversions, Overhauls	2,771
		3,250
Cars -	New	5,920
	Rebuilds	58,927
		64,847
Track -	Miles of Welded Rail Installed	3,843
	Crossties Installed	18.4 million
	Pass Miles Surfaced	26,800

Achieving improvements through capital expenditures has been a crucial element in Conrail's turnaround effort - but, without also initiating actions to improve Conrail's capability to use more effectively these improved physical assets, a profitable operation for Conrail would be impossible.

In terms of productivity improvements through negotiations with labor, significant advancements have also been achieved. Specifically, Conrail's new agreement with the United Transportation Union, when fully implemented, provides for a reduction in train crew size on almost every freight train operated by Conrail (Figure 1). What's more, we will have replaced 43 separate agreements with the UTU with a single agreement. In a recent agreement with the Brotherhood of Locomotive Engineers, we have reduced 18 agreements to 1. In the first 40 months of negotiations ending July 31, 1979, Conrail has signed 22 new collective bargaining agreements which replaced 246 agreements inherited from the former lines. These new agreements cover more than 82,000 employees, about 99 percent of Conrail's union affiliated work force.

LABOR AGREEMENTS

U.T.U. AGREEMENT

43 Separate Contracts Into a Single Agreement
Crew-Size Reduction Will Achieve Savings
And Increased Efficiency

B.L.E. AGREEMENT

18 Agreements Into Single Agreement

In the 40 months of negotiating ending July 31, 1979, Conrail signed or came to agreement on 22 new collective bargaining agreements that replace 246 agreements inherited from the former lines.

These new agreements cover more than 82,000 employees, about 99% of Conrail's union-affiliated work force.

FIGURE 1. LABOR AGREEMENTS

The third thrust of Conrail's cost reduction/productivity improvement effort relates to the achievement of management efficiencies. Programs to accomplish such management efficiencies range from traditional industrial engineering studies (observation of work; development of work plans; implementation of improved methods; design and implementation of performance measurement systems) to more esoteric network planning studies using simulation models.

Since the fall of 1977, Conrail has launched an aggressive Operations Improvement effort at each level of its three-tiered operating organization (Figure 2). At System, an organization with more than 140 "turned-on" OI analysts, has been assembled to focus on productivity improvement. Some of the functions covered by this Headquarters organization are shown in Table 3.

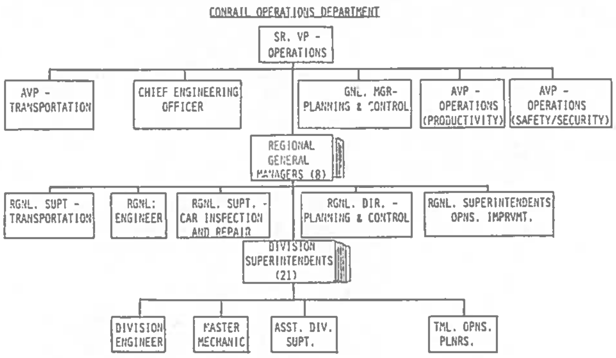

FIGURE 2. CONRAIL OPERATIONS DEPARTMENT

TABLE 3. OPERATIONS IMPROVEMENT-SYSTEM*

NETWORK PLANNING
- Operating Strategy
- Blocking/Scheduling
- Plant Rationalization/Route Consolidation
- Class Yard Planning
- Dynamic Yard Management System
- Locomotive Utilization

COST REDUCTION
- Terminal Improvement
- Car Repair and Inspection Productivity
- Mechanical Productivity
- M of W Production Gang Efficiency
- Fuel Conservation
- Clerical Efficiency
- Computer Assisted Crew Dispatching

OTHER
- Management/Skills Training
- Management Control Systems
  - Crew Performance
  - Car Movement Measurement
  - Upgrade Responsibility Reporting System

*Excludes Car Utilization

Returning once again to the organization chart, Conrail also has on-going productivity improvement effort in its operating regions (Figure 2). These organizations are currently being expanded in size from approximately 6 to 18 people per region, to accelerate Conrail's rate of achieving productivity improvements through operating analysis, detailed operations planning and the measurement of performance against plan. Additionally, some of the planning functions originally carried out at System are being transferred to Region and Division, such as terminal yard crew planning and Car Repair and Inspection productivity improvement activities.

In total, Conrail has more than 200 people focusing on cost reduction/production improvement through increased management effectiveness.

I've now described to you the three principal areas in which Conrail is seeking cost reductions and productivity improvements - through capital expenditures, through the execution of new or revised labor agreements, and through more effective management.

It's fair to ask the next logical question - is it working? Is Conrail getting better? In terms of financial results, the answer is yes (Table 4). Losses in our first year of operation were $413 million. That figure was reduced to $375 million in our second year and further reduced to $297 million in our third year. Most recently we reported net income of $29.4 million for the second quarter of 1979 - the first time Conrail has reported net income in any quarter in its 39-month operating history. In fact, for the first half of 1979, we reduced our losses by $1 million a day as compared with the first six months of 1978.

TABLE 4. CONRAIL FINANCIAL RESULTS
Profit/(Loss) by Quarter
($ in Millions)

	1st	2nd	3rd	4th
1976	$ -	$(34.4)	$(32.0)	$(139.1)
1977	(207.6)	(27.6)	(54.6)	(76.8)
1978	(216.0)	(60.9)	(48.5)	(60.0)
1979	(127.7)	29.4		

In terms of its average number of employees, Conrail has also shown an improvement, with a reduction of more than 9 percent having been achieved since April, 1976. More specifically, for the second quarter of 1979, as compared to the same quarter of 1978, the number of employees dropped by approximately 4000 while physical volume went up (Table 5).

TABLE 5. AVERAGE NUMBER OF EMPLOYEES

	1976	1977	1978	1979
Total Operating & Administrative	95,467	94,600	91,320	87,900
Less: Passenger, Capital and other Reimbursable Employees	17,769	17,992	18,909	18,300
Net Employees-Freight Operations	77,698	76,608	72,411	69,600

In terms of productivity as measured by net ton miles per employee, Conrail has made significant progress, shown a cumulative improvement of 9.1 percent during the past 2 years - with this improvement having been made in the face of a volume decline, a difficult task given the high element of fixed costs in the rail industry (Table 6).

TABLE 6. CONRAIL PRODUCTIVITY IMPROVEMENT 1977-1979

	1977	1978	1979	1977-1979
Net Ton Miles (Billions)	94.5	94.3	93.6	
% Change		(0.2)%	(0.7)%	(0.9)%
Net Employees-Freight Operations (Thousands)	76.6	72.4	69.6	
% Change		(5.5)%	(3.8)%	(9.1)%
Net Ton Miles/Employee (Thousands)	1233	1302	1345	
% Change		5.6%	3.3%	9.1%

To achieve its goal of financial selfsustainability, Conrail must satisfy a dual set of objectives that at times conflict: improving service while reducing costs. You've seen that Conrail has been successful on the cost reduction/productivity improvement front. We have also been quite successful in improving service, showing a steadily improving trend since the beginning of this year - with service quality for each month having shown an improvement over the same month in 1978 (Figure 3).

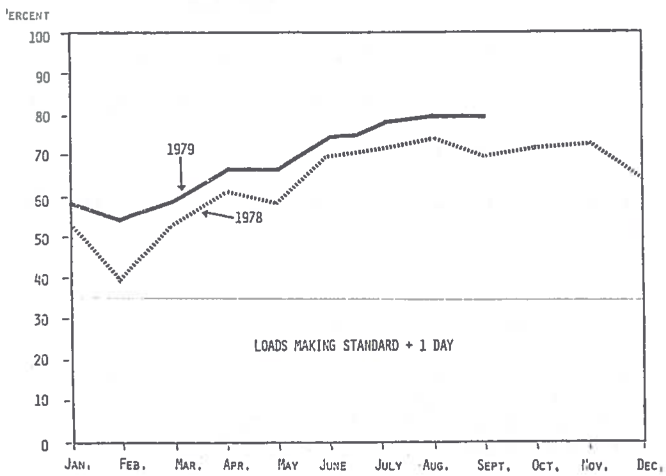

FIGURE 3. KEY POINT SERVICE QUALITY CONTROL PROGRAM

In the brief time alloted to me, I hope that I have provided to you some insights to the way in which one large corporation (Conrail) is managing for change in a complex operation - thus far, with some degree of success.

PROGRESS AND OPPORTUNITIES IN SAFE MOVEMENT OF HAZARDOUS MATERIALS

BY

J.H. NORTON

On behalf of the DuPont Company and the chemical industry, I welcome the opportunity to speak before the 15th Railroad Engineering Conference. My subject this morning is "Progress and Opportunities in Safe Movement of Hazardous Materials." Since this conference is concerned with rail transportation, my remarks will be directed to that area, although they are applicable in general to all modes.

I believe significant progress has been made in transporting hazardous materials more safely, and I also believe opportunities exist to continue that improvement.

The problems of safe transport of hazardous materials are continually with us. Certain materials transported every day on the rail system are inherently dangerous and, in some cases, that dangerous property is what makes it useful and why it is being transported. Many of the chemicals and petroleum products on which the nation runs can burn, explode, asphyxiate or poison. The highly toxic properties of hydrocyanic acid for instance, make it useful as an ingredient in pesticides. The toxicity of chlorine enables it to be effectively used to reduce the bacteria count in water and sewage treatment operations. Chemicals are essential to our modern society. They have been woven into the very fabric of our everyday life such that we take for granted the conveniences and efficiencies which come from the way we have found to use them.

The public, however, does not always recognize the benefits derived from these materials but sees only the risks involved and the potential for disaster when a tank car of hazardous material passes through their town or near their home. According to the Materials Transportation Bureau, in 1971 there were 343 rail incidents involving hazardous materials. By 1978 that number grew to 1091 with a corresponding five-fold increase in property damage. Some of the increase can be attributed to progressively more thorough reporting over these years; nevertheless, the trend is upward. Events such as the rail accidents in Youngstown, Florida, and Waverly, Tennessee, only accentuate the problem to the public and the Government. The problem of safe transport of hazardous materials is real, regardless of the statistics or the perception, and action must be taken to improve its performance. Today and over the past several years this problem has been addressed in various degrees by industry, state and Federal regulatory agencies, and the Congress. Various studies, panels and reports have been undertaken. Progress has resulted, but more action is required. Cooperative action by those directly involved, that is the carriers and shippers, is the most productive and efficient.

Just prior to the Waverly and Youngstown incidents in early 1978, a group of chemical and railroad executives met to discuss their common concern about the safe transport of hazardous materials by rail. From this initial meeting the Inter-Industry Task Force on Rail Transportation of Hazardous Materials was formed. The Task Force was made up of top executives representing the Chemical Manufacturers Association, the Association of American Railroads, the National Liquified Petroleum Gas Association, the Fertilizer Institute and rail car manufacturers.

Historically, railroads have proven to be the safest means of shipping hazardous materials. The Task Force, however, wanted to make it even safer and accepted that challenge. The Task Force divided its work into four basic areas: Safety Systems Analysis, Accident Response, Equipment Design and Maintenance, and Transportation; that is, problems relating to the movement of rail cars.

The Task Force's purpose was to accelerate present programs and take steps to reduce the number and severity of rail transportation accidents involving hazardous materials. Each of the sub-committees addressed certain concerns in its area, identified specific items that could yield improved safety performance, and issued recommendations to achieve the overall goal. The Task Force functioned actively from its formation in March, 1978, to June, 1979, when it issued its final report. The findings and actions of this group made significant progress. They also act as a base for future work and opportunities.

By identifying certain actions of each of the Task Force's subcommittees, you can get an appreciation of what progress has been made.

EQUIPMENT

The principal objectives of the Equipment subcommittee were first, to support efforts already underway to improve the containment capabilities of certain rail cars carrying hazardous materials, and second, to develop and recommend additional actions which would maximize safety of all rail transportation equipment used in shipping hazardous materials. Included in the scope of the subcommittee interests were issues involving equipment design, maintenance and inspection.

The subcommittee made five recommendations from their studies. These recommendations focused on methods to expedite the retrofit of class 112 and 114 tank cars with shelf couplers, tank head protection and thermal protection, seeking completion of this task earlier than required by regulations; they suggested giving consideration to utilizing shelf couplers on rail cars transporting hazardous materials other than the 112 and 114 tank cars; they considered the issue of lading releases from bottom outlets; they reviewed the possibility of upgrading and reducing the number of specifications of cars approved by the DOT for specific products; and they focused on the need for prompt action to improve the quality and uniformity of maintenance practices.

The most challenging activity of this subcommittee involved the accelerated schedule of the retrofit of Class 112 and 114 tank cars. This acceleration with respect to shelf couplers created severe logistics problems. It appeared doubtful that coupler manufacturers could deliver sufficient couplers or that car owners could find repair facilities for installation by the required date.

The Task Force supported the order and accordingly completed a survey of shelf coupler manufacturing capabilities, approved repair facilities, and location of the major concentration of 112/114 cars requiring the retrofit. In a joint effort of all concerned, couplers were delivered to appropriate retrofit facilities, and owners of the cars were notified of the capabilities, capacities, and facilities available. The railroads agreed to do some operations at their repair facilities, especially repair tracks, and helped manage the movement of cars to these facilities.

TRANSPORTATION

The Transportation Subcommittee centered its efforts in developing programs to enhance greater rail safety in the areas of improved rail car inspection procedures, improved en route monitoring of cars containing hazardous materials, train speeds, car handling procedures in yards, train makeup, routing, and problems associated with poor track.

The subcommittee recommended:

1) Training - that every railroad and shipper employee whose duties affect the safe movement of hazardous materials not only be trained, but that training be reviewed to keep pace with changing safety needs.

2) Inspection - that inspection procedures be further tightened by requiring that shippers and carriers assure effective inspections of all cars carrying hazardous materials at initial terminals and loading facilities.

3) Train Speed - that all trains with placarded, loaded 112/114 type tank cars operate at a speed 10 miles per hour less than the maximum speeds authorized for freight trains operating on Class 3, 4, 5, or 6 tracks.

4) Mechanical Defects - that the AAR Mechanical Division will be notified immediately of any mechanical problems or defects in locomotives or cars that may have national implications. Instructions contained in early warning letters issued by the Mechanical Division are to be promptly carried out.

ACCIDENT RESPONSE

The third subcommittee, Accident Response, addressed the analysis of hazardous materials transportation incidents, the need for notification and product identification as well as the actual emergency response. The committee made recommendations and took action in four areas:

1) The necessity for a broad based emergency communications network

2) Methods of providing positive identification of commodities involved in incidents

3) Development of training programs and informational materials

4) The need to broaden industry mutual aid and mutual assistance programs.

In the area of improved emergency response, the subcommittee invited AT&T to evaluate the existing emergency system and develop a new communications system or systems to significantly improve industry emergency response capabilities. AT&T willingly accepted this challenge, and they have developed a concept which places even greater emphasis on cooperative efforts of carriers, shippers, and emergency services to communicate through CHEMTREC if a transportation incident occurs.

The new system, which has been accepted in principle by CMA, will be developed in three building block phases and will provide faster, more accurate and reliable information between the scene and the shipper. The system in its complete state will require use of computers and hard copy links between the concerned parties in addition to sophisticated telephone bridging networks.

Detailed engineering and cost studies are now underway with the objective of implementing the complete new system. The first phase of this project is underway.

The subcommittee also worked with Professor Charles Wright of Western Kentucky University to develop a training program for volunteer and small emergency response forces. The program has been field tested with a number of such forces and was enthusiastically endorsed. Distribution has already begun.

The interim use of 49 series Standard Transportation Commodity Codes to provide emergency forces with more precise identification of hazardous materials involved in an incident was also adopted by the Task Force.

SYSTEMS SAFETY ANALYSIS

The fourth subcommittee concentrated on Systems Safety Analysis. There is a great deal of data relating to transportation of hazardous materials and duplicative and overlapping accident reports abound. However, this information has never been analyzed in a systematic, coherent fashion to assist the carrier and shipper in preventing future accidents. For this reason, the subcommittee focused on the identification of an acceptable data base and the development of a uniform approach for identifying and evaluating proposals which, in a cost-effective fashion, can reduce the risk of transportation of hazardous materials by rail. Because of the contemplated complexity of Systems Safety Analysis, the subcommittee also retained the consulting firm of Booz, Allen and Hamilton.

Preliminary analysis of the available data and trends led to several major conclusions on causes of hazardous materials releases, effects of many train operating characteristics, the probability of certain car components and types of cars to cause derailments and whether additional use of risk management techniques can be made with better data.

The subcommittee presented recommendations and action programs for further analytical study to include:

1) A continuing assessment of data requirements, data sampling approaches, and risk management systems in cooperation with all interested agencies and organizations to facilitate on improved accident data reporting systems; the NTSB and DOT have been contracted to explore common approaches.

2) As appropriate data become available, continued efforts will be made to identify significant causes for hazardous material releases and to conduct comprehensive analyses of those countermeasures that will reduce such releases.

3) An approach will be developed to gather data necessary to evaluate the effectiveness of various safety practices. Procedures or operations which materially improve safety will be identified and disseminated to all railroads.

It is important to recognize that the recommendations made by the subcommittee were based on limited data, and therefore, should be viewed only as a first step toward completion of a total systems safety evaluation. It is hoped that the work of this subcommittee will provide a solid foundation on which further research analysis can be based as more and better data become available.

The accomplishments of the Task Force have been encouraging. It is also encouraging to see the opportunities that are available and have been identified by Task Force activities. As mentioned earlier, several concepts and approaches used by the Task Force can act as a base for future work and development to improve the safe transport of hazardous materials. I have identified four of these concepts, of which some were evaluated by the Task Force. I have blended into these concepts some DuPont philosophy on safety and I offer them for your consideration. They are:

1) Continued cooperative effort between carries and shippers of hazardous materials to address areas of mutual concern

2) The potential effect on safety with re-regulation of the rail industry

3) Continued improvement in engineering equipment design and modifications on a cost/benefit basis

4) And lastly, the involvement of industry with the appropriate governmental agencies in developing, planning and undertaking research and development in hazardous materials transport.

Of major significance in the efforts and accomplishments by the Task Force is the concept of shippers and carriers working together to meet a common objective. Although this has been done in the past, it was not done at the level or intensity as the present Task Force. This synergetic effect must be continued to resolve all the safety problems in the transport of hazardous materials. We must act as a whole to concentrate our resources productively. Currently, the AAR, RPI and CMA are funding the continued work of the Task Force to develop an adequate data base on rail incidents. We see this cooperative effort as a keystone to identifying specific problem areas and their resolution.

This group is instituting mechanisms to gather data from both shippers and carriers concerning rail incidents to include design specifics of the rail car, also damage and repair details. This data will be combined with the existing FRA and DOT incident reports to provide a more comprehensive data bank. With this base, additional analysis can be made, leading to further conclusions regarding improved operating characteristics. Hopefully the effects of train speed, train length, train composition, car characteristics, position of cars within a consist and so on, can be determined more accurately. This analysis should be beneficial; however, we must take further steps to understand the interaction and relationship of each of these variables to each other and as a whole.

Derailments account for almost 90 percent of accidents with a release of hazardous materials. Causes for these derailments fall into four major reportable categories: (1) Human Factors, (2) Equipment, (3) Track, and (4) Miscellaneous as established by the FRA. It is understandable and makes reporting simpler to have the cause fit into one of these categories. Our belief is that all things don't always necessarily fit into nice rows and columns, but that other factors and operating characteristics must also be considered.

Take for example a train that is traveling over poor track with a consist of hazardous materials that has a derailment. Initial reaction is that the poor track is the cause, and this is likely what will appear on the FRA report. However, it is probable that a train with a similar consist and operating conditions operates over this same track without derailing just before or just afterwards. Doesn't this suggest that factors other than simply track conditions are involved? I think you will agree that the answer is "yes" and, therefore, we err in categorizing accidents too precisely.

Based on my company's experience, we suggest that the human factor is involved in far more accidents than the FRA reports indicate. These reports show that 4 percent of mainline derailments with a materials release and 20 percent of yard derailments with a material release are caused by human factors. Yet we know that equipment is designed, built and maintained by humans; tracks and roadbeds are built and maintained by humans; and humans develop and issue train operating instructions. Therefore, I think you understand why DuPont believes significant progress in the safe handling of hazardous materials can be achieved by developing greater awareness of and responsibility for safety in all the humans involved in railroading. At DuPont, perhaps because of our beginning as a small family company making black powder 177 years ago, the commitment to safety begins with the chairman and chief executive officers. It is the responsibility of each DuPont employee to perform his job in a safe manner and this is a condition of employment and accepted as a line responsibility.

This type of philosophy needs to permeate more broadly, we believe, in the rail transportation industry. If each individual carries out his specific safety responsibilities, the positive effects will be widespread. We'll see better inspections, improved quality of repairs, better handling in operations, and most importantly, less incidents. This improvement will not take place overnight, but will be a continuing process with one step building upon the other. To accomplish this end, dedication, commitment and motivation are required. Without it, safety is only a hollow word, something we hear about but is not a reality.

Another area for cooperation is in the response to transportation emergencies. As I mentioned earlier, the Task Force developed a training program for emergency services personnel and, with the assistance of AT&T, developed an improved emergency response communications system through CHEMTREC. The continued development and improvement of both systems in conjunction with those efforts by the DOT with its National Response Center and its pending issue of an Emergency Response Guide will make substantial inroads to improvements in this area.

The second concept that provides opportunities for improvement involves the pending legislation on re-regulation of the railroad industry. We in DuPont, and we are supported by others, believe re-regulation will open up new opportunities to improve safety in transport of hazardous materials by permitting specific contractual arrangement between shipper and carrier. As you may know, the ICC took a major step forward in this direction last November when they declared that contracts between shippers and railroads would be permitted, under certain circumstances. Although many railroads and shippers have thus far focused on the economic factors which might be addressed in contracts, DuPont sees many opportunities to enhance safety as well. Although the ICC has taken this positive step, we look for its confirmation and expansion in the hoped-for new rail bill. If so, I believe you will witness many major shippers of hazardous materials examining their lists of hazardous commodities and then, determining, with the involved railroads, what conditions would most enhance safe movement. The arrangements which might be specified in a resulting contract could include additional and more frequent inspections, standards for the inspections, when the commodity can be moved (night, day, weather conditions), speed at which it moves, length of train and its route, etc. The number of conditions would probably be tailored to the needs of the commodity. Services such as these will have to bear their cost; however, a service which results in improved safety performance and precision of delivery could well be worth the extra cost, if any.

We feel the re-regulation of the rail industry will also result in more competition among railroads, especially in the area of safety. One aspect that is not capitalized by most of the railroads is the "marketability" of safety. At DuPont we believe and have witnessed that we can maintain and gain market share due to the services provided to the customer in the area of safety. Our concern for the product and how it is controlled and handled safely is sometimes the only difference between us and a competitor receiving the order. We are promoting this concept in our discussions with railroad management and we encourage other shippers to do likewise. Safety is a product! It is marketable and profitable.

A third opportunity is the continued improvement in the engineering and design of equipment. Safety has always been a consideration in development and design of rail cars, track, and other components of the rail system. The development and testing of the modifications to the type 112 and 114 cars is a classic example of design improvements. The installation of double shelf couplers, head shields, and thermal protection to prevent inadvertent hazardous material releases are cost effective and beneficial. Accident data over the next several years should provide the effectiveness of these changes. More new designs, modifications and ideas to improve material containment should be promoted and encouraged. As these innovations develop, they should be examined and studied carefully to insure that they improve safety on a cost beneficial basis. The projected effect of systems in place or being adopted also must be taken into account in the analysis of new countermeasures. Efforts must concentrate on those measures which produce the best results.

The last concept I would like to explore is the involvement of industry with government in long range research and development programs. The RSPA and the various modal administrations appropriate millions of dollars per year in R&D in the hazardous material area. There is little or no involvement by industry in the development of this program nor in the actual research. It seems appropriate that the expertise and experience of industry in handling hazardous materials should be consulted with and its advice considered in the R&D area. I would not say the non-involvement is the fault of industry; however, if we don't participate, we have no excuse when regulations are promulgated that unjustifiably restrict our business. We need to be involved to help set the mission and its objectives. Both government and industry desire the safe movement of hazardous materials, and we should work together to achieve that end.

In summary, progress has been made to improve the safe movement of hazardous materials as witnessed by the Task Force's recommendations and activities. There are also opportunities to build on this progress through continued cooperation between carriers and shippers to resolve mutual concerns. The building of a data bank and analysis of the data to determine effects of the variables and the interrelationship of the variables is needed. The human factor must be continually addressed. Individuals must be accountable for safety and safety must be a commitment by top management on down the line. The effect of re-regulation should provide opportunities and incentives for both carriers and shippers. Rail carriers should also take advantage of the marketability of safety. Continued emphasis must be placed on safety in design and engineering of equipment and all measures should be cost beneficial.

Lastly, industry should involve itself with government in the long range R&D efforts. With our expertise we have a lot to offer. All these concepts require dedication and effort by those of us attending this conference; we must be willing to make the commitment to meet the objective.

RECENT ADVANCEMENTS AND FUTURE OPPORTUNITIES IN ENERGY CONSERVATION

BY

J. KOPER
D. SPANTON

EXECUTIVE SUMMARY

In 5 years of research on potential means to conserve railroad energy, a variety of projects have produced significant new knowledge and analytical techniques. Although the knowledge base is incomplete, there are some areas where practical implementation can now be undertaken.

Accomplishments include:

1) Development and application of several versions of Train Performance Simulators

2) Wind tunnel and full-scale investigations of the effect of aerodynamic drag

3) Framework for further research on total train resistance other than aerodynamic forces

4) Preliminary insight into the potential of alternate fuels for diesel locomotives

5) Feasibility studies of stored energy concepts in both yard and line-haul applications

6) Prototype development and initial testing of a critically needed measuring device called Locomotive Data Acquisition Package

7) Initial assessment of selected advanced propulsion system presently not in use on railroads.

Areas where future research is required are identified. A concluding section indicates a number of non-energy activities which coincidentally will contribute to energy conservation.

INTRODUCTION

In 1974, FRA's Office of Research and Development initiated studies at the Transportation Systems Center (TSC) related to fuel usage in rail freight service operations. These early investigations were primarily analytical with only limited field data available for correlation purposes. By late 1975, the research had been expanded to include more extensive measurements in the field as well as experimental testing. In 1976, formal coordination was established with the Department of Energy's predecessor organizations in order to establish the framework for future cooperative research between government and industry and to support the railroad industry's efforts to improve energy utilization.

Augmenting the initial investigations by FRA, a DOE-sponsored study by Stanford Research Institute[1] outlined various options and alternatives to pursue relative to railroad energy conservation research. In the last 3 years, FRA has focused its conservation research on near-term (present-1985) applications while DOE has concentrated its efforts on a combination of near-term and mid-term (1985-2000) alternatives. The following project summaries present the status of results of the analytical, experimental, and hardware technology research conducted under FRA sponsorship. Also indicated are the cooperative projects with DOE and AAR support.

ANALYTICAL STUDIES

Train Performance Simulation

In 1974, FRA asked TSC to provide analytical support in the area of fuel usage in branch-line operations. At the time, this related primarily to an assessment of the environmental impact of rail line abandonment, under the assumption that the freight would then be moved by truck. This work indicated that the typical fuel-efficiency advantage of rail over highway declines sharply for light loads and low train speeds, vanishing at levels common to branch-line operations. The study was then expanded to provide rough estimates and sensitivity analysis for general freight and passenger service, and was documented in Report FRA-ORD-75-74.I, "Railroads and the Environment-Estimation of Fuel Consumption in Rail Transportation; Volume I - Analytical Model" (May 1975).[2] This work was followed by actual revenue-service measurements made on an 87-mile, Missouri-Pacific Railroad branch line; these confirmed the basic findings and brought out the additional importance of fuel use while idling, which can be a substantial portion of the total consumption in such cases.

In 1975 both the analytical and measurement activities were expanded substantially. Development of a comprehensive capability for computer simulation of train performance began with purchase of the Missouri-Pacific Train Simulation (TPS), which has been modified and expanded greatly by TSC in the subsequent years. It is now suitable for a wide variety of freight and passenger service applications, and is fully documented. In addition, a large library of track data has been accumulated. The TPS has been described in detail in Report FRA/ORD-77/48, "The U.S. DOT/TSC Train Performance Simulator" (Sept 1978). At the same time, a major program of fuel-usage measurements was undertaken in order to validate the TPS and to provide a firmly based set of actual values for rail freight-service fuel consumption. Results of tests conducted during more than 50,000 miles of line-haul operations, including TOFC, manifest freight, and unit coal trains, under a wide variety of circumstances, have been documented in Report No. FRA-ORD-75-74.II, "Railroads and the Environment: Estimation of Fuel Consumption in Rail Transportation; Vol. II - Freight Service Measurements" (Sept 1977).[3] Volume III of this series, "Comparison of Computer Simulations with Field Measurements" (FRA-ORD-75-74.III),[4] compares these findings with fuel usage predictions made with the TPS; in general, the findings are similar.

Two related modeling efforts at TSC also contributed to improved simulation techniques. Union College, first working under a DOT University Research contract and then for FRA, has developed a simplified program intended to be compatible with small computers. Carnegie-Mellon University, also under a University Research contract, has developed an elaborate model for electric-powered systems, which includes detailed consideration of power distribution and control and propulsion systems. This has been utilized by FRA in electrification studies. As part of a current FRA program, TSC is preparing concise documentation relating to these programs, and plans to keep them operational on the TSC computer.

Under FRA sponsorship, TSC also conducted a small but comprehensive review of various strategies for improvement of fuel efficiency in railroad operations. (Report No. FRA-ORD-76-136, "Fuel Efficiency Improvement in Rail Freight Transportation," Dec 1975).[5] This effort covered many aspects of railroading, including locomotive design features, power-to-weight and operating speeds, fuel storage and spillage, etc.

Future research activities of several types are possible. At the simplest level, a compendium of preferred practices — a kind of "fuel efficiency handbook" written for both working-level and managerial use — could play an important role in assuring that the wisdom, experience, and research findings now known to a limited number of individuals could permeate the industry and come to be widely used. Major changes in equipment design and usage are also possible avenues to improved fuel economy, but the necessary research and development is probably better left to industry. However, DOT assistance in testing and evaluation may stimulate and accelerate acceptance and implementation of improvements.

Aerodynamic Investigations

The aerodynamic forces of importance to freight train operations are primarily the axial force, and secondarily side forces and rolling moments. At high speed, 60 mph, the train's aerodynamic resistance while running at constant speed on a level track is about half of the entire train resistance. The fuel expended to overcome aerodynamic resistance is 0.04 gallons/car-mile at 60 mph. The information available on the aerodynamic forces on freight trains has been quite limited and much of it conflicting. The recent investigations consisted of several phases and were carried out over a period of 5 years.

Wind Tunnel Tests - After evaluation of different testing techniques it was determined that a wind tunnel was the best way of making a large number of tests on many different configurations for a reasonable expenditure of time and money. A wind tunnel test program was planned consisting of several parts. In order to gain a basic understanding of the aerodynamics of a train of cars, tests were run on a series of blocks in which the effect of spacing and size was examined. To study real railroad configurations, tests were run on railroad car models. These were models of real and proposed cars. A scale of 1/43 was selected in order to be compatible with wind tunnel size and to take advantage of model kits available in this scale. Most tests consisted of a train of five cars: a locomotive, three test vehicles, and a final car. This train was approximately 10 feet long. It was tested using a ground plane in a 10 foot diameter wind tunnel. The six components of force and moment were measured on the middle car of this train. The three middle cars in the configuration were varied in order to obtain measurements on different cars in different relations to each other. Tests were run on different TOFC and COFC configurations, both existing and developmental configurations. Different freight cars have also been tested consisting of most of the cars used by the railroads. These cars were tested both in trains of like cars and with various combinations of other cars.[6,7]

Full Scale Tests - In order to relate the wind tunnel tests to the real situations some full-scale tests were run on actual TOFC configurations. These tests were run at the Transportation Test Center (TTC) at Pueblo, Colorado. Two trailers were mounted on a TTX car in such a way that the forces applied to the trailers could be measured by load cells. The train was then driven over a selected section of straight track at approximately constant speed. After corrections were made for grade and acceleration, the only remaining forces on the trailers were aerodynamic. This experiment had to be performed with considerable care in order to minimize the oscillating forces and the data had to be processed to remove these components. After the techniques had been developed, reliable results were obtained.[8]

Results - At the completion of this program, considerable understanding of the aerodynamics of freight trains had been achieved. The full-scale results substantiate that the wind tunnel is a meaningful way of conducting aerodynamic testing.[9] There are several aspects which have important effects of the aerodynamic resistance. Cross winds cause major increases in the aerodynamic resistance of the train and an accurate prediction of the aerodynamic resistance cannot be made without knowing the magnitude and direction of the wind. Open spaces in the train are very important. At low cross wind conditions, the spacing between cars has to exceed about half the width of the car before an appreciable increase in resistance occurs. Between-car spacings are generally small enough so that closer spacings would not be a major advantage except for high cross wind conditions. Larger openings in the train, such as an unloaded flatcar between two other cars or trailers missing from TOFC configurations, cause large effects. Other open spaces in the train, such as that between trailers and the body of the TTX, car, are also important contributors to resistance. Open unloaded cars such as hopper cars are also important causes of resistance. The resistance of an unloaded bulkhead flatcar was found to be very large. Tests of different TOFC models demonstrated the difficulties caused by trying to provide flexibility to carry different loads. Systems designed to accommodate 45-foot trailers had appreciably higher resistance when loaded with 40-foot trailers.

Future Benefits - There are a variety of future benefits that can be obtained from this program. The improved understanding of aerodynamic effects now available allows a more realistic appraisal. This information allows better train prediction programs to be written and more realistic evaluations of the effects or dangers of side forces caused by large cross winds. An understanding of aerodynamic effects can lead to better operating procedures. Improvements may be possible in the making up of train consists to minimize open spaces in the train and methods of reducing the large aerodynamic resistance of open unloaded cars. Now that a background of information is available and testing techniques have been evaluated, aerodynamic testing technique has already been used in the testing of developmental TOFC and COFC cars.[10]

Train Resistance

An examination of the train resistance phenomenon, with particular reference to freight trains, was initiated under FRA sponsorship in 1977. During this work, a different methodology for computing the resistance of a given consist was developed. The methodology involves calculation of the resistance of each car and summing the individual resistances, rather than using a single formula for the entire train. This approach enables one to compute the resistance of a given arrangement of cars, which will be different from another arrangement on account of the different aerodynamic drag. A computer program was developed which uses inputs describing the types of cars, their weights, and their order in the consist to compute the total train resistance.[11]

The program was used further to explore the significance of certain design improvements or equipment modifications upon fuel consumption when the train is operated over level tangent track. It was found that under such circumstances the arrangement of the consist is quite significant in affecting fuel consumption. Other improvements were found to be not as significant under these circumstances as might have been expected. For example, the use of lightweight equipment did not save as much fuel as expected; therefore, the premium price for such cars appeared not to be justifiable. Track rigidity was found to be a significant factor in fuel consumption, but the potential for saving fuel was not great in this country, as track is already rigid by world standards. Improvements in the design of trucks and bearings were found to result in modest savings.

Because the previous work had been restricted to level tangent track, a computer program was devised which would permit the operator to compute the fuel consumption of a given train when operated over a track whose characteristics are known. The program utilized the previously developed methodology for computing the resistance of the train in determining the fuel consumption. In addition, the results from previously discussed wind tunnel tests on blocks simulating railroad vehicles were incorporated into the aerodynamic drag calculation. Fifty-two runs of different but representative types of trains, such as coal trains, intermodal trains, and average consists, were simulated over real track.

It was found that the conclusions were not the same as before when level tangent track was used, and that fuel consumption is heavily weighted by factors other than train resistance. In most cases examined, both the absolute savings in fuel and the percentage savings were noticeably different from the previous ones. In many cases, the magnitude of the fuel savings was highly dependent upon the type of operation: low or high speed, empty or loaded train, comparatively straight and level track vs. complex track with many grades and curves and changes in speed limits. In certain cases it was shown that reduction of track resistance on half the trip is equivalent to merely increasing braking requirements and that no savings are effected. Savings with lightweight equipment were shown to be considerably more favorable in operation over complex track in most instances. In general it was found that fuel savings appear highly sensitive to the type of operation being run. Because of this apparent sensitivity, it concluded that the program or a similar program be utilized to analyze a particular operation in detail before making investment decisions.[12]

As a result of the foregoing work, it has been recommended that sensitivity analyses be conducted, utilizing the program developed, to determine the sensitivity of fuel consumption to such things as locomotive assignment policy, velocity of operation, train handling, and maintenance. It has also been recommended that certain full-scale experiments be conducted to complete the data base, where information is presently lacking. Some recommended areas for investigation were bearing friction vs. speed, and confirmation of the extent of bearing seal friction; completion of aerodynamic testing in the wind tunnel and confirmation of the results of same by full-scale tests; establishment of the resistance attributable to jointed rail vs. welded rail; and confirmation of some of the theories advanced as a result of the recent work regarding the use of lightweight equipment. Cost-benefit studies are currently under way to quantify the potential energy savings attributable to reduced train resistance.

It should be noted that as a result of the completed and ongoing analytical studies discussed above, FRA has decided to conduct an initial Energy Management Workshop for the railroad industry in order to explain further the applications of the various computer programs and train performance calculators to specific operating conditions for improved energy use.

EXPERIMENTAL INVESTIGATIONS

Alternative Fuels

In 1978, under FRA and DOE sponsorship, work began to investigate the use of alternate fuels in medium-speed (800-1200 rpm) diesel engines. Two categories of fuels are being investigated in the initial phase of the program, off-specification diesel fuels and non-diesel fuels. These fuels are defined as follows:

1. Off-Specification Diesel Fuels - Diesel fuels are currently defined by specifications which set quantitative values or limits on properties such as cetane number, viscosity, boiling range, ash and sulfur contents, and so forth. Engine manufacturers recommend a certain minimum fuel specification and define performance of their engines in terms of this specification. Crude petroleum must then be refined in a manner required to produce such a fuel. If one or more fuel specifications could be relaxed or broadened, while still permitting acceptable engine performance, the number of steps in the refining process could be reduced, along with refining energy consumption, and less expensive and/or higher availability liquid hydrocarbon products could be produced for use as finished engine fuels. Off-specification diesel fuels are therefore defined here as fuels with one or more properties which do not lie within the currently accepted range of specifications.

2. Non-Diesel Fuels - Fuels such as alcohol and gasoline are included in this category. These fuels obviously differ greatly from specification diesel fuel with respect to cetane number, viscosity, boiling range, and other characteristics. Non-diesel type liquid fuels derived from coal are also placed in this category for purposes of this project.

The objective of the current test program are as follows:

1. Through experiments with a 2-cylinder, 2-stroke cycle, medium-speed diesel engine, define the degree to which pertinent properties of diesel fuels can be varied from specification-values while still allowing acceptable fuel economy, combustion characteristics, exhaust emission levels, and piston ring wear to be obtained.

2. Perform a similar series of engine experiments with alcohol (methanol), gasoline, and a simulated coal-derived liquid as primary engine fuel. (Ignition of the primary fuel is to be obtained by pilot injection of diesel fuel.)

3. Prepare a comprehensive program plan for the future investigation of alternate fuels for medium-speed diesel engines; this plan to make use of results of the current project, ongoing alternate fuel projects by other organizations, and engine manufacturer and user requirements. As part of the planning task, the AAR, the locomotive manufacturers, and other interested railroad industry groups are actively participating in the coordination for the program plan.

The test engine used in the current program being conducted at Southwest Research Institute, is a 2-cylinder, 2-stroke cycle EMD Model 567C featuring bore and stroke of 9.5 and 10.0 inches, compression ratio of 16:1, and needle-valve type unit injectors. The engine is instrumented to obtain data on engine speed and torque, continuous pressure in one cylinder, injection timing, fuel consumption rate, and pertinent temperatures and pressures. Exhaust smoke opacity is measured by the Bosch method. The engine is set up to run at the nine speed/load conditions commonly used in line-haul locomotive service.

The so-called regulated diesel emissions (unburned hydrocarbons, oxides of nitrogen, carbon monoxide) are measured using conventional instrumentation. Exhaust particulate content is measured with a stainless steel dilution tunnel.

Rate of piston ring wear is measured by the radioactive tracer technique. This method employs a radioactive piston ring and continuous measurement of the amount of radioactive wear particles in the lubricating oil. A stabilized rate of wear can be measured for a given speed/load/fuel combination in one 8-hour shift.

A standard commercial No. 2 diesel fuel meeting all the requirements of ASTM D-975 was selected as the base-line fuel for this program. Engine experiments have been conducted with the following nonspecification diesel-type fuels:

Low Cetane Number Fuel Series - Cetane number was systematically reduced from the base-line value of 55 by blending progressively greater amounts of secondary fuel components with the base fuel. The lowest cetane number thus obtained was 17.

Non-Standard Distillation Range Fuel Series - These fuels were obtained by blending the base fuel with either lube oil stock or unleaded gasoline, and by blending lube stock with gasoline. Varying the amount of each constituent in these blending schemes produced so-called dumbbell fuels (with a preponderance of light and heavy ends) and extended boiling range fuels (with a preponderance of either light or heavy ends). Fuels in this series had the following distillation characteristics: normal initial boiling points and very high (greater than 1100° F) end points, normal end points and very low initial boiling points (less than 0°F), and a combination of low initial points and high end points. It is important to note that all of these fuels could be obtained in practice by blending together common components, thus producing a greater quantity of an off-specification fuel.

High Viscosity Fuel Series - A heavy fuel with a viscosity of 145 centistokes at 40°C was gradually heated to reduce the viscosity. This approach allowed all other fuel properties to remain unchanged while viscosity was altered.

Water-In-Fuel Emulsion - Water in the amount of 10 percent by volume was emulsified into the heavy diesel fuel, and a stable emulsion was obtained by adding a small amount of surfactant. The amount of water in the emulsion was later increased to 20 percent by volume.

High Sulfur Fuel Series - Sulfur-containing additives were added to the base fuel to increase sulfur content from the normal 0.2 percent by weight value to about 1.0 and 1.5 percent. Since sulfur content has no significant effect on engine performance, only emissions and ring wear measurements were conducted with these fuels.

The last series of tests featured engine operation on methanol and unleaded gasoline (separately) as the main fuels, with ignition by pilot injection of diesel fuel. The main fuel was introduced through the centrally located, standard-unit injectors, and the pilot charge was injected through a small secondary injector in each cylinder. It was necessary to furnish the pilot injectors with their own injection pumps. Results of the initial test series will be available in a joint DOE/FRA report by the end of 1979.

The next phase of the alternative fuel test program will involve the selection of non-diesel gaseous fuels (e.g., hydrogen, propane, dissociated alcohol, etc.) for 2-cylinder engine experiments, developing criteria for fuel screening (cost, safety, handling, engine use) based on previous results, and multi-cylinder engine experiments with the "of-spec." and non-diesel liquid fuels using both Electro Motive Division/ General Motors and General Electric full-size locomotive diesel engines. The actual candidate fuels identified in this screening process for further testing and evaluation will be closely compared to the recommendations of a DOE study performed by EXXON Research and Engineering Company[13] on alternative energy sources for non-highway transportation.

HARDWARE TECHNOLOGY

Flywheel Energy Storage Feasibility Studies

Flywheel Energy Storage Switcher (FESS) - This study quantified the benefits to be derived from the recuperation of braking energy from a switching locomotive as it decelerates a cut of freight cars during the switching operation.[14] The systems considered for this study were restricted to those which could use developed hardware with a minimum of modification. The energy storage unit chosen was the one developed for the Department of Transportation Advanced Concept Train (ACT-1) vehicles.

The system, as originally conceived, required the use of separately excited traction motors and, therefore, a major task of the study was to test a separately excited version of the GM/Electro-Motive Division's D77 traction motor.

The benefit of this system was clearly dependent on the operating duty cycle of the switching locomotive and, therefore, the study examined in detail the operation of three flat yards to enable a realistic operating scenario to be developed.

In order to accurately predict the performance of the FESS system a computer model was produced which, starting with the internal parameters of the diesel locomotive, is able to predict fuel consumption of the locomotive with and without a flywheel system. The correlation of this model was shown by comparison with the measured yard data.

The study concluded that a boxcar was necessary to carry the ESU because no room existed on the locomotive. This, combined with the increased auxiliary load, results in the same energy consumption with or without the FESS system, for a typical flat yard operation, in spite of the energy recuperated and reused. Brake maintenance savings, although significant, were not sufficient to give an attractive return on investment.

Wayside Energy Storage Study - This study quantified the benefits to be derived by recuperation of braking energy from freight trains descending long grades.[15] This energy, now wasted by dynamic or friction braking on the diesel-electric and electric locomotives, represents a valuable resource that could be conserved. As an example, in the hour it takes a large freight consist to descend Cajon Pass near San Bernardino, California, enough electrical energy can be generated to supply a residential community of 30,000 for 1 hour. Storing this energy for use by an ascending consist would substantially reduce energy costs for the railroad. For the Cajon Pass example, about $500 in savings for diesel fuel would be realized from the recuperative braking of each large consist based on 1977 fuel costs.

The energy storage concept could be supplanted by the availability of a receptive electric utility tied to the electric lines used for regenerated electric power on the grades; however, this mode of operation is possible with only a few utilities that have policies permitting them to accept power from intermittent sources. Also, if the utility accepts such power, it is brought back at a price substantially below the cost of newly generated and distributed power from the utility, often at zero credit to the customer.

Yet another approach to recuperation of braking was the scheduling of train operations so that a receptive (ascending) train is available when a train is descending the grade. Such an energy interchange would require an unrealistically precise scheduling of train operations. In practice, it would be necessary for one train to wait at the start of the grade for the second train to reach the grade. Based on railroad dispatching data, these waiting periods often would be of several hours duration. Also, in the real world of freight railroads, several other factors appear to make the interchange of energy directly between trains impractical. The most important of these factors are the following:

1) Many grades are single track and require consecutive train operations
2) Most railroads have a greater flow of freight in one direction than in the return direction
3) The times required to ascend a grade are usually different.

Consequently, it is necessary to provide an energy storage system at grades possessing the proper combination of change, traffic density, and length. These energy storage systems would be installed at the wayside rather than onboard the lomocotives. This is because the required level of energy storage (up to 3 MwHr per locomotive) makes the size and weight prohibitive for vehicle installation.

A number of wayside energy storage system (WESS) configurations were considered before the conclusion was reached that the optimum system was that the one shown in Figure 1 in which the interface between the locomotive and the storage device is a high voltage ac catenary, and the storage device is a flywheel.

The optimum system requires locomotive(s) with a fully regenerative capability. For an electrified railroad, this is relatively easy to achieve with modern electric locomotives. For the more common diesel-electric railroad, major modifications are necessary to the locomotives and consideration of this requirement led to the identification of the dual-mode locomotive (DML) concept, in which a standard diesel-electric locomotive (such as the SD40-2) is equipped with pantograph, transformer, thyristor converter and choke to enable it to operate as either a diesel-electric or electric locomotive.

The optimum flywheel design was determined to be one with a 604 ton steel rotor, having a diameter of 15.3 feet and a length of 19 feet. The flywheel, rotating at speeds ranging from 1017 to 2037 rpm, would be installed in a pit below ground level on the wayside adjacent to the grade.

The study concluded that up to 80 locations existed where WESS could be economically deployed based on the nine railroads surveyed. The spread of railroad electrification would increase the number of potential sites.

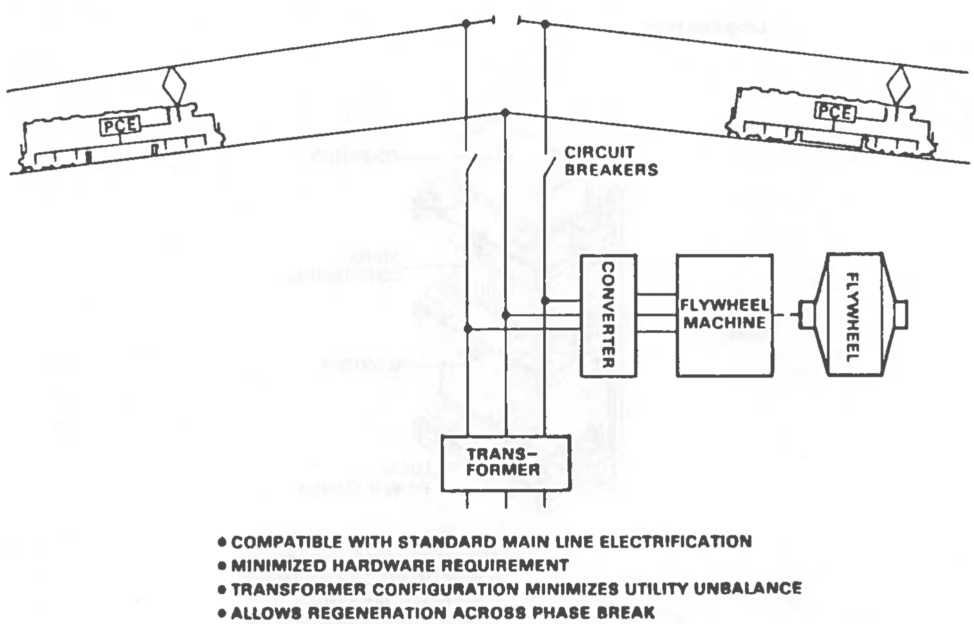

FIGURE 1. OPTIMUM WESS DESIGN

As a result of this study the Canadian Government has initiated a site specific study of WESS applied to two Canadian railroads. The FRA is currently sponsoring, with the cooperation of DOE, a system engineering study of the DML concept. The study will result in preliminary performance specifications for the system and components, preliminary cost estimates for the locomotive modifications, and related fuel savings/energy consumption.

Locomotive Data Acquisition Package

With the understanding that any program for energy consumption improvements - whether it involves the use of alternate fuels, diesel heat recovery, energy storage, traction control, or improved operating procedures or equipment - must be based on statistically valid samples of engineering data gathered under a wide variety of operating conditions, the problem that arises is the lack of good solid technical data upon which to base decisions. The importance of statistically valid data, under actual railroad freight operating conditions cannot be overstated. In the past, the problem of data acquisition has been approached by developing different instrumentation for each separate program. Not only has this proven to be somewhat inefficient, but often the individual contractor ended up owning the equipment.

In previous research efforts, extensive examinations of the literature failed to produce actual published data on locomotive equipment operation; questions that appear almost trivial often remain unanswered. For example, at different times attempts have been made to determine: (1) Locomotive fuel economy as a function of train handling and HP/ton ratios; (2) Traction motor efficiencies; (3) Terminal-to-terminal run times and schedule compliance as a function of HP/ton ratios; (4) Freight ride quality as a function of train handling procedures; (5) Locomotive voltage transients - their causes, effects, and magnitudes; (6) The shock and vibration environment that locomotive components are subjected to; (7) Locomotive duty cycles; (8) Slip/slide circuitry performance and efficiencies; and (9) Aerodynamic forces on containers, boxcars and trailers. As a further example, at this time it is not clear how to write a good performance specification for locomotive carried equipment; the shock levels, the vibration levels, the electromagnetic interference environment, etc., are unknown. The lack of this information has definitely been an impediment to our efforts. To a larger extent it has also prevented "outsiders" from successfully entering the railroad marketplace. Private enterprises could conceivably supply equipment for our research investigations, but unless the environment is described accurately, suppliers are reluctant to risk investment in developing such equipment. The need to provide reliable data is perceived as critical to the success of the FRA energy conservation research program.

FRA is sponsoring a project at the University of California, Lawrence Berkeley Laboratory/DOE to develop a portable locomotive data acquisition system in an attempt to obtain and publish some of the information noted above. The system includes not only the locomotive data recorder, but also an ensemble of transducers and some analysis software. The system is known as the Locomotive Data Acquisition Package (LDAP).[16] The data recorder portion of the system is mini-computer based; as shown in Figure 2, it is designed to be installed in the long-end hood of a freight locomotive. Figure 3 shows a block diagram of the system. The unit is being designed as a research tool capable of supporting a wide variety of testing programs. Near-term applications of this instrument involve supporting FRA's Locomotive Performance

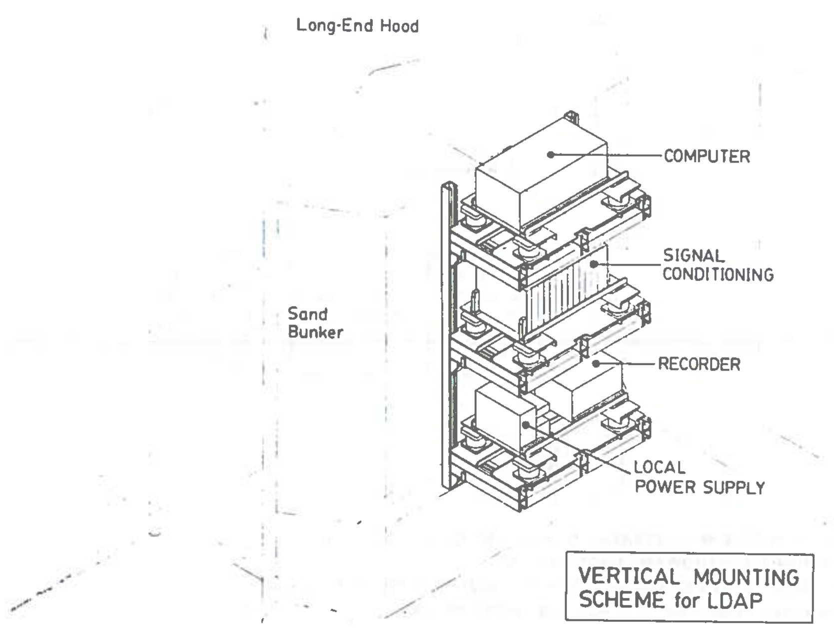

FIGURE 2. LDAP INSTALLATION, TYPICAL LOCOMOTIVE

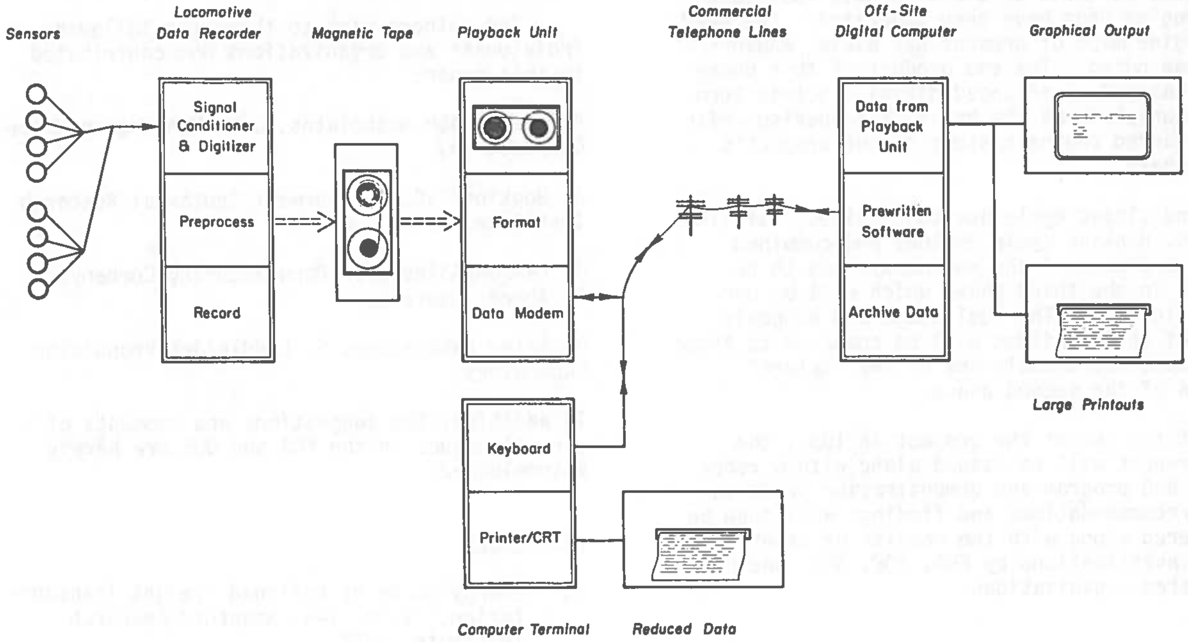

FIGURE 3. BLOCK DIAGRAM, LOCOMOTIVE DATA ACQUISITION PACKAGE

Analysis Project and Energy/Environment Research Program. Our immediate objectives for the LDAP project are to prove the validity of the concept and to establish the reliability and credibility of the device. Field testing began this summer and will continue for 3 months. Current plans are to continue the development and testing of the LDAP on selected railroad properties by fabricating additional prototype LDAP units next year. The procurement of these additional units will be based on bids from the private sector using the specifications developed in the current program.

Advanced Propulsion Systems

This study is concerned with propulsion systems and alternate fuels usage in freight service line-haul locomotives. As such, it is concerned with the consist only as it impacts the fuel consumption of the locomotive.

The project began in 1978 under DOE sponsorship with the Jet Propulsion Laboratory of the California Institute of Technology.

The first phase of this project is concerned with collecting and establishing a data base for present day diesel-electric freight locomotives and with the development of a locomotive propulsion system mathematical model and simulation program. This phase has resulted in the development of a conventional diesel-electric locomotive model, several duty-cycle models and their integration into a full-scale simulation model which can be used to predict the fuel consumption of a train. Data has been collected for use in this model from the open literature and from various private firms, some by letter agreements which provide for the safe-guarding of some proprietary data. The data itself has not been published, but the results of the analysis using it will be released in the final report. Base line data banks are established for engines, alternators, generators, traction motors, fans, inverters, rectifiers and other components as well as the overall locomotive characteristics such as weight, frontal area, aerodynamics, adhesion and tractive effort. Data was also collected for the train including its rolling resistance, aerodynamics and the effects of curves and grade. Cost data as well as technical data is collected in this way. The cost data is used to predict the capital and life-cycle costs of operating both present day and advanced locomotive systems.

Information developed in other FRA and DOE sponsored programs has been used to augment the data base and will serve as a future source for updating the results in the initial phase of the study.

The second phase of the project is currently under way. It is concerned with modifications to the diesel engine which can reduce fuel consumption. These are such things as bottoming cycles, turbo-compounding and the adiabatic diesel. It is also concerned with the use of alternate fuels in the diesel engine. Of principal concern is their effects on engine performance, wear, special equipment needed, maintenance and the related costs. Fuel properties and the combustion properties have been collected and tabulated. The effect on engine power has been estimated for most of the alternate fuels and some engine maps have been generated. The need for engine maps of present day diesel engines has been noted. The end product of this phase is a "mature" or advanced diesel-electric locomotive which forms the basis of comparison with the advanced engine systems of the project's third phase.

Open and closed cycle Brayton engines, Stirling engines, Rankine cycle engines and combined cycles are some of the engine systems to be studied in the third phase which will be performed in 1980. The fuel usage and economic costs of these systems will be compared to those of present day diesels and of the "mature" diesels of the second phase.

At the end of the project in 1981, the final report will be issued along with a recommended R&D program and demonstration projects. These recommendations and findings will then be considered along with the results of other ongoing investigations by FRA, DOE, AAR, and other interested organizations.

CONCLUDING REMARKS

The research projects described above have been supported by limited Federal funds; in parallel, many other efforts are ongoing in the private firms of the suppliers and railroad operators. Although much has been learned, much remains to be learned and implemented to achieve significant conservation.

In addition to investigating fuels and their usage per se, there are a number of related and interdependent areas where research and development ultimately will contribute to petroleum conservation. Rolling stock with a lighter tare weight and radial trucks are examples of mechancial equipment changes which will conserve energy. The installation of electrification on high-density freight lines will at least allow the option of using something other than petroleum. And, of course, improvements in car utilization produce a side benefit of conservation. Finally, although difficult to quantify, the gradual improvement of the nation's track structure must surely make a contribution to our conservation efforts.

We are prepared to address these challenges in the 1980's. It is anticipated that we will be able to report significant progress in 1989 when we convene again to assess the challenges of the 1990's.

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OBSTACLES AND SOLUTIONS IN TECHNOLOGY IMPLEMENTATION

BY

AARON J. GELLMAN

Things are looking up for the railroad industry. I say that because I note this morning, with great pleasure, that on a session on railroad technology, there were two — and I had really thought three — non-engineers on the panel. I say I thought three because I've known Don Spanton for a long time and spent many happy hours with him in which he pridefully told me he was an economist. I heard all that stuff about all those engineering degrees. I really didn't believe it until he used the word "C-Tane". That did it. There are only two of us, Hugh Randall and myself, who are not engineers. If I think the railway industry is looking up from that small, microcosmic event, it gives you a clue to my bias which, in part, is reflected in a small story.

As you know, the Department of Agriculture has a County Agent Program which is generally thought to be one of the most effective means of transferring technology that has ever been devised. Indeed, American agriculture is far ahead of that in any other country in terms of productivity technology — however you want to measure the technological productivity of that industry; and it is in part because of the County Agent Program.

It was a great surprise to the Secretary of Agriculture recently to learn that one of his county agents was being routinely maimed, with increasing severity, by a particular farmer in the midwest. This county agent was first assaulted by the farmer when he came on the farmer's property and suffered a broken arm; next it was two broken arms, then with a broken leg and two broken arms, and then finally all four limbs and his nose to boot - with a boot, I guess. In any event, the Secretary of Agriculture got wind of this after four limbs were simultaneously broken, and he called the farmer up and said, "We're not going to prosecute you, but we sure are curious here in Washington. Here's a guy we send around to bring you the latest information about science and technology and agriculture, we spend a great deal of money — public money — doing this. It's a generally successful program, and all this guy wants to do is good for you. Why is it you keep assaulting this poor fellow?" The farmer said, "Mr. Secretary, what you people don't understand is I ain't farming now as well as I know how."

Well, that generally reflects my continuing view of the problems of railroading. There is no shortage of science and technology. There is no shortage of technological possibilities in the railroad industry, and that is unique among all modes of transportation. I'm not saying that there are no problems to be solved. There are many. But there is one hell of a lot we can accomplish through judicious application of science and of the technological possibilities that exist.

I would like to establish a couple of definitions with you at this point (see Table 1). The phrase "technology implementation" is used in the table which was assigned to me. I look upon that as a synonymous expression for technological innovation. Innovation is the process by which an invention or idea is translated into a product or process and brought to the marketplace. Innovation does not take place until there is use in the marketplace of a good or service sold and acquired in an arm's length transaction.

"Technological possibilities" are the results of what someone perceives to be "successful" research and development activities. The word successful is in quotes for that reason, the qualifier being, of course, one's perceptions. The sponsor of R&D usually perceives it to be successful when a technological possibility results.

Finally, technological possibilities become innovations through the development and exploitation of what we have come to call "technology delivery systems."

TABLE 1. A FEW DEFINITIONS

"TECHNOLOGY IMPLEMENTATION" = "TECHNOLOGICAL INNOVATION"

<u>INNOVATION</u> = THE PROCESS BY WHICH AN INVENTION OR IDEA IS TRANSLATED INTO A PRODUCT OR PROCESS AND BROUGHT INTO THE MARKETPLACE

<u>TECHNOLOGICAL POSSIBILITIES</u> ARE THE RESULT OF "SUCCESSFUL" R&D

<u>TECHNOLOGICAL POSSIBILITIES</u> BECOME INNOVATIONS THROUGH "TECHNOLOGY DELIVERY SYSTEMS"

Next we can move to the observation that there are many obstacles and catalysts to technological innovations, and they are initially best seen by considering them in terms of fundamental resources. If we look at the fundamental resources that go into producing goods and services in this and any other economy, we find that they are made up of such things as real property, labor, technology and underlying science, capital, and entrepreneurship and management (see Table 2). To complete the list of influential factors where technological innovation is concerned, we need to add what I call the influential "environmental factors" which are regulations and demand.

TABLE 2. OBSTACLES (AND CATALYSTS) TO TECHNOLOGICAL INNOVATION IN TERMS OF FUNDAMENTAL RESOURCES

- REAL PROPERTY
- LABOR
- TECHNOLOGY AND UNDERLYING SCIENCE
- CAPITAL
- ENTREPRENEURSHIP AND MANAGEMENT

* * * *

"ENVIRONMENTAL" FACTORS INFLUENCING TECHNOLOGICAL INNOVATION -

- REGULATION AND REGULATIONS
- DEMAND (E.G., SHIPPERS/RECEIVERS)

What do I mean by "regulation and regulations"? There is a body of regulations abroad in the land that condition what we can do and can't do and must do and must not do. In addition, there is a concept called "regulation." In fact, there is a host of concepts that go under the name of regulation, and later in our brief time together this morning, we will want to come back to this notion of the concept of regulation since we are going to talk somewhat about reforming it or even abolishing it.

Now, if management of an enterprise - a railroad enterprise or railroad-supplier enterprise - is not to be an obstacle to innovation, certain propensities must be present within the railroad industry and within its supplier group (see Table 3).

TABLE 3. KEY "PROPENSITIES" RELATED TO INNOVATION

- PROPENSITY TO DEVELOP UNDERLYING SCIENCE
- PROPENSITY TO DEVELOP TECHNOLOGICAL POSSIBILITIES
- PROPENSITY TO TRANSLATE TECHNOLOGICAL POSSIBILITIES INTO INNOVATIONS - BY ASSUMING (PRUDENT) TECHNOLOGICAL RISK
- PROPENSITY TO ACCEPT BENEFICIAL INNOVATION

There must be healthy propensities to develop underlying science as needed. Now "as needed" is an important qualifier because right now, at this point in railroad history, there is no evidence that railroading is suffering for lack of underlying science for raw materials. If we are at all successful in this meeting and afterwards, it will not be very long before a session is held here at TSC where, at least, part of it will be devoted to identifying underlying science that needs to be developed to move railroading still further. May that time come speedily.

A second propensity that needs to be developed is one that causes management to seek explicitly to generate technological possibilities on a routine basis. There are some technological possibilities that railroading needs now. There are unmet needs, but not very many. For the most part, the technological possibilities are at hand to take railroading much further in terms of efficiency, market expansion and so on.

A third propensity of great importance is that of translating technological possibilities into innovations, and this includes the necessity to assume prudent technological risks. The technology delivery system we earlier referred to is part of this, but fundamentally, we need to develop much sharper instincts, much greater knowledge about risk-bearing than the industry has displayed for many, many years; and I explicitly include risk-bearing where technology is concerned. For instance, to fail is not and should not be to commit career or professional suicide. Failures have great value, too.

Generally, technological risk is counted for too little in the railroad mode of transport. I say this with some considerable knowledge and experience in the other modes of transportation. Railroading has the most risk-averse positive where technology is concerned. The industry needs to develop a propensity to accept beneficial innovation, whether that beneficial innovation comes from outside railroading or whether it comes from a competitor or some other railroad in the United States or out of it.

In general, the railroad industry does not get very high marks when it comes to accepting beneficial innovation from other sources. Parenthetically, I just heard Don Spanton refer to the aerodynamics tests. You may find it amusing that when I was with North American Car, for a number of reasons we thought it would be useful to canvas the railroad industry and find out whether there were any aerodynamicists there. (This would have been in the middle or early 1960's.) You will be interested to learn we found one. It was a pretty thorough canvas, and we had some things in mind that we wanted to talk to railroaders about as we were hoping to find a home for some new technology.

Well there was one as I said. He was working on things far removed from aerodynamics, but it had become clear already to students of railroading, most of whom were outside the mainstream, that aerodynamics was a very important issue. And this was when fuel was only one-third to one-quarter the price it is today.

Now, with regard to railroads accepting beneficial innovation, as in some other industries, there is a real "not invented here" (NIH) problem. For example, consider where we are on solid state signaling equipment. (I am sorry to beat that old horse again. Some of you know I've recently given some Congressional testimony on this and related matters.) In 1980 and 1981 we will see installed in the United States, at Federal expense - most tragic of all in a way - signaling systems with vacuum tubes and mechanical relays. We are the laughing stock of signaling technologists the world-over.

Again, explain the lack of use of polyurethane paints and costings on a large scale in the railroad industry as contrasted with its very rapidly increasing use in myriad other fields where it is already considered quite mundane technology.

Moving on, and getting somewhat more positive, in the 1980's, where are the obstacles to beneficial technological innovation in the U.S. railroad industry? (By the way, I would call your attention to the fact that I qualify the phrase "technological innovation" with the word "beneficial." It is absolutely not to be accepted that innovation is always beneficial. Innovation is not always beneficial, either in cost terms or social terms or any other terms, but we are talking about innovation that truly generates more benefits that it does costs.)

So, where are the obstacles to beneficial technological innovation in the United States railroad industry as we approach 1980? We can start by listing the fundamental resources and - in the old sense - the environmental constraints which represent my own judgements as to where we stand. The accompanying Table 4 covers the point.

TABLE 4. OBSTACLES

IN THE 1980's, WHERE ARE THE OBSTACLES TO (BENEFICIAL) TECHNOLOGICAL INNOVATION IN THE U.S. RAILROAD INDUSTRY?

	POWER OF OBSTACLE*
REAL PROPERTY	1
LABOR	2
TECHNOLOGY AND UNDERLYING SCIENCE	1
CAPITAL	1 TO 4
ENTREPRENEURSHIP AND MANAGEMENT	5
REGULATION	?
REGULATIONS	1 TO 5
DEMAND FOR FREIGHT TRANSPORT SERVICE	1 TO 5

*1 = NOMINAL; 5 = VERY SUBSTANTIAL

With regard to real property, there is no significant lack of land to constrain railroad technological innovation with one very important exception which relates to Conrail. The "taking" process left Conrail with relatively little real property to develop industrially and to provide some flexibility to move operations that are real-property such as yard and terminal operations. Putting that aside for the moment, real property is not a significant constraint to technological innovation in the railroad industry.

It may come as a surprise, but labor is not the constraining force in technological innovation in railroading that, frankly, I used to believe it was, and many people in railroading still believe it to be. Most of the beneficial technological changes that this industry cries out for can be introduced either independent of labor or by "buying off" labor on a basis that is modest as compared with the benefits to be gained.

Technology and underlying science I have already mentioned. There seems no warrant for believing that there are severe constraints yet placed on the railroads' technological innovation performance as a result of a lack of underlying science or technological possibilities.

Capital is clearly a problem. In some cases, capital is not a constraint while in others it is. It depends on the individual case.

Entrepreneurship and management: Bingo! (We will come back to this.)

Regulation, or more appropriately, the concept of regulation. The existence or lack of regulation is a big question mark in the future. We are going into debates - endless debates - about regulatory reform and deregulation without really having done our homework correctly. It is absolutely clear from the experience we are now going through with respect to airline deregulation that the homework was not done there. I am not suggesting that a mistake was made in "deregulating" the airlines; I am merely suggesting that we are experiencing far too many surprises. Mostly, the lawyers are surprised. Economists generally are not as surprised by what is happening. Most competent economists - maybe that is how you recognized them - predicted substantially the course now being taken. In any event, the nation does not yet have a credible projection as to what effect deregulation will have if and when it comes to the railroad industry of the United States.

The word "regulation" presents a different set of problems. As we already know, the existing body of regulations can have, depending on the nature of the innovation at hand, no affect or a very small affect on the one hand, or a completely governing affect in other cases. With safety appliances for example, there are restrictions against innovation that are absolutely ground into the applicable regulations.

The demand for freight transport service is another element. Again, depending on the individual innovation that one is considering, the demand for freight transport service may have great or small effect.

Since we are short of time, I would like to move to Table 5 which lists the really high-leverage obstacles to innovation in the United States railroad industry of today. One is capital. Second is entrepreneurship and management. The third is the existing body of regulations and the expected increases to that body of regulations in certain areas. The demand for freight transport services both with regard to the level of demand and with regard to the character of that demand is the fourth obstacle.

The key unknown other than "are we going to have recession or depression" is "regulatory reform." It is an unknown not only because we do not know how much or how little we are going to see, but because we have not spent the resources necessary to understand regulation's fundamental effects on technological innovation in transportation — or in most other fields, for that matter.

TABLE 5. THE KEY OBSTACLES

— CAPITAL

— ENTREPRENEURSHIP AND MANAGEMENT

— REGULATIONS

— DEMAND FOR FREIGHT TRANSPORT SERVICES

A KEY UNKNOWN: REGULATORY REFORM

Now, before considering some possible solutions to our problems with regard to technological innovation in railroading, I would like to run quickly through the following.

When one is thinking about technological innovation it is necessary to recognize that the motives for undertaking, for sponsoring, or for committing resources to technological innovation are limited in number. Specifically, there are just four basic motives that really count, that have high leverage (see Table 6). One is to stimulate demand. Another is to reduce costs. A third is to achieve the first two at the same time. The fourth is to meet regulatory requirements or conditions. An example of each, I think, might be useful.

TABLE 6. MOTIVES FOR UNDERTAKING TECHNOLOGICAL INNOVATION

- DEMAND STIMULATION
- COST REDUCTION
- (A) + (B)
- TO MEET A REGULATORY REQUIREMENT OR CONDITION

Pure cases of demand stimulation are very difficult to find in the railroad industry where freight transportation is concerned, given the nature of the economic regulatory scheme which overlaps railroading. The great exploitation of RBL type of equipment for canned goods and paper products beginning in the fifties and carrying through since that time represents innovation in the marketplace that was demand-stimulating. (It surely was not cost-reducing as I am sure many of you know.)

An example of cost reducing innovation would be improved signaling systems where capital or maintainance costs or reliability were improved. Such innovations would have little or no impact on demand, but would be reducing costs. Again, in an earlier age, diesel locomotives represented primarily a cost-reducing innovation.

Examples of innovations which were both demand-stimulating and cost-reducing in the railroad field would include the Big John covered hopper which certainly has been cited favorably for many reasons over the years. Big John moved a lot of traffic off the competition and onto rails. It certainly reduced the unit cost of producing that transportation by rail.

Another case is the unit train. In many instances, the advent of the unit train was a demand-stimulating and cost-reducing innovation. At the same time, I am not thinking only, or even primarily, of coal unit trains. There are other kinds of unit trains which are an even more dramatic combination of cost-reducing and demand-stimulating.

To meet regulatory requirements or conditions, there have been many innovations. One of the best examples, of course, is the double-length rather than single-length flat cars. These were clearly born, more than anything else, out of a necessity to meet the requirements of Rail Form "A" which has as a major independent variable cost per car-mile. With the long cars, railroads could demonstrate to the Commission that costs on a ton-mile basis were lower. When you have cars twice as long this can be shown because of the way the formula was (and remains) structured. So, we have a clearcut case of technological innovation being induced largely by regulation.

Competition and innovation are intertwined. Competition is without doubt the greatest single spur to innovation. There is no doubt that the railroad industry in one sense has suffered grievously from a lack of competition in certain areas, even while it may have benefited in other instances. Let me be more specific. There are four kinds of competition that one wants to consider when thinking about technological innovation in railroading. One is intramodal competition between railroads. This kind of competition has generally been suppressed. I don't say it's nonexistent, but it certainly has been suppressed. It is perhaps destined to grow if we get regulatory reform along the lines now suggested for the future. We need to watch developments in this area and make sure that any increase in intramodal competition results in an increased rate of beneficial innovation.

Intermodal competition is potentially the most effective spur to technological innovation where the movement of freight is concerned in this country. Some would say we have had insufficient intermodal competition because it, in fact, has not induced railroads to do anything like what they could and would have done with the available technological possibilities to improve their lot. Be that as it may, intermodal competition under any regulatory reform scenario that we have seen projected will be highlighted, and one of the great benefits anticipated by the theorists and practicalists alike is improved and increased technological innovation of a beneficial sort.

The next form of competition is that between suppliers. There is no question but that in the railroad supply field in the United States the concentration ratio – that's economic jargon for how much of the business enjoyed by a few suppliers is scandously high. In the braking equipment field, as you all know it, at the two-firm level we approach one hundred percent concentration. The same is true in the signaling field. And now you know a fundamental reason why we have solid-state electronics being excluded in the latter field in the United States as compared with what can be observed in some other countries and in other settings, in other industries, even in the United States. We need more suppliers in the railroad field. We need them desperately. We need to spur competition among suppliers for railroad patronage. Such supply-side competition must be heightened far beyond what it is today in many, but not all, areas of railroading.

Finally, we have competition within the firm. Now, competition within the firm, the railroad firm, takes two fundamental forms. One is competition for resources. Railroad management only has so many bucks to spread around. So, there is competition for internal resources between those who would like to advertise more and those who would invest in promising technological innovation, for example. The other kind of intra-firm competition is more subtle but no less important.

It is the competition for recognition and for reward. In the railroad industry, those who take technological risk, who promote technological risk, who promote technological innovation and change, are treated very shabbily for the most part, and that is true throughout the entire sweep of American railroad history. If you compare this with other forms of transportation in the United States, I think you would be very surprised to see how few rewards go to those who pin their hopes and their careers to technological changes in railroading.

An effective way of summing up is to consider Table 7. In this matrix the "X's" mean there is an effect between what is on the left stub and what is across the top. The blank spaces reflect my view that there are no significant relationships, while the question marks represent intersections where we ought to know what the relationships are – at least the direction of the sign – and we do not know very much at all.

Across the top you will recognize our old friends from Table 4 somewhat compressed. These are the factors influencing technological innovation. On the left there are some suggested solutions. I call this a "first out" because that is exactly what it is. It needs to be refined. More work needs to be done on it.

Certainly, if we want to stimulate beneficial technological innovation in the railroad field, we certainly could provide government grants and subsidies. It would affect the availability of capital to railroads. It might even affect the management of railroads. I'm not quite sure. Possibly, in the supply trades it would have a marked affect on the quality of entrepreneurship - the quality of risk taking, technological risk taking and the quality of management of R&D oriented resources.

Government supported production programs. By that I mean to convey the notion of avoiding the whipsaw feast-or-famine situation such as in the freight car production field. Government has two motives, at least, for thinking about guaranteeing production programs. One is to avoid the whipsaw, but far more important in both the short run and the long run would be the imposition of enforced <u>performance</u> specifications rather than design specifications historically most often employed.

Government loans. Here is one of the more promising means for improving technological innovation in the transportation field generally, and in railroading particularly. I believe loans are better than grants because the power of the balance sheet is upon the private sector entrepreneur; using loans, he knows he has to pay it back. Perhaps a federal equipment development bank, which I have long suggested, should be created. It may provide subsidies through long-terms and low interest rates loans, but advance the funds as loans not grants.

I think we better not take the time to talk about shifts in burdens of proof except to say that, for too long in this business, people who say that something won't work have succeeded in putting on the backs of those who say it will work the burden of proving their case for change. For a period like 10 years, we ought to shift the burden and see what happens. Surely, it can't hurt.

The concept of "performance-specification purchasing" should be underscored. I think it is probably the most powerful single thing we can do. Those of us who have any clout with the purchasing function can say "By God, everything we buy from now on, or most things, are going to be bought on performance specs. We're going to learn how to write a performance spec, and we're going to adhere to them." That might have the most beneficial effect of all!

Heightened competition. I need not say more.

TABLE 7. A "SOLUTIONS" MATRIX
(FIRST CUT)

SOLUTION	CAPITAL	ENTREPRENEURSHIP - RAILROADS	MANAGEMENT - RAILROADS	ENTREPRENEURSHIP - SUPPLIERS	REGULATIONS	DEMAND
GOVERNMENT GRANTS/SUBSIDIES	X		?	?		
GOVERNMENT-SUPPORTED PRODUCTION PROGRAM	X	?	?	?		
GOVERNMENT LOANS (E.G., "TRANSPORT EQUIPMENT DEVELOPMENT BANK")	X	X	?	X		
SHIFT BURDENS OF PROOF		X	?	X	X	
PERFORMANCE-SPECIFICATION PURCHASING		X	X	X		X
HEIGHTENED COMPETITION		?	X	X	X	X
IMPROVED PERSONAL INCENTIVES TO INNOVATE		X	X	X		X
ASSURE Bpub - Cpub		X	X	X	X	
ASSURE Bpub - Cpvt	X	X	X	X	X	
DEREGULATION ("REGULATORY REFORM")	?	?	X	?	X	?

Improved personal incentives to innovate. Remember that the process of innovation is a people process. It's a highly individual process. People's necks are on the line as well as money, and we ought to recognize it. We had better humanize railroading more than at present, at least to the extent necessary to get people interested in innovation. That is not the way it is today all too often.

Moving on, Table 7 suggests that one of the most promising "solutions" to the problem we have been considering is to assure that the public or social benefits from technological innovation exceed both public and private costs. The government often spends money on technological innovation in railroad (and elsewhere) where the benefits to the public are not clearly in excess to the costs to the public, and there is clearly a terrible distortion of the process of innovation, and it is also how a lot of the non-beneficial innovation results - which gives the concept of innovation a bad name generally.

Where government mandates private costs, such as in present railway yard noise reduction programs, government ought to assure that the benefits to the public are equal to or greater than the costs that it is attempting to load onto the backs of already over-burdened railroads.

I shall conclude by suggesting that the value of the people-intensive process we call innovation is highly under-appreciated in the railroad field, as in many others. I believe however, that it has been under-appreciated in railroading far longer than any major U.S. industry. It is time to redress this situation. It was terribly impressed by Hugh Randall's recognition of the people-nature of railroad operations from the most fundamental to the highest levels, but then again, he is not an engineer. Also of John Norton who stated his conclusions in terms of DuPont's reliance on individual initiative and individual responsibility. I think that is highly refreshing and conveys a very important message.

By humanizing railroads in the sense that I mean it, by recognizing the people-nature of the process of producing rail transportation, we will do something that a few industries, but only a few, have already begun to recognize: within each of them there are considerable of what I have come to call "contingent assets." Contingent assets are assets that are unexploited; they are the property of a rail carrier, but can be exploited if, and only if, the right "switches" are moved in the heads of the people who know about such assets - such intellectual capital.

Let us now go out and indentify these contingent assets in railroading and re-organize our organizations, our railroads, in such a way that these contingent assets can be converted to real earning assets. The future can be nothing but rosy through the decade of the 80's and beyond if we will only dedicate ourselves to this sort of activity.

(R)* MR. CANN: Now, we'll give you an opportunity to question our panelists, and perhaps to clarify or to bring up divergent points of views. So the period of questions is now open. I thank all of my speakers for their very informative talks this morning and for establishing what, I think, is a very good basis for this next period.

(Q) MR. HANSEN: I'm John Hansen with Union Switch & Signal Division. I take exception to some of the remarks that Mr. Gellman made concerning lack of progress in the signal industry. Mr. Gellman mentioned that he expected people would come over here and find, in the 1980's or 81's, new installations of vacuum tubes in our signal business. I don't believe, to my knowledge, there's been a vacuum tube installed on a railroad signal project in this country for at least the last decade. We introduced solid-state devices in 1950, and they have received a considerable amount of acceptance in most areas except that of vital circuit design. We've introduced digital computers, and I'll talk more about that this afternoon. We're presently working on the application of micro-processors, and the reference to electromegnetic relays still being in service, and I'm going to talk about that this afternoon. Nobody has found a suitable substitute for that kind of reliability. Thank you.

(R) MR. CANN: Aaron, would you care to respond?

(R) MR. GELLMAN: I'll be here this afternoon, and I'll be anxious to hear what he has to say.

(Q) MR. POWELL: I'm Ed Powell from Portec in Pittsburgh. I have a question for Mr. Randall. We've all been pleased with the accomplishments of Conrail over the last 4 or 5 years, and I'm wondering why they decided to cut back on their rail and tie program for next year?

(R) MR. RANDALL: As some of you are aware, I'm sure, we're required to submit various planning documents to the U.S. Railway Association every year a 5-year plan. In the plan that we submitted in August, we presumed that with the advent of regulatory reform in the rail industry, effective January 1, 1981, it would mean enough to Conrail that we would be able to become a financially self-sustaining railroad without going back to the Federal Government and asking for more money. We have already requested and been authorized to receive $3.3 billion. We think that with regulatory reform and with the reduced capital program for 1980 and '81, we'll be able to get to the point where we could be financially self-sustainable. The figures you saw on track rehabilitation, and it also applies to the equipment area too ... we think that we made enough progress that we can cut back for 2 years without losing much, if any, of the ground that we've made up in the past 4 . There's no question that we're not going to eliminate any more deferred maintenance over the next couple of years. We think, for example, in the rehabilitation area, with our reduced program next year, we have not cut back the servicing program. In fact, that's been increased. The rail program, as it is now planned, is cut back substantially, and the tie program is cut back substantially. It's a strategy that is designed to keep us from going back to the Federal Government and request more money. With that request would come ... we're just afraid it would continue the impression that we're into the Federal Government for even more, and with that would come some conditions that we don't think would be terribly satisfying.

(R) MR. CANN: Thank you, Hugh.

(Q) MR. CHRISTIE: Christie, Pittsburgh and Lake Erie Railroad. A question addressed to Mr. Gellman. During the course of his discussion, he mentioned some obstacles to technological innovation. One of them listed was managerial entrepreneurship. I thought he was going to dwell on that a little deeper. I wonder if you could give us some ideas and some thoughts of just exactly what you mean. It seems surprising to me that entrepreneurship should be an objection for the obstacle to technical innovation. Management, yes, extrepreneurship, no.

(R) MR. GELLMAN: Well, I think if you recall the slide, it said "obstacles," and then in parentheses, "and catalysts." The reason why "obstacles" was unparenthesized, if there is such a word, is it was the topic I was assigned. The opposite of obstacle is a catalyst. The existence of competent entrepreneurship is most definitely a catalyst to technological innovation, beneficial or otherwise. It's absence is what I think represents the obstacle. I think that deals with your problem. I do not think that the railroad industry in the United States ... (inaudible) ... for its supplier will not cross the full spectrum for the suppliers. Generally speaking, I don't think the entrepreneurial always displayed in the last 20, 30 or 40 years, has really been very good. I don't think it's been sufficient in this industry both from the standpoint of railroad management, but even more, among the suppliers. I want to underscore that, in part, it's the railroad's own fault that the supplier falls short, again, because of the almost total reliance on specifications, which is other than the performance specifications. There's no way with the size of the market that you see in the Congress' scale in production,

*(R) and (Q) designate the response and question interchange, respectively, between the session panel members and the conference attendees.

the production function being what it is in signaling and braking equipment, is sufficient. That's just ridiculous. There has to be continued publication of specifications that are not performance specifications but a design specification. One to adopt is a cardinal policy to the introduction of new technology and new competitors in this field. That's really the point of that. There's no need for there to be any entrepreneurship displayed among the suppliers if they don't have to get the business. They should have to be an entrepreneurial in order to win your business. That's not the way the game is generally played in this industry very often up to now. Let's change that.

(R) MR. NORTON: I would like to add to that comment by Aaron by making two observations, First, in this field of management entrepreneurship in the railroads, I think one of the things that is often overlooked is that we're not buying just the delivery of goods. I was astounded and very pleased with the display of mechanical - the work that's been done in the mechanical interphase between the shipper, the railroad, through the rail cars. There's another dimension even beyond safety that determines whether or not DuPont Company and many other companies buy railroad transportation service and that's time. There seems to be an internal conflict within railroads by which the people are producing their freight transportation service, generally in the operating department, that don't understand the value of time, at least, to the people who are buying transportation. I think that more transportation is lost from the railroad transportation industry by failure to understand this, and there's opportunity for tremendous innovation. I've just described one thing. Maybe this is so complicated - not complicated, but difficult. I'm reminded and every one of you knows, let's say, a complicated air trip, you can pick up the phone, make a reservation, and probably within 5 minutes get confirmed reservations on eight different airlines to go the 30 different cities if you wanted to. Why can't a company routinely buy a car space on a train? The trains are numbered like planes. They go between destinations on a daily basis, usually. They have a certain capacity. I can't get reservation freight routinely from freight transportation company, rail freight transportation, in the United States. I can get it from every other mode. I can't get it from railroads. You want me to rely on you, but you won't give me the tools. You won't give me that security. That's one thing.

The other thing is that there seems to be a big feeling within the railroads that it has to go completely on the rails or we won't touch it. There has been some attention given in Plan III - I mean to Plan II, TOFC - but I wonder where the railroads will be and where this supply industry, represented here today, will play their cards in trying to convert bulk, chemical commodities now moving by truck, are not going to swing back to railroad simply by the announcement of a new design of railcar. They won't swing back by simply an announcement that you can get reservation freight on trains. Much of the chemical bulk transportation, and that's what it mainly is, bulk, it moves by truck because of the lack of rail facilities that are either the origin or the destination. The whole system cries out for the integration of a tank container moving intermodally. People will build tank containers for us if we order them. Rail cars will reluctantly move them if we place them on the railroads. Where's the entrepreneurship if some owner wants to put the system together and come in and say, "Mr. DuPont Company, I have a system here for you that is going to deliver the freight on time securely in our equipment, and relieve you of the burden of that equipment." There's at least two opportunities there. Aaron said the world is full of them. I agree endlessly. I just touched on two that would affect the movement - the participation of the railroads in the chemical traffic which is now probably at less than 35 percent in terms of dollars.

(R) MR. GELLMAN: I agree with what you said about the lack of significant or sufficient appreciation for the value of time. In the areas we've done of shippers, we have found that perhaps even more important than the time is the reliability of the railroad situation.

(R) MR. NORTON: I didn't mean erratic speed, I meant dependability, but not necessarily in 3 months.

(R) MR. CANN: That's all right, John, we sometimes sit around and wait for DuPont too.

(R) MR. SIEMENS: I'm Werner Siemens, Kaiser Engineers. I would like to ask this question of Don Spanton. In your presentation, you pointed out that in order to get more efficient energy one of the areas that was looked at was the wayside storage system. You mentioned that presently a dual locomotive is being investigated. Besides that aspect of it, is there any plans of implementing the wayside storage system, and approximately what is the time table?

(R) DR. SPANTON: There is no plan to pursue the wayside storage in the form that it has been done today. If the electrification grows someplace in the country, there well may be that there are other sites nearby which will be suitable for wayside applications. It may be a modest back door approach to electrification, however, there is still a lot of capital involved. There are no concrete plans.

(Q) MR. HOOD: My name is Charlie Hood. I'm with American Steel Foundries. I think my question should probably be addressed to God, but perhaps Mr. Gellman will interpret.

(R) MR. CANN: We've got six of them here, go right ahead.

(Q) MR. HOOD: There was a meeting of railroad people, I think 4 years ago at Woods Hole on the needs of research, and one of the most important needs, at least in the minds of the people there, was economic information. Our company, as you know, supplies freight car trucks, and we can supply a minimum truck or a maximum truck, or anything in between. We have a difficult time getting from our customers any expression of what the benefits of these various additional equipments and innovations might be - benefits in terms of dollars - so there can be established this cost-benefit ratio which is a bit overworked, but nevertheless, meaningful phrase. I wondered if there's any real work going on anywhere to measure or to establish means of measuring some of these benefits. For example, I think the radial truck was mentioned by one of you gentlemen. A very intriguing concept. It weighs more and it costs more. It certainly will reduce wheel wear or we can assume it will. It can reduce rail wear or we can assume it will. But, where are the dollar signs?

(R) MR. CANN: Aaron, let me take a whack at that one. I think there are tremendous inspirations in the railroad industry, and they do keep your nose focused right on that very issue that you've raised. He has forced us to analyze the very issues that you're talking about. The preliminary shot at us says, yes, it's economical and so you have to go ahead then with more data. The only way you get more data, of course, is to bite that bullet and buy maybe a 100 car sets and put it out and keep analyzing it from there on. That's what we're doing. I don't know if all railroads are.

(Q) MR. HOOD: Perhaps I didn't phrase my question properly. I didn't mean to get into specifics. If the railroads had a cost-reporting system that permitted the acquisition of some of this information...

(R) MR. CANN: Well, I use that. I could go on to concrete ties, I could go on to other things, but in any other issue we got into, the same thing is applied.

(R) MR. GELLMAN: I don't think I'm telling any tales out of school. There are a couple of people who I see in the room who were present at Woods Hole in the rerun of that this June. It was rerun again this June. The same issues fundamentally were raised. If any of you who were there disagree with what I say, please, I'm sure the chairman would not object if you did so, but you're absolutely right. Four years ago, the data problem was raised as a major one. We don't have data sufficient to really structure the optimum research and development program. I would say that from this June's experience the same lack of data was referred to. I think it has gone very little in the direction of solving that problem. But, notice I used the work "optimum." This industry is in the unfortunate position for its employees and officers and executives that a little improvement will go a long way. We're way down on the learning period. I'm not saying that to make anybody feel bad. There's all kinds of evidence to support it. Now, we're in a position of wanting to do with what Simon and Carnegie Tech refers to as satisfying. We don't need to optimize. That's tough. We can do the easy thing for a long time to come and still show great improvement in satisfying. We don't have to know the last details as they do, for example, in the commercial airplane industry. Still, we are very short of rail data. I hate to keep beating this theme, but it's really important, one of the evidences of how woefully short of data we are is the fact that we don't use performance specifications purposely in railroading, in sharp contrast, to every other industry you can name that is so much with technology as railroading is. One of the reasons we don't write performance specifications is that we don't have the data to write them. We ought to start gathering it. As a matter of fact, we do have a lot of data that would permit us to write much more of a performance specification and go with the benefit-cost relationship. I don't agree with you that the concept of benefit costs is overworked. I think it's overworked only when it issues from the mouth. It sure as hell is not overworked in terms of calculations on pieces of paper. We've got to do a lot more of it, and we do need data to do it better, and more broadly across the technology of railroads.

(R) DR. SPANTON: You may be aware of the so-called TDAP program we have, Truck Design Authorization Program, and while I don't wish to promise you the moon, we are making some progress on collecting maintenance costs on quite a few trucks. Next year we'll publish the final results of that project there which should be considerably more known than it was 4 years ago at the first Woods Hole Conference. On the other hand, I think, depending on where you come down on regulatory reform, we should all recognize that if regulation, the report of records, is in any way decreased, that makes it imperative that we have a greater attention to cooperative projects because if the data is not sent to the Commission, the AAR, or any other collecting agency, and it isn't collected, we will have to go into cooperative projects to a greater extent than we have now. Otherwise, we won't be able to get to the performance specification or testing procedures, or things that do come out of research projects. So, if you are a one-handed trapper for deregulations, please remember the other hand will have to go with it in the form of joint projects.

(R) MR. CANN: This becomes a touchy subject on the United States. I appreciate that, about the cooperation between government and industry. Some of the things that are being done by FAST and by Track/Train and so on; Dr. Harris is not here to expand on it because he had a personal matter to attend to. I think Aaron, that's where some of the fundamental data starts to come out and then gets expanded as you get into practical application and you move on. I agree with Aaron. You can't get the ultimate, and you have to get sufficient to get into the entrepreneurial end of it and then move on a little expansion and so on.

(R) MR. GELLMAN: You ought to recognize one other thing that Don brought up that's very important. This cooperative project idea is very important. I want to suggest to you that if you propose or promote - I don't care what your attitude is towards regulatory reform in the railroad transportation field ... let me give you an idea that ought to be pursued individually by each one of you about his industry. When the United States Congress, in its infinite non-wisdom, passed the Airline Deregulation Bill, you're not going to believe what I'm going to tell you, because nobody believes it until they look it up. They made air freight totally deregulated as of November a year ago. Totally deregulated from an economic standpoint. Do you know that they also wrote the Bill of Prohibition from Government gathering any data about an air freight. What I'm saying is, it's not necessary to kill data gathering in support of cooperative technology ventures and so on. In order to have regulatory reform, we should all make absolutely sure that we protest any attempt to couple deregulation with stop knowing what the hell the industry is doing. We don't need to stop gathering data just because you're deregulating.

(Q) MR. DETMOLD: Peter Detmold, Canadian Railway Advisory Committee. Aaron talked about deregulation, he talked about intramodal competition, and intermodal competition. I would rather like to put a question to him which tends to put these three concepts together. Does he believe that more integration of railroads, truck lines and airlines, into what we might call transportation systems, would be a positive factor in the development of intermodal transport systems?

(R) MR. GELLMAN: I did a study in the early 60's when I was with North American Car, and a bit of a study on the multimode transportation companies, and concluded that we ought to start moving in that direction so as to reach the multimode transportation company, in the late 70's and 1980's. Well, we're here, and we haven't done it, and I think it's a tragedy. In answer to your question, yes, there's a lot that could be done to create a more competitive environment within the firm, within the single firm. I see no problem with just a few, say, half a dozen, ten, twelve, whatever number, of multimodal transportation companies replacing what we've got now. The key is effectiveness of competition, and you don't measure by the number of firms on the market, you're measuring in other ways.

(R) MR. NORTON: I would like to make a comment on that respect because we have supported in recent discussions with people in Congress, and there is some evidence that an intermodal ownership bill is being considered by the Administration. We've given that strong support, and I hope we see it. It probably will not come in this session. However, it's remarkable to me that much of the talk about cost-benefit is talking about your cost and your benefit. It again, it's an introspective kind of analysis. An industry that has only 33 percent of the intercity freight ton miles ought to be talking about the shipper's benefit and the shipper's cost because that's the kind of cost-benefit - I would agree whole-heartedly with Aaron - that's the kind of cost-benefit that's going to get you big bucks in a hurry. You won't have to make even any kind of change in your equipment if you can latch onto what our costs and our benefits are and what part you'll play in that. I would call attention to the fact that intermodal transportation does exist, but not as a company. People like DuPont put it together. When we make the movement by pipeline from one of our large plants that's located inland down in Texas, to an inland waterway, load that material on a barge, and then deliver it to a terminal in Cincinnati and thence by truck, that's intermodal. Who's put it together? The DuPont Company. We've had to because nobody else is permitted to put it together. Now, statistically it shows up as a lot of different moves. Statistically it looks as though there isn't intermodalism. We beg for intermodalism. I think the railroads would play a tremendous part in intermodalism. I see very, very few executives in railroad companies speaking out in favor of it.

(R) MR. CANN: We're not bright like you fellows, and we didn't know that, so we put together some trucking companies, and a few other things, and you know, if you want to ship it in liquid form, well, we'll run it in the railway car and then we'll pump it into a truck and take it around for you. Sometimes if you want to put a schedule on the train, we'll reserve you a place on the train, too. We don't know these things won't work. I'm sure interested to hear that they don't, and we'll avoid all these things in the future. The National Transportation Act that we passed there a few years ago all about deregulation and other stupid things we got into, you see, we don't know these things. It allowed us the freedom to move in areas that we wanted, and that economist friend of Aaron's down there, that guy I ultimately work for, was a very much a part of putting that National Transportation Act together, or convincing the Government they should pass it. That, in effect, which was what got us into fields and ultimately said that the "regulatory body" was the marketplace. I think that that has been the greatest single thing that we old hicks up there have managed to do, and it has spurred us on to many of the things that John is suggesting of using our ingenuity in what to do. It scared the hell out of the marketing group when they first started because when they found out you just couldn't put across the board rate increases on and a few other things, they ran for the washroom because their pants were full of it. Ultimately, they found out how to do it, and they have been extremely innovative in what to do. I love the economists because we finally got to the point where I would go up and say, well, boss, we can go ahead and do that, it just costs this much money, and he would turn to the marketing VP; and said, well, get out and get it. They either got it or they didn't get their service. I think deregulation, properly done, can be a great inspiration on it.

(Q) DR. KUMAR: I'm Sudhir Kumar from the Illinois Institute of Technology. I wanted to ask a question and make a comment. The question is to Dr. Spanton. I enjoyed the presentation regarding the conservation approaches that we are taking in railroads, but in the area of aerodynamics, the area of the alternate fuels, the achievements are there but proportionately not as large as they can be in the dead weight to payload ratio investigations. The airline industry and the foreign high-speed trains and so on, they have dead weight to payload ratios which are far, far less than some of the railroads that we have practiced in terms of designs in the past. I can see immediate benefits in dead weight to payload ratio investigations and their improvements in the energy conservation. I also want to think that maybe the same type of energy constraint that is being put on auto industry, in terms of fleet mileage per gallon, might be getting, one day, developing in the railroad industry also. If that does, then we should be getting ready for that in the future. Could you comment on what is the thinking and the plan in the future, perhaps?

(R) DR. SPANTON: So far as investigating lower tare weight, that's our primary task aimed at developing performance specifications on cars that would put less of an impact on the track, be more energy productive and introduce new technology. The FRA, in conjunction with several people, has in the past looked at light weight flat cars and light weight low-profile flat cars for effective use in the movement of either trailer or (inaudible)... I did not happen to refer to them in this petroleum conservation orientation. With regard to putting NECIP or EPA-like standards on locomotives, I wish you wouldn't. To say the least, clearly you recognize the weaknesses of the miles per gallon stickers placed on automobiles now even though there's been some attempt to standardize a city profile versus an over-the-road profile. To try to get that standard transient to our 200,000 miles of track and various rolling stock and locomotives that are available, I think, would be a significant task. I think there are some other things you should do first. I'll give you a specific example. In the program known as FAST, Facility of Accelerated Service Testing, which we have run for 3 years and produced in excess of 400 million gross tons of traffic, we have always borrowed locomotives from different railroads. Sometimes for a 3-month period, sometimes for a 6-month period. Basically, we have taken very crude fuel consumption measurements, but pulling the same consist around the same 4.8 mile track, we had observed as much as a 50 percent or more difference in their ability to pull the same thing. To be specific, one set of locomotive will produce about 800 gross ton miles per gallon, and some locomotives, essentially, doing the same job. I'm talking about the same operator driving. It's basically the same concept. We look around the room and say that was a GE problem or an EMD problem. That's not the case. The machines may be very well designed. They may be poorly maintained. They may be well maintained and poorly designed. I don't know. All I know is I'm paying for the fuel at $1.14 a gallon. I'm concerned when I get a factor of two involved in the performance of those machines. When I look around to try and find some data as to why, there's a lot of empty data.

(Q) DR. KUMAR: I really did not replying so much for the locomotives as I replying for the rolling stock. The maximum benefit can be, perhaps, derived in the passenger service other than in the freight service. The payload to dead weight ratio or dead weight to payload ratio for passenger service can be as much as 30 or 40 in a train as compared to aircraft of three or four, and factor of ten difference. In the highest speed trains, in Japan, for example, that same ratio is only as little as six or seven. As a result, they can have a train traveling at 150 miles an hour with dead weight payload ratio of only about six or seven as compared to some of the older designs of trains we have where it is 30 to one for the same type of passenger service at a much smaller speed. What I'm trying to say is the dead weight to payload ratio in a proper design of an energy system can be a very significant mechanism of pay off for energy systems.

(R) MR. GELLMAN: One semisimple-minded answer to that is we were talking about people who designed trains, not cars, and locomotives independently of each other. The Japanese engaged in training design. We don't design trains. We design cars, and we design locomotives, which is one hell of a difference. Now we've talked to engineers, both in the United States and several European countries about it, and there's a fundamental different approach.

(Q) MR. BILLINGSLEY: I'm Bob Billingsley, ACF. My question, I think, is probably directed at Mr. Gellman, though, it affects all of us. The effects of profits in our industry really wasn't brought out as a depressant on R&D. I know it is within my own company, and I'm sure it is within most railroad organizations. To me, it seems that one of the big suppressants happens to be our subsidy systems that Mr. Dustin referred to last night of the competitive modes. I wonder if that's not one of our big problems. I know within my own organization we have many ways of reducing costs to our customers, one of being cost reducing equipment, but just this week I'm struggling. For example: one of my responsibilities is capital facilities, and I'm struggling with whether to buy a new piece of cost-reducing equipment or put a new roof on one of our plants. It's obvious we're going to put a new roof on the plant. I think the railroads have the same problem.

(R) MR. GELLMAN: There's no question about it. The railroad industry - not as a supplier so much - but as railroads, across the spectrum of railroading in the United States, the problem of profit. Conventional profit, I might add, there's the monetary profits and also those who take the trouble to try to see the future as well. I think both kinds of profits are needed. However, it is not clear that the railroading industry require its profitability at a greater level than it has now to improve itself markedly by judicious application of R&D resources that are, in fact, now being made available even internally or externally. One of the big problems relates to cooperation between carriers. Some of the resources being made available collectively by the railroad is much greater than we generally suppose. There's too much work being done in the closet. I might add that when you think about regulation, also, don't forget internal regulation. One of the most effective forms of regulation in this country in railroading is regulation of railroading imposed upon themselves. The AREA, of which I am a proud member, supports an awfully technology ... (inaudible) ... inter-carrier regulation that ought to be looked at in that way and modified or abolished. That also relates to what you're saying because we tend to have to do a lot of ... the railroads tend to have to do a lot of their R&D work independent of each other. Well, that's just nonsense in a mutually independent railroad as we have. The one reason the Canadian railroad is so successful is they represent very large aggregated markets in and of themselves, both R&D and to the output of supply.

(R) MR. NORTON: Once again, I find I have something to say. I think it's maybe because I'm one of the very few shippers in this audience.

(R) MR. CANN: Also because you like to talk.

(R) MR. NORTON: That may be so. This is something new and I'd like you to think about it. With respect to regulation and deregulation, if the ability to make contracts between shippers and railroads is advanced in the new law and made a part of the new law, it will enable a relationship between companies like ours and railroads like we have with other carriers. I may call your attention that we regularly make contracts with pipeline operators, with barge operators, and ocean ship operators, and to a limited degree with truck operators, giving them a bankable contract, a document that they take to their bank and get the money to underwrite their equipment. Here again, it's a mystery to me, why the great reluctance on the part of the railroads, the resistance it seems to me, to enter this new field. It's a source of tremendous capital acquisition, formation.

(R) MR. CANN: Thank you, John. There are several other questions on the floor, and regretfully I have to say that we will have to close off. We're in sort of a scientific institute here, and they scientifically got all their staff to eat a little earlier in the day so we could go precisely at 12:30 out and 12:45 show up precisely to eat our lunch. Let me thank all of you in the audience for your very intelligent questions and my panel for a very commendable job that was done this morning, and I would hope that perhaps we can be finished with lunch within the hour so that we can complete early.

[Whereupon the discussion was concluded at 12:20 p.m.]

SESSION IV : MAJOR R&D OPPORTUNITIES OF THE 80'S

Chairman: J.L. Cann, Vice President of Operations Canadian National Railways

INDUSTRY'S PERSPECTIVE

BY

J.L. CANN

Well, here we are again. I note that the program says I'm going to give the industry's perspective on major R&D opportunities of the 80's.

I think it's difficult for anyone actively working in our business to claim he can give an objective assessment on behalf of the whole industry. We are all, of necessity, influenced by our own experience - what works for us, what doesn't work for us - and the success, relative or absolute, of our own railroad.

For that reason, let me admit that what I have to say is based, at least in part, on the perspective that we at CN Rail have about the 80's.

Let me get things going by saying something that you might not expect an Operations guy to say, and that is, "we must begin our outlook from a Marketing point of view."

Does that surprise you? If there's one thing I've learned, it's that Marketing and Operations better think, plan and execute in tandem, or you're in big trouble. The vice-president of Marketing in our railroad is the guy who came up with the line, "if you're not making money, you're only playing trains!"

It took us a while to learn that lesson. Like most railroads, we went from the days when the Operations function called all the shots to a period in the early 60's when Marketing became prominent - but all they seemed to do was keep hollerin', "the customer is always right and you Operations guys better waken up and smell the coffee."

Well, we learned, that, at best, the customer is always right only about his own business (and I could give you some arguments even about that!).

Now I don't know whether it was the Marketing or Operations people who got smarter. What I do know is that we began to tackle things jointly. Each side made the effort to understand the other side's objectives - but neither side lost sight of their common goal, the company's bottom line.

The way I see it, Marketing represents the income, and Operations, in its control of costs, represents the profit. That's where productivity comes in. And why the search for greater productivity will be the hallmark of R&D in the 80's, addressing everything from operating longer, heavier trains to better centre casting on cars, from improved car utilization to better design of equipment.

I've taken a bit of time to make that particular point because I believe it is crucial to railroad success in the 80's.

Ok, so we begin from the Marketing point of view.

One of the most important things we have to work at is knowing more about our own cost structure. As any of you who have delved into railroad costing know, it has some pretty nightmarish qualities to it. There are so many variables which come into play, each of which affects the other parts of the total cost equation.

And this is probably as good a place as any to remind everyone that costing and pricing are not the same thing. While the two words are often used interchangeably in everyday language, they mean very different things. The most important thing to remember is that price is not an automatic function of cost. Price is not just "cost-plus-something." Cost is one element of price - obviously, pricing at less than cost is a quick way to bankruptcy - but it is only one element. Pricing is probably the most important marketing function. It takes account of much more than the seller's costs and is, in large measure, determined by the market.

But it does begin with cost, and at CN Rail we made two really significant changes to our costing system. First, we developed much more sophisticated costing models to allow us to analyze our traffic in much greater depth. Second, for any traffic which required future capital for new plant or equipment, we adopted replacement cost as our primary yardstick for determining rate minimums.

Although this method of measuring costs is not accepted by either your ICC or our CTC for regulatory purposes, it's the only way we know of to make sure that the traffic growth we want will completely support the capital investment that such growth forces on us.

And that's the next challenge for Marketing, to sort out the traffic that's wanted from the traffic that's not wanted. Traditionally, the railroad industry has been hung up on the ton-mile syndrome. If revenue ton-miles were up over last year then the universe was unfolding as it should.

But in the words of the song, "it ain't necessarily so!" Sharper profitability analysis shows that low rates can attract all the traffic you want, but the contribution is inadequate - indeed, you'd be better off not carrying it at all.

What's needed is a much closer look at the price-volume, or contribution-volume, trade-off. And if I'm beginning to sound like a Marketing type, it only reflects what I said earlier about Marketing and Operations working closely together. At CN Rail, we're prepared to raise our rates even if the volume of traffic decreases, as long as the new rate-volume combination gives us a higher contribution to profit.

That still leaves lots of traffic we do want and that means more call for high cube capacity. It means increased demand for heavier loads. These are two of the ways in which railroad marketers can offer the customer what he needs at competitive rates.

If I'm right about that, it means more R&D in the design of cars which can carry more volume or more weight without increasing the gross load.

It means more R&D on locomotive efficiency - doubly so, since the fuel crisis will both cause us problems and bring us business. There's a great need for more railroad input into locomotive technology - and if the manufacturers are not prepared to ask us for that input, it's up to us to offer it so loudly, so continually and so persuasively that they have to listen.

And since heavier axle loads will pound the hell out of your track, it means maintaining and increasing R&D on track/train dynamics. Those of you who have heard me preach this particular sermon before know that, for me, that means everything from the sub-grade up. In the 80's we are going to have to use research to handle the traffic more productively. What should the metallurgy of rail be to reduce wear? What should the profile of wheels be to prolong usage? What are some of the ways to improve car utilization so the cars are more productively used than today? What about car design to carry goods more safely? How do we make our maintenance-of-way forces more productive?

I guess we can claim to have done pioneer work on CN Rail in the development of track work equipment. Our concrete tie program led to the introduction of the P-811 tie layer and our experience with it - and forgive me for getting in a plug here, but a few weeks ago we laid over 6600 concrete ties in one 16-hour day with it - led to the development of our new Rail Change Out machines.

Necessity, they say, is the mother of invention. Our "invention," if you like, of the RCO came from the necessity to do more maintenance work in less time. Why? Because aggressive marketing put more of those bigger, heavier trains on our track. More use of the track means more need for maintenance, but it also means less time to maintain it. So again, the search will be for greater productivity in track maintenance work.

And that leads to a continuing challenge, at least for us, in the 80's. We are fast approaching track capacity on some heavily trafficked sections of our railroad. We've extended sidings to accommodate longer trains, and we've added new sidings where needed. But our tonnage continues to increase - for which we're mightly glad, provided, of course, that it improves the net profit - and fitting in decent-sized work blocks becomes more and more difficult.

This incidentally raises two research needs - in models to determine track capacity; and ways in which that capacity can be increased at minimum cost.

Now I'm not suggesting that everyone run out and spend great quantities of money on new equipment - at least not until they've closely examined the costs and the benefits. And the time to do that is before you do the spending, not afterwards.

But I am saying that we'll need to look for new ways to do some of the old things to increase productivity by better work methods, easier maintenance and better utilization of equipment. We need the courage, backed by sound homework, to do some new things.

In summary, I believe there is a busy decade ahead for R&D in the railroad industry. I think we're going to see new Marketing emphasis which will gain us share of market, but will require better track, better cars, better locomotives, better control of costs and better productivity.

The challenge is to remain viable as a transportation mode while growing wisely into the future. I believe we have to break away from traditional ways of resolution. R&D is the only acceptable way to meet these challenges.

Can we do it?

Damn right we can! Thank you.

ASSOCIATION OF AMERICAN RAILROADS' PERSPECTIVE

BY

WILLIAM J. HARRIS, JR.

Speculating for the future is one of mankind's most enthusiastic pastimes; and yet, as you know, unless something has been thought of as possible, it is likely never to be pursued. Obviously, not everything thought of comes off; but surely some do. Let me give you a view that might be in the future of railroading.

By the end of the 1980's, a significant fraction of the mainlines will have consolidated traffic patterns and will be moving with high-adhesion electric locomotives. Thus, some of the problems encountered in the diesel engine part of the diesel-electric locomotive will be eliminated. A smaller number of locomotives will be required because of the ability to pack more horsepower in a single frame. Many of the environmental problems plaguing us with emissions would be eliminated, and the railroads will be identified as having a program compatible with national energy policy to reduce the use of petroleum-based fuels.

Cars pulled by these trains would include a substantial number of lighter tare weight cars which permit carrying 10 to 15 percent more load per car. Their suspension systems will draw on the technology developed by FRA and the Track/Train Dynamics program and individual competitive efforts such that problems of the 1970's with rock and roll, poor steerability of trucks, and excessive dynamic loads on the track will be eliminated. Thus, trains will be able to operate at high speed minimizing wheel and rail wear and eliminating significant mechanical causes of derailment.

Simultaneously, the track structure will be significantly improved. Over that structure will run improved flaw detection equipment and equipment that will establish quantitatively the lateral strength of track. This equipment will identify objectively those ties and tie fastening combinations that need replacement, will sense and detect voids in ballast, and will identify other problems that can lead to difficulty in maintaining alignment. Thus, track will be maintained in a manner which is responsive to the new more stable and more efficient locomotives and cars.

Advance information on these trains will be made available to yards, and the yards will represent an interesting combination of longitudinal sorting and lateral sorting with pre-blocked trains minimizing intermediate and terminal yard delays. In the yards, advanced coupling systems on cars will provide a capacity for coupling on every switchyard impact thus avoiding delays arising from moving a locomotive into the bowl to complete coupling. They will incorporate automatic coupling of air lines thus avoiding the problems of putting men between cars for coupling air.

As the train enters the yard, there will be available a printout identifying all cars whose performance in passing a wayside detection system suggested the need for special attention. A hot box detection system is currently in place on many railroads. Cars that have trucks which introduce excessive lateral forces for some possible mechanical reason such as a worn or cracked centerplace will be identified.

Improved cars will be designed so that the high-stress areas will be in regions of the cars accessible for inspection. A set of transducers and actuators will be brought into play so as to identify by sonic signature and other means areas that may be cracked or that require immediate repair. There will be a printout available on each car type of each production model indicating its maintenance record such that the shops would be alerted to problems that frequently recur in each car type. This will facilitate inspection and focus maintenance attention on critical issues.

As the train leaves the yard, it will leave without a caboose. An automatic system will be available to establish for the locomotive engineer whether the train has adequate air. In the cab will be a display identifying the forces at critical points in the train, the condition of the locomotive and other related information. Wayside detection systems will signal to the crew problems that are observed as the train passes these detection devices. These wayside systems will alert the crew to pending problems at the earliest feasible time.

The locomotive engineer would have spent extensive time in simulators so as to learn the route carefully and to establish optimum operating practice. Regenerative power systems will be installed to return into useful work derived from the movement downhill, thus reducing the power requirements and improving the energy efficiency of the overall system.

The condition of each empty car will be sent to the terminal well in advance of the receipt of cars. Cars dispatched for loading will match shippers' needs and will eliminate current problems of car rejection.

By virtue of the dynamic stability of cars, lading losses will be significantly reduced and packages and packing systems will be subjected to dynamic analysis before loading so as to detect deficiencies that could otherwise lead to significant problems.

At grade crossings, highway traffic will be monitored by the appropriate law enforcement agencies placing the burden of proof on the highway vehicle and not the railroad to avoid grade crossing accidents. New low-maintenance and low-initial cost grade crossing detection systems will ensure that the highway vehicles are given adequate information about the on-coming train. The braking system will be in the process of transition from an exclusively hydraulic system to an electric-hydraulic system so as to minimize time for propagation of the signal to the brake shoes. Microprocessors will control the brake signal propagation consistent with the weight of the car, whether the car is loaded or empty, the terrain, and other conditions that affect braking.

A unique car identification system will be in use. Through appropriate image or other information processing systems, an effective man-machine interface will emerge that will ensure more complete notification of advance consists. Individual car scheduling systems will be in use such that all car distribution systems will draw on current information on car location and plans for car movement. Continuous monitoring of car cycles will make possible the identification of points of congestion and causes of delay in car movements.

The railroads, shippers, and consignees will be in position to work out more compatible programs to improve service and facilitate car utilization.

Improved highway-railroad interfaces will be in extensive use, some through cars that can move on either mode, some through more efficient rail transportation units. Their effectiveness will be enhanced by the use of improved car and container management information systems.

With such a railroad system in place, service quality would improve and railroads will be carrying an ever larger fraction of intercity traffic thus competing effectively with trucks whose problems will be exacerbated by the increasing cost of highway maintenance and the recognition that heavy trucks are playing a major role in highway deterioration.

Research is not yet completed on all elements of the concepts required for the system described. But work is well advanced on many aspects of track/train dynamics, on non-destructive testing systems, on freight car management and utilization systems, and on advanced cars and locomotives.

It can be concluded that this kind of railroad system is technically and technologically possible. The forces that keep it from happening are (1) inflation which may place disproportionately heavy financial burdens on such a capital intensive industry as the railroads; (2) energy costs which could inhibit manufacturing in the United States and change the entire pattern of demand for transportation; (3) energy efficiencies which could require a dramatic increase in railroad transportation services; and (4) safety and economic regulation which may take such a large fraction of current resources for compliance so as to deny industry that opportunity to marshall resources to carry forward the development of an advanced railroad system.

While some freedom to set rates is almost certain, that rate freedom may be coupled with antitrust controls as to make it impossible for the degree of cooperation between the separate companies that is necessary for a harmonious network serving the shipping community.

Unless opportunities for substantial interaction of railroads are permitted and coupled with rate freedom, a scenario quite different than the one described above would be likely to occur. We could find ourselves with a monolithic national system with management selected by non-economic and highly political forces. Under that circumstance, the network that would emerge could fall far short of that possible with the computer information systems and the management insights that are emerging from research and demonstration programs being completed in the 1970's.

For the technology described in the first optimistic scenario to apply, there must be much greater earnings by the railroads. Those earnings would require substantial rate freedom. It would also require minimizing regulatory burdens that only add cost without improving safety or other objectives sought for. It is possible to move in the direction of a much more dynamic and effective railroad system. There are signs of it in some of the major companies in this country, but there is equally visible evidence that the alternative may also be pursued.

Because I believe the railroad industry can make a very real contribution to the effectiveness of the United States industrial programs, I hold with the first view as a desired goal and I think we should continue in a coordinated, organized way to cope with regulation and inflation and energy issues so as to ensure that model choices are made that favor rail transportation and that the revenues from that increased patronage will be translated into the clean, high-performance, efficient railroad system that our technology could deliver for us.

There must be a commitment to change and the allocation of sufficient resources to facilitate desirable change if the railroad system is to achieve the level of excellence that is within its grasp.

SUPPLY INDUSTRY'S PERSPECTIVE

BY

GLENN E. STINSON *

INTRODUCTION

This "Perspective of the Supply Industry" will relate primarily to the area of automatic signaling and train control systems.

The record of past accomplishments show that more technological R&D innovation has occurred in this segment of the railroad supply industry than any other. Of course there have been major breakthroughs in other segments such as the introduction of the diesel-electric locomotive, roller bearings, welded rail, but these have largely been a single time occurrence with relatively minor incremental progress since their introduction.

In the signal and train control portion of this business there has been a steady and continuous introduction of systems and their related hardware to improve safety of train operation and at the same time increase operational efficiencies. There is no doubt that the contributions of the railroad signal and control industry have been a major factor in making railroads the most efficient form of high volume transportation existing today.

THE PIONEER DAYS - SIGNALING FOR SAFETY 1832-1871

It is an unfortunate fact that many technological innovations have been the result of catastrophes; however, it was several train collisions in the middle to late 1800's, during a period of rapid railroad growth, which demanded that something be done to protect trains now operating on "high speed" crowded schedules.

Two examples were the Chicago "Grand Crossing" wreck of 1853 and the famous collision involving one of Commodore Vanderbilt's track New York Central express trains in 1871 in which 16 people were killed and hundreds injured.

This New York Central wreck created a national scandal; everyone became safety-conscious, the cause of railroad safety attracted engineering geniuses of the age, who attempted to develop mechanical safeguards to protect against human error.

At this time a few mechanical devices were in limited use to prevent train collisions such as mechanical interlockings to prevent trains from moving on conflicting routes where tracks intersect and the very early disc ball and semaphore signals used to advise locomotive engineers of potential dangers.

EARLY APPLICATIONS OF ELECTRICITY AND PNEUMATIC/HYDRAULIC POWER 1872-1900

All of the early signaling devices were manually operated mechanical equipment, but with the introduction of electricity, pneumatic and hydraulic power, the manual operations started to change to power operation and electricity provided a major breakthrough in the form of electric track circuit for train detection. This invention in 1872 of the so-called "closed track circuit" is still the basic train detection system in use today, although many improvements have been introduced.

This era was also responsible for the introduction of power operated interlockings, electrically lighted signals, an automatic train stop system to enforce compliance with signal indications, and motor operated switch machines and semaphore signals.

SIGNALING FOR MORE EFFICIENT TRAIN OPERATION 1900-1920

Signaling for safety was now well established, and the engineering talents of signal supply companies and those of railroad operating personnel turned toward making signaling serve a double purpose, that of providing the required safety of operation plus assisting in moving trains with fewer delays resulting in operating cost reductions and improved efficiency.

It was during this period that Train Operation by Signal Indication Rules was introduced. It made communication between the dispatcher and train crew much easier and reduced the opportunity for misunderstood orders. A variety of systems were introduced including a Controlled Manual Block System; Automatic Interlockings where trains cleared their own routes when safe to proceed, and Absolute Permissive Block (APB) System, to provide automatic train protection for opposing and following train movements on single track.

Also introduced to force compliance with the signal indication was the Intermittent Inductive Train Stop.

REFINEMENTS IN EARLY SIGNAL DESIGNS 1920-1940

The introduction of new design technologies was now accelerating at a rate never before experienced. The period of 1920-1940 witnessed the introduction of many innovations such as searchlight signals for better visability and all relay interlockings which eliminate entirely the

*Presented by John Hansen.

mechanical locking previously required to prevent the establishment of conflicting routes.

This period also was responsible for a number of advances in train control systems which continually force the locomotive engineer with speed restrictions imposed by the signal system. It started with a Continuous Inductive Cab Signal System employing vacuum tubes for the first time outside the radio communication industry. Four years later the Continuous Coded Cab Signal System was introduced which today is in use on the Northeast Corridor and elsewhere to provide automatically, on-board the locomotive, speed commands indicating maximum allowable safe speeds. Failure to heed these speed commands results in an automatic brake application on several railroads including the Northeast Corridor.

This era was also responsible for the introduction of Centralized Traffic Control Systems which provide a means for a dispatcher at operating headquarters to monitor and direct the movement of trains by signal indication over hundreds of miles of track. The success of this development should be apparent to everyone in the railroad industry. There is not a major railroad in the United States or Canada that does not operate hundreds of miles of railroad by CTC.

Centralized Traffic Control Systems were introduced using only two wires for communication between dispatcher and field locations which also permitted these wires to be used for a multitude of other communication circuits. The length of CTC territory was also being expanded to entire operating divisions.

Although not directly related to main line signaling and control, a major breakthrough occurred with the introduction of a power operated car retarder to make possible the mechanization and later the automation of freight classification yards. This innovation not only improved safety by eliminating car riders in hump yards; it also reduced lading damage and increased throughput of freight terminal areas.

Many technical improvements were made to these same systems and products before the end of this period.

Route type, or entrance-exit interlocking control systems, permitting a train movement through a very complex interlocking by operating only two pushbuttons, was introduced during this 20-year span.

ADVANCING ELECTRONICS 1940-1950

The emergence of electronic techniques, starting with the vacuum tube in cab signal equipment in 1923 is now making waves in other areas.

Vacuum tube operated carrier transmission equipment is being used to extend CTC control territories and to consolidate remotely controlled interlockings. Beamed radio and microwave communication links are being applied to CTC projects.

The invention of the transistor was very rapidly followed by its application to vital signal circuits.

Last but not least in this period was the introduction of Automatic Train Identification employing inert transponders on the vehicle to interact electronically with wayside equipment.

EARLY REMOTE CONTROL AND AUTOMATION 1950-1960

In the 10 years beginning in 1950, automatic controls in freight classification yards in the form of pushbutton control of classification yard track selection and manually selected but automatically controlled car retarder speed control was born. The analog computer was also introduced to select retarder car speeds based on predetermined car rolling performance.

Wayside control of the movements of a commuter train was also demonstrated as a future possibility. The system although not applied to revenue service passenger trains has found application in the control of switcher locomotives in hump yard service and in industrial plants as well as in the control of the helper locomotive from the lead unit.

COMMERCIAL APPLICATIONS OF AUTOMATION 1960-1965

At this time many of those innovations introduced to the railroads (and to rail transit) were becoming commercially available.

During this period a demonstration of automatic train operation was applied to the Times Square-Grand Central Station Shuttle Train on the New York City Transit Authority which operated in revenue service without a motorman in the control compartment.

Automatic train operation was also applied to the Expo Express, the backbone transportation system at Canada's Expo '67 where the motorman operated three pushbuttons; "doors open," "doors closed" and "GO". The equipment controlled acceleration, speed, deceleration and station stops automatically.

Automatic train operation equipment was also successfully applied to ore hauling freight lines at Lander, Wyoming and the Great Slave Lake Line of the Canadian National; the latter being more than 400 miles in length.

THE DIGITAL COMPUTER GETS ON TRACK 1965-1970

The tremendous capabilities and capacities of the digital computer for real-time process control on the railroads started in 1964 with an installation on the Alton & Southern's East St. Louis classification yard. There are approximately 30 digital computer controlled yards in service today. In terms of the variety of functions performed and the amount of sophistication the Louisville & Nashville Yard at Louisville, Kentucky, the Seaboard Coast Line Yard at Waycross, Georgia and the Southern Pacific's West Colton Yard (Figure 1) are the leaders today.

FIGURE 1. SOUTHERN PACIFIC'S WEST COLTON YARD

Ever since railroads recognized the need for organizing random cars into trains having common destinations, classification yards have existed in one form or another. Since this early beginning, Union Switch & Signal Division of American Standard Inc. (US&S) has been a pioneer in the use and development of products to support this critical railroad function.

In the mid 1950's, the analog computer emerged as a viable control device. Between then and the early 1960's, US&S built 10 analog computer yards. During this era, the digital computer expanded from being strictly an accounting device into the realm of Process Control. From the beginning US&S helped to pioneer the use of digital computers for classification yard control by the installation of our first digital computer controlled classification yard in 1966. The early systems were limited in size and performed primarily route control and retarder exit speed calculations. Real-time control was the next major step in the evolutionary process.

At first both the car control and inventory control functions were performed in the same computer. Because car control logic is unchanging in nature, and inventory systems constantly change to keep abreast with current needs, the next major step was to separate car control from inventory control and house each system in separate computers. The Southern Pacific West Colton Yard system, placed in service in 1973, was the first major attempt. So successful was this arrangement that, today, it serves as the model for the computer architecture of classification years.

To achieve the requirement of high reliability required for the car control system, US&S developed a system that utilizes a dual computer configuration allowing one computer to be on-line and in control and the second in hot standby. The hot standby system automatically assumes control should a failure of the on-line computer be detected.

US&S also supports two different data control concepts. The first calls for the control computer to receive all data and all requests from the inventory management computer. In addition, all outputs, except for the display of cars being humped and warning messages, are sent from the control computer to the inventory management computer for further processing. This requires a high degree of reliability on the part of the inventory management computer.

The second data control concept calls for the control computer to be capable of continued operation in the event the data flow between the control and inventory systems is inhibited due to either data link failure or failure of the inventory management computer. This concept requires the control computer to handle input and output data terminals and to provide for a variety of functions to support a continued humping operation without a tie-in to the inventory management computer. Figure 2 shows the computer controlled classification yard designed by Union Switch & Signal for the Netherland Railways at Amsterdam.

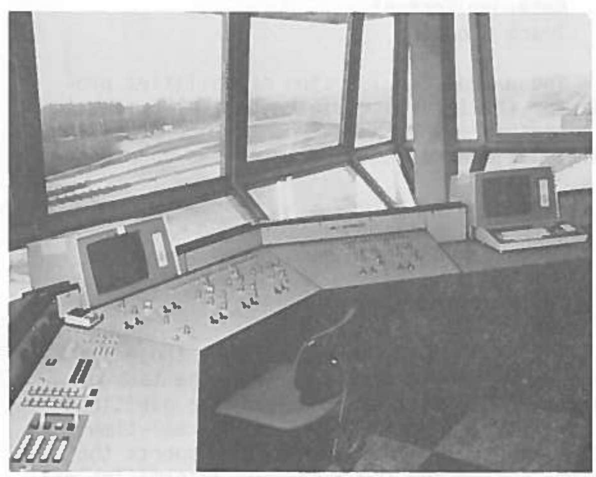

FIGURE 2. COMPUTER CONTROLLED CLASSIFICATION YARD ON THE NETHERLAND RAILWAYS AT AMSTERDAM

The following is a brief description of the various system functions that US&S is providing to the railroad in support of freight car classification yard systems.

The advancements of classification yard control hardware and the technical evolution of the digital computer have matured to provide integrated real-time process control of automatic freight classification yards. The impact of the control sophistication provided can best be seen in the objectives of a Freight Classification Yard, Terminal Control System:

- Safe, expedient and damage free throughput of cars
- Reduced terminal time
- Improvements in the utilization of terminal resources
  - Engines
  - Yard Crews
  - Clerical and administrative personnel
- Availability of timely, accurate information
- Maximum system utilization and availability.

A Terminal Control System (TCS) is configured of modular elements tailored to provide the level of sophistication desired for a specific application. The TCS functions that achieve the integration of car control and the information process are categorized into the following six primary subsystems:

Control System Software (CS)

The control system logic are those software modules that deal directly with car control and real-time process information in raw data form. Representative of the modules that make up the CS subsystem are the following:

Car Tracking
Automatic Routing
Automatic Speed Control
Retarder Control
Track Blocking.

These additional system capabilities provide for the interface of the Control System to self-contained yard hardware, thereby providing additional enhancements of automated yard control:

Automatic Weighing
Hump Engine Speed Monitor
Computer Regulated Hump Speed.

Information System Software (IS)

The IS software is composed of those system elements primarily concerned with the task of managing data obtained from operator positions, an inventory management system and real-time system hardware inputs. It also supports the control system and the access of information regarding yard status. Although the architectural structure of an IS subsystem will vary from one installation to the next to conform to specific customer procedures and operations, a nucleus base system can provide the following functions.

Hump List Maintenance and Support - This set of IS software modules provides for the support of hump inventory and the dynamic hump display. Typical of the capabilities included in this area are:

Start Hump List
End Hump List
Hump Add-A-Car
Hump Delete-A-Car
Change Track Assignment
Classification
Control System Support
As-Humped Processing
Message Processor.

These Base Information System elements together with the CS data base, provide the nucleus for additional enhancements to the hump control process. The following are examples of optional functions which can be added to the base system to meet a diversity of operational and procedural needs:

Hump List Makeup Request/Cancel
Re-Hump
Auto Trim
Change Classification Assignments
Track Swings
Assign "No Hump" Status
Special Handling
Inactive Hump/Train Lists
Hump/Train List Review
Print Hump/Train List
Pin Pullers Display
Pre-Hump Report
Yard Statistics Reports
Auto Pullout Monitoring
Bowl Yard Inventory Maintenance.

The means of implementation of the above functions are as diverse as the functions themselves. Automatic real-time inputs as well as console pushbutton and formatted interactive Visual Display Unit (VDU) data entry can be used. Data entry through VDUs by an operator is accomplished by use of the VDU keyboard. The displays generated for an interactive VDU allow for a fill-in-the-blanks process. The input fields are the only area of the display where characters may be entered or changed.

Communications

The communications software modules support a number of activities for the following functional areas:

Data Link Control
Video Display Unit Support
Printer Control
Inter-Computer Communications
File Management.

Hot Standby/Computer Failover

The hot standby subsystem is designed to prevent the loss of car control or stored information in the event of on-line computer failure or hardware malfunctions. The system provides for both automatic and manual transfer of control from the on-line to the off-line computer. These three primary software modules support the computer failover system and function to initialize, maintain, monitor and initiate computer switchover.

Backup Initialization and Update
Hot Standby Maintenance
Computer Switchover.

Simulator Software

The purpose of the simulator is to provide simulated real-time inputs which drive all process software modules and facilitate the task of debugging the Process Control computer application software. The simulator is able to pass to the application programs field sensor input information, such as, wheel detectors, track circuits, etc., as well as failure states, in such a way as to simulate cars traveling from the crest to the classification tracks. The simulator also has the ability to react to digital outputs set by the Process Control System. By reacting to digital outputs, car routing becomes a function of the Process Control computer as it is in the real world, rather than a function of preset circumstances in the simulator. This permits an interactive relationship between the application software and the simulator.

Digital and Analog Input/Output Software (DAIOS)

All digital and analog I/O to the field hardware is received and transmitted by the DAIOS software. The DAIOS software also is able to recognize I/O from the simulator.

Most inputs may be classified into the four categories:

- Wheel detector inputs - used for tracking
- Switch position indication and track occupancy - used for tracking
- Alarm and miscellaneous inputs - such as, Dragging Equipment Detector (DED), emergency stop, mode change, etc.
- Distance-to-Go - used for computing group retarder exit speeds and for providing information on class track availability
- Scale Inputs.

Most outputs can be classified into the following categories:

- Switch request for routing
- Miscellaneous outputs, such as, alarm lights, bells, etc.
- Requested retarder exit speed for car control.

Yard Calibration

The Yard Calibration software logic automatically collects data associated with a car's performance. Data collected includes:

- Car initial and number
- Tangent and curved track velocity measurements
- Retarder exit speeds
- Velocity at point of tangency
- Distance-To-Go for target track
- Car weight or weight class
- Car length
- Temperature
- Car bowl track velocity on calibration track.

The data is formatted, stored, and output on request for analysis.

The data collected is used as input to a regression analysis software package. Outputs from the regression analysis is then applied in the equations used for calculating exit speeds from retarders. Sufficient data to calibrate a yard can be collected in a short time and with little effort.

The functional element just described should provide a general idea of the software modules available for the development of a Terminal Control System. Since placing our first digital computer controlled marshalling yard in service in 1966 we have seen that although each yard has the same purpose, no two yards operate identically the same. From one yard to the next we have provided solutions for a great variety of yard operation problems and due to this have evolved control system packages that are flexible, reliable and efficient. Along with the system we have developed a group of approximately 70 experienced real-time application programmers capable of solving Terminal Control System requirements. Over the years we have developed and refined an approach to system design and implementation. We have found that the success of a project is proportional to the amount of effort applied to the early definition stages of a system. Because of this we employ a team approach to system definition which involves participation of the railroad. As many details of the system as possible are defined at the start of the project and accumulated in what we call a "Description of Operations" or D.O. book. This book then becomes the document around which the system is designed. This method has with time proven very successful.

COMPUTERIZING THE MAIN LINE 1970-1980

But real-time process control digital computer application have not been confined to terminal areas. In 1966 the first computerized Centralized Traffic Control system was installed on the Union Railroad in the Pittsburgh area.

It was 5 years after this first computerized CTC installation that the next project went in service on the Canadian National at Kamloops, B.C. After that, the installation rate accelerated so that today approximately 18 projects are in service or under construction. This amounts to more than 5000 miles of the more than 55,000 miles of CTC in service today in the United States and Canada.

Again, as with the early computerized yards, initial applications of computers to CTC nearly performed only control, indication and minimal logging functions. In more recent times a number of additional features have been added that have advanced the state of the art to Computer Aided Dispatching. Figure 3 shows Computer Aided Dispatching on the Louisville & Nashville Railroad at Corbin, Kentucky.

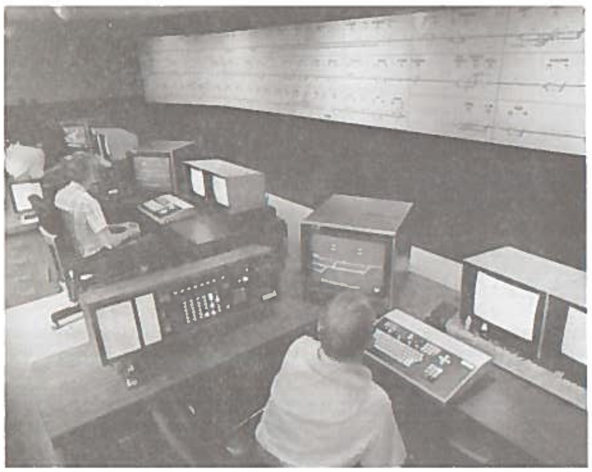

FIGURE 3. COMPUTER AIDED DISPATCHING ON THE LOUISVILLE & NASHVILLE RAILROAD

The functions included today in Computer Aided Dispatching (CAD) include:

Computer Aided Control
- Automatic Clearing Out of Sidings
- Automatic Advance Signal Clearing
- Automatic Identification
- Automatic Meet
- Automatic Pass
- Automatic Conflict Determination
- Conflict Analysis
- Manual Override
- Automatic Tracking
- Automatic Blocking Control
- Automatic Routing Control
- Dark Territory.

Dispatcher Information System
- Automatic Train Graph
- Automatic Train Sheet
- Computerized Dispatcher Aids that include:
  - Train Lineups
  - Estimated Time of Arrival (ETA)
  - Train Length/Tonnage
  - Estimated Run Times
  - Projected Meets and Passes
  - Maintenance-of-Way Time Available
  - Crew Run Time Status
  - Motor Car Lineups
  - Clearance Status
  - Train Order Status
  - Slow Order (Bulletin Order) Status
  - Train Permit Status
  - Weather Status
  - Territory Assignment Status
- Train Order Handling
- Slow Order Handling
- Clearance Form Handling
- Automatic Train Priority Determination
- Event Logging
- Crew Call.

Interfaces With:
- Remote Terminals
- Management Information System at Headquarters
- Locomotive Management System
- Automatic Performance Analysis System to provide:
  - Delay Time by Crew
  - Run Time by Crew
  - Delay Time Station-to-Station
  - Delay Time at Control Points
  - Run Time Station-to-Station
  - Delay Due to Maintenance-of-Way Activities
  - Run Times by Horsepower to Ton Miles.

Computer Aided Dispatching (CAD) Systems are now in operation on:
- Seaboard Coast Line
- Burlington Northern
- Louisville & Nashville (Figure 4).

Additional projects are under construction on:
- Union Pacific
- Irish State Railways
- Burlington Northern
- Southern Pacific (with microprocessor).

FIGURE 4. COMPUTER ROOM ON THE LOUISVILLE & NASHVILLE RAILROAD AT CORBIN, KENTUCKY

CAUSES OF TECHNOLOGICAL PROGRESS

The requirement for safety of train operation is the primary underlying element that controls and guides all research and development efforts in the signal and train control supply industry. It is the foremost factor in the design of control systems and implementing hardware.

The "fail-safe" principle is the accepted and proved principle on which our product designs are based. Accidents related to signal failure are so insignificant that they are almost immeasureable. This is why the death and injury rate for railroads and rail transit is the lowest of all transportation systems by a wide margin.

The current oil shortage is placing emphasis on the energy efficient railroads. As this country continues to grow, the railroads must play a more and more important part in its growth. As a result, more efficient train operation becomes a necessity not only to reduce ever increasing costs, but also to increase the capacity of the physical plant without major expenditures related to adding tracks to the main line or building new terminal facilities where none existed to handle an increased flow of traffic.

This is the second reason for signals and controls to be installed. The operating efficiencies and increased capacity that can be obtained through installation of Computer Aided Dispatching and automated freight classification yards will be a major factor in increasing capacity and efficiency without tremendous capital expenditures that would be required if the physical plant were enlarged.

The continued increase in the costs of labor exert tremendous pressure on the railroads to reduce the number of employees on the payroll. The natural result - a search for labor saving equipment. Again, automatic control systems that require fewer employees to operate are providing part of the answer.

The day of the operator at every way station has almost been eliminated. Dispatchers can now direct train movement safely over thousands of miles of track with less effort than handling one operating division in the past, and he does it without help along the wayside.

In the past when car riders were required to control rolling cars in a freight classification yard, it took as many as 50 persons to hump one train. Today it is done with less than five persons.

These same factors have had the same effect on other segments of the railroad supply industry; the prime example being mechanization of maintenance-of-way forces that have resulted in a very large reduction in manpower required when this work was accomplished by hand labor.

Last, but certainly not least, it is providing service to the shipper that will attract his business. On-time delivery of damage free goods is a basic requirement if the railroads are to remain a viable form of transportation.

Here again is where previous R&D efforts on the part of suppliers are paying off today and will continue to help the railroads meet their customer's demands for good transportation service.

All these efforts are aimed at one objective - providing the railroads with methods of increasing the usefulness of their locomotives, rolling stock, rights-of-way and employees to better serve their customers at a profit.

RESEARCH FOR THE FUTURE

In our search for technological improvements in signal and train control systems, there are certain basic fundamentals that must not be overlooked in the design of any system involved in train operation. They are:

1) Train Detection - a proven, reliable system to detect the presence of a train on a section of track.
2) Train Separation - a system designed on a "fail-safe" basis to prevent one train from overtaking another.
3) Route Control and Protection - an interlocked system to prevent the establishment of conflicting routes where tracks intersect.
4) Cab Signaling - the display of information in the locomotive cab to inform the engineer of track conditions ahead.
5) Overspeed Control - the automatic enforcement of speed commands displayed by the cab signal system.
6) Line Supervision - a non-vital communications system that permits a dispatcher to monitor activities and direct train movements over a section of track.

With proper application of equipment and system described there is a strong possibility that the railroad's physical plant can be reduced in size, or at least prevent further plant expansion to meet increased demands for transportation.

We are currently working towards equipment and system simplification as well as reduction in size and weight. Some of this will be the result of solid state electronic application such as microprocessors, although the current failure rate is much higher with solid state equipment than with the conventional electromechanical relays now being used in these systems. The time will come when this new equipment will become equally as reliable and safe and at the same time will simplify maintenance procedures.

In theory, the railroad concept of safety is simple: everything is designed to "fail-safe." In essence, a vehicle is normally at rest. You must signal it to move. If the signal is deliberately or accidentally interrupted, the vehicle stops. You also need a safety interlock system wherein it is virutally impossible to create an unsafe condition.

The big problem is hardware. On paper, many people can design a "fail-safe" transistor circuit, relay or safety interlock system, but in the end you must make these components from actual materials. Each part is affected by physical, electrical, or chemical stress - things such as vibration, power surges, moisture. And, there is always a size limit, you can only "overdesign" so much.

Our answer to safety problems like these is to design components with maximum reliability. It is probably true, if immodest, to say that no company knows more that Union Switch & Signal about reliable service life of transportation control devices. Although many of them are now obsolete, we have supplied thousands of components that have been in continual service without failure for 40 to 50 years. Today, these venerable components appear heavy and bulky, and they are quite expensive. The one good thing about them is that they always work.

KEY TO R&D IN THE 80's

The same economic forces that apply today will only be intensified in the 80's to bring about even more innovative research and development to make railroad operation more cost effective.

Research and development of new and improved products is the key to reducing those operating costs that will continue to climb.

It is the responsibility of the entire railroad supply industry to join in this effort to keep our railroads on track.

A GOVERNMENT PERSPECTIVE

BY

STEWART B. HOBBS

It isn't easy to have the last spot on a program like this and with slave driver Cann in charge, I should probably tell you where the busses leave for the airport and then invite questions. But I do feel that we have spent an intensive 2 days here in pursuit of that difficult goal of where we should head in R&D in the 80's and sense that by analogy to the Pittsburgh Pirates in our recently completed World Series, the railroads have come from behind and even though it is late in the game the right strategy and plans will win the game.

I want to remark that this conference indicates a marked change in the institutional relationships between Government, the railroad industry and the supply industry; past tendencies having been for the Government spokesman to explain his research and development initiatives first with the industry counterparts providing their (not unusually positive) comments afterwards. We have indeed come a long way in terms of mutual understanding and mutual respect and are reaping the many benefits of cooperative projects and more open discussion of our respective plans for R&D. I feel this change in the atmosphere perhaps more than many of you as it was not all that long ago that the Transportation Systems Center was viewed variously as an impractical "blue sky" aerospace outfit or an irresponsible group of technologists reinventing wheels and everything else for the railroads. My giving this segment of the program today is a positive reflection of TSC's growth and acceptance and the changes in the whole railroading community.

I must quickly tell you, though, that a horrible miscasting has been perpetrated. After agreeing to prepare this talk Bob Parsons called and told me we needed to change the title from the "Government's Perspective," which presumably only the President could give, to the "FRA Perspective" - but then we realized that a TSC member shouldn't do that either and we agreed on the title, "TSC Perspective." But somehow the title was not changed in your program but you should really mentally retitle this talk as, "A Government Perspective." I will introduce TSC's view as to what the future environment may be like and its implications for railroading R&D.

Actually the Government's perspective really only differs from the general industry posture in that it slightly emphasizes the longer term aspects of need and payoff. Bill Harris has often been heard to say that all railroad R&D is long term since, if it develops a useful product or process, implementation will take another 15 to 20 years. I will return to this phasing duration later - but in addressing R&D opportunities for the 80's I choose to deal with the subject in the following way:

1) Considerable R&D dealing with the problems facing the railroads today is already in progress.

2) Excellent progress is being made in answering many of the current problems from the cooperative programs like FAST and Track/Train Dynamics, and the work in computer applications, data systems and communication which is increasing markedly.

3) It must be presumed that the Government's regulatory environment will have changed to at least a condition of stable and near equitable treatment of the railroads and their competing freight modes.

4) It must be presumed that the Government will have a positive view towards supporting increased innovation, particularly in those industries fostering energy efficiencies and assisting the nation's economic recovery.

5) That utilization of the provisions of existing legislation can essentially produce a financially viable rail transportation industry in the private sector.

Now with these as a backdrop what can we see coming in the next decade and what are the messages for the railroad R&D community?

<u>First</u> - The railroad system will have evolved toward a viable network and will be well along in rebuilding its aged facilities and replacing its equipment. But is there some danger that it will have only succeeded in restoring the restructured system to a condition of 20 to 30 years ago, perhaps still unable to effectively compete with the other modes?

<u>Second</u> - Energy concerns, availability and cost, will still be with us and be of increased severity and unless action is taken the natural energy efficiency advantage of the railroads over trucks could be eroded.

<u>Third</u> - Safety concerns will continue to reflect themselves into government/industry interaction although with decreasing intensity. Hazardous material movement will be a dominant concern. There could be a growing acceptance of the thesis that safe railroads are profitable rather than today's view that safety costs more than it returns.

Fourth - Implementation of available technology will still be following the equipment/facility replacement time cycle.

WHAT ARE THE MESSAGES FOR R&D?

1. We must emphasize energy efficiency in our thinking, planning and programs. We must concern ourselves with the changing condition of fuel availability, maintaining and improving our competitive posture as a mode and responding to the national conservation requirement. The RR's can and should seek to evolve toward petroleum fuel independence.

2. We must anticipate the change in market share and commodity mix resulting from the railroad's existing energy efficiency advantage over trucks. In September the Wall Street Journal carried a front page article titled "High Trucking Costs Spur Interest in Rails for Many Companies." Safeway Stores have shifted some items from truck to rail and John Norton, Director of Transportation for DuPont Co. says "The high cost of energy is forcing us to reassess which transportation mode we'll use." DuPont expects its truck share to decline to 30 percent from the present 35 percent in 10 years. Although he does not suggest that this traffic will shift to rail.

3. There is a solid potential for more coal and grain movement fostered by increased demand and the energy efficiency of rail, so unit train operations must increase and more run-through trains will be needed for an increased share of manufactured commodity traffic.

Thus, the trends of the 80's can demand increased system efficiencies; and by system I mean the fleet, the facility, the labor and the management.

WHERE ARE THE R&D CHALLENGES?

For the car fleet we need different cars to meet the shipper's needs - ones with decreased tare weight and better dynamic characteristics. We need to use the materials research from many sectors and probably do some of our own. The theories from the Track/Train Dynamics Program need to be put into application to get cars with better payload fraction, better load carrying capacity and be less damaging to the track. Intermodality needs emphasis. We need more cars at competitive capital cost and reduced maintenance cost, suggesting an industry need for better specifications, performance based on cost oriented system type assessments - and better and faster introduction of new technology - and these are R&D problems.

Fleet maintenance must be improved to increase car availability. Like the rail transit industry has started we need to share hard information on failure rates, identify high maintenance cost items and designs and enter a program of designing reliability and low cost maintainability into all equipments. And since we already know that people can cause many of the problems and failures, we need to work on planning, processes and training for the labor segment of the system. We also need to consider field maintenance and preventative maintenance processes. Fleet management needs new and more creative developments. Progress has been made in the management information systems area. But it appears that we may have taken a step backward in car identification. We need to seriously attack the question of interline management and develop the building blocks to do it. Here, I think, is an area where railroads have great institutional difficulties to overcome, but I suggest we must increase the service options offered, not restrict them. And if service reliability and special services require more interline information transfer and management control - and I believe they do - then R&D and the industry must be responsive to that demand.

Fleet motive power and system energy efficiencies and petroleum independence need R&D. A reassessment of electrification is needed in the face of markedly changing costs and fuel availability. The technology and engineering of internal combustion engines will undergo extensive changes in the next decade - much of this being sponsored with Federal dollars. We must stay up to the minute with these developments, be responsive to the need to change, and - there's more - we need to maintain a high priority thrust on all those other aspects of motive power and milk each percentage point of energy efficiency where we can. Our perspective needs to deal with fuel utilization since costs may be too dynamic a measure for decision.

Increased fleet operations, with more unit trains, raises facility degradation and safety related questions. As a consequence of current R&D program emphasis we are establishing a good handle on how to specify track that is safe. But in conjunction with the directions taken for improving the cars and the motive power a system look has to be taken at the track to establish how to get it safe and keep it that way - all in a cost-effective manner. The track safety standards being developed jointly with the industry will tell you the what - but there is a very large job that needs to be done - and it is "soft" R&D and "hard" R&D - to decide how it will be done.

We can all see so many needs and avenues for productive R&D. It is mind boggling to know where to begin. Two additional points need to be covered before I end. First, I must remind you of Jim Costantino's opening comments. The auto industry will be interacting with the Federal Government in an $80 million per year research program to improve autos, trucks and busses for more fuel efficient operation. It is not only crucial that the railroads and their suppliers stay current with these technology and research endeavors but we must mount our own initiatives. Bob Parson's budget in actual dollars has been declining and, of course, with inflation effects considered the picture is even worse. The need for capturing increased

R&D budgets is paramount, and it takes well constructed initiatives and strengthened government/industry planning and priority decisions to make it happen.

Second, the implementation segment of the innovation process in the railroads is too long! We have worked together on the front end of this problem - e.g., FAST has cut the time of developing engineering information and disseminating it to the industry. We think we have cut that part of the time cycle nearly in half - but when will the new technology be used throughout the industry? How long will it take for the "lowest common denominator" approach to decision, and the investment process, and the rules change, and the labor acceptance to make the payoff real - how long?

Our perspectives cannot be limited to the view that reflects business-as-usual. The institutional impediments that are in place cannot continue to resist the introduction of beneficial technology and systems operations improvements for the survival of the railroads and the suppliers. We need to realize that we have wasted some of our precious R&D resources by permitting the contest between technology push and industry shove.

The message should be quite clear to all - government, railroaders and suppliers - "R&D" is a needed investment for restoring a healthy rail system in our country. The time is critical. The broken link that needs repair is energy, the missing link is the hastening of the innovation process - and these are the province of R&D.

COMMENTS/DISCUSSION PERIOD FOLLOWING SESSION IV

(R)* MR. CANN: We have some more time and I would like to now open this portion of the meeting to questions to any members of the panel or to foster any suggestions for discussion along that line. So the floor is now open.

(Q) DR. KUMAR: I have an observation to make, if I may, Mr. Chairman.

(R) MR. CANN: By all means.

(Q) DR. KUMAR: We are here to discuss the railroad's problems and railroad engineering and railroad economies, management and so on. The fact remains that a disproportionately large amount of mobility of this country is by roadways and highways. And I, as a professor teaching transportation to my students, have often tried to relate it to them that we cannot ignore the fact that our real state in this country is developed thoroughly on the basis of highways, and we cannot go back, so the progressive outlook that we like to have has to take this fact into account, and I did not see an extensive amount of multimodal, bimodal total transportation system discourse in our conference which I think is perhaps very appropriate for us to take. We take the lead and the aggressive attitude in managing the transportation system. If we take the lead, other links will fit, but I think it is highly necessary for us, for the new decade of energy shortage, to have our house in order in view of intermodal, bimodal, and systems which will incorporate the other modes into us rather than we following them. I thought that this was worth making an observation. I try to teach that to my students, and this is not teaching, but it's only making an observation, that we as a group should continue to recognize that. If any input in that regard from Mr. Parsons, Dr. Harris, or others is there, I'll welcome the comments.

(R) MR. CANN: It's a good observation. I don't think there would be any thought about going back even though the country has developed not necessarily entirely along the highways. One doesn't necessarily go back to sort of modify and move on. First came the steamboat on the river and then came a form of highways of carts and so on, and then the railroads. In some instances, we've got the Corps of Engineers which, thank God, in Canada nobody has invented yet. We have a few good ideas up there. We shoot them. So they're trying to force you back into the river mode whether you like it or not.

Things at any moment in time are forced along a little bit by circumstances. Even though you may have highway systems and you can't afford to operate economically, then things will stand to move on. But there are other areas in which that is coming about. For instance, there is great concern on the part of the railroads in terms of running ships right into the heart of the continent through the Great Lakes and through the Seaway system.

Well, the railroads, in some instances at least, got kind of busy and started to do something, and the result is we're knocking the can off of the container ships that are trying to get into Canada through that system by giving them a good service out of Halifax. The cost of operating a ship is so high that, in many instances, they can't come in. So you don't have to lie over and play dead.

In the matter of intermodal, at one time there was great over-the-highway movement of automobiles in our country. There still is some but it's in a very restricted area because, again, our marketing people got busy, we got working with them as to how we could offer a better service, or equal or better, and so you don't see any long distance trucking of automobiles in our country. There is some long distance trucking, yes, there is, but we've also taken a great lot of it and taken it off the highway and put it into an intermodal mode.

We've also moved out in areas in which we've got the vehicles onto the rails to do any number of things or to work with them in conjunction with the moving of many products such as cement, for instance - taking it by rail where that is the prudent mode and then having an intermodality transfer system that blows it out of the cars and into the trucks and distributes it from there. The same applies to fuel and so on and so forth.

There's always going to be competition. I think, really, what some of the speakers were trying to say is that there's opportunities for the rail. Perhaps they haven't exercised them. Perhaps they haven't been allowed to, at least in your country because of the many regulations which you're into. I think Aaron this morning kind of poked at the railroads and I have to applaud him on this thing in the sense that they seemed to have lost some of their entrepreneurship and how they've utilized things.

But I don't happen to think it's discouraging. I just happen to think that it's an opportunity that's going to tumble into here, so having recognized you do have a very extensive interstate down here, and in some areas, that's going to be the way to go. I do think there is the technology, as

*(R) and (Q) designate the response and question interchange, respectively, between the session panel members and the conference attendees.

Aaron has said, to get on to using the best of both systems.

(R) MR. HARRIS: With respect to the intermodal question, there are a set of options that one can contemplate, one of which I think you are suggesting we ought to give the proper attention to. You can either use the current institutions, that is, railroad management and a whole set of truck fleet managers, including individual operators, and by some tariff means and others, arrange to achieve intermodal movement of goods. In fact, under that system of intermodal movements, piggyback movements have been among the most rapidly growing form or element of rail transportation.

Another option is to say there ought to be greater freedom of entry, railroads ought to have the opportunity to get their own truck cabs and themselves move the commodity and provide a total transportation service. In Canada, where the restrictions on multimodal ownership are different from those in this country, I have not seen a particular movement toward an integrated transportation service, although conceptually that was a very attractive thing as far as I was concerned some years ago. I haven't seen it come into fruition because the differences in attitudes and in management skills and in the processes by which these transportation services are offered appear to be significantly different and therefore the motivation and the management style and the institutions just turn out to be different.

There are innovations in progress. The Santa Fe is innovating in this area. The S.P. has been working in part in some intermodal container concepts. As you know, Reibe Associates has invented recently a combined highway and railroad wheel vehicle intended to make it unnecessary to go from a solely highway to a solely railroad operated vehicle and that, while conceptually attractive, has not yet passed the acid test of commercial application and operation.

There is surely a view that says the bulk of merchandise traffic over the next decade is going to move from open packing to a containerized kind of movement which will give some real advantages to those elements in the intermodal system that do provide an effective service. In a study being conducted under the inter-industry task force on rail transportation, the FRA is funding a demonstration program on the Milwaukee Railroad right now in which it's been shown that by increasing the frequency of movement by putting more trains on in one intercity pair, a significant amount of highway traffic has been diverted to the rail mode and, because of more effective equipment utilization, it appears that a profitable operation may emerge. There's going to have to be some capital investment to take full advantage of that, and we haven't yet sorted out how a railroad in the financial straits of the Milwaukee can raise enough capital to put in that investment.

With the intermodal program, while it may depend on some improved vehicles and Bob Parsons has been importuned to work in this direction, it still is more an economic institutional process, and I have personally not seen it as an element in which the kinds of research that I know how to do, from our point of view, are going to have a great impact on the development of the intermodal system.

(R) MR. CANN: Bill, to just enlarge on some of the things you said in regard to the management styles and so on of the rubber trade versus the steel trade in terms of transportation, it's quite true, and while we do own a great number of trucking companies, we do operate them as independent from the railway in one sense. At the same time, we're cognizant of the fact they are there, and we do give the shipper an opportunity to ship from origin to destination by using both modes. We have found that the styles of the two industries are so divergent that it's best to keep them separate that way. But we have instances, for instance, where mines are a long ways off our line, where we have combined with one of our trucking companies and given the company a rate which went from the mine down to the railway to the destination point by rail. It's a joint rate. We have given rates on other commodities that move from manufacturer to a transfer point to a user point, again a complete through-rate working with our trucking division, but we still manage them as separate entities in the respect that Bill is talking about because they are different approaches. But the fact that they are kissing cousins, if you want to call them that way; has made us more amenable to going at it as a family than I think we might have done independently. I don't say you can't do it that way. I'm just saying that we have chosen to go that way.

(Q) MR. HARRIS: Ted Mason is here from the Santa Fe. Ted, have you got any particular observations on this matter?

(R) MR. MASON: No thank you, Bill. I think it has been covered very well.

(R) MR. CANN: That was a good point that you raised, though.

(Q) DR. KUMAR: In connection with that, one thing that I have been curious about... several representatives of the railroad companies are here. Before a right-of-way is abandoned, is there availability of an economic analysis program by which they could determine whether this right-of-way, if converted to a bimodal utilization like the trailer on train concept, or container concept, might turn out to be rather profitable or useful. I know that the analyses are based on the previous data which is based on the past practices, but the new situation, as it's developing in the country now in terms of fuel and all that, certainly might enable the re-examination of the abandonment of many rights-of-way. I really don't know whether there is such an availability of decision-making process at this time or not.

(R) MR. HARRIS: My observations are that the railroads that have been looking at abandonments are looking at real dogs. That is, they're looking at areas in which the opportunity for adequate rail or multimode traffic is just essentially non-existent. Railroads are damned inefficient when you're pulling one or two or three cars. They are not as energy effective as trucks are in that mode of operation. You've got to have a train which is properly powered, that is, in balance in terms of power where you're using all the available tractive effort of the locomotive before you get to this three or four to one energy efficiency that has caused all of us to feel confident about the future of the industry, and you don't have that in any branch line that I know of that's being seriously considered for abandonment, so from what I have seen, the economic analyses are surely available, and while there are potentially some real concerns on the part of the locals, I don't think there's need for any new economic analysis tools to cope with the abandonment studies insofar as I have seen.

(Q) MR. POWELL: Mr. Cann, you've alluded to the Track/Train Dynamics committee and some of your other speakers have. I wonder if you could comment briefly on some of the benefits that your railroad has derived from the production of this committee.

(R) MR. CANN: Well, I can name one that comes really quick because it's truly current. One of the geniuses in the past in our era decided that he would shorten the spirals on some of the curves in northern Ontario for whatever reason. It's lost in antiquity anyway. All of a sudden, we started to have substantial number of single car, single truck derailments which unfortunately were falling into quite a pattern and we quickly began to zero that down into either a container or a trailer flat car loaded in a particular way. And by working with the data that has come out through Bill's groups, we began to find out what the cause was in terms of the long car, the loading of that long car, and the inability to negotiate from tangent through curves on these short spiral curves, and they were simply lifting the car off. We then quickly started to change some loadings to get away from what appeared to be the cause of the thing, and ergo, we don't have the derailments anymore and, of course, in due course we'll get around to lengthen those spirals out and take other corrections. I'm sure if there hadn't been this focus on track-train, if there hadn't been the data, that we'd have been fumbling around with the thing for God knows how long, wondering whether we had a real cause, and if we did, what the results were, why it occurred, and what the corrections were going to be. As it was, as soon as we saw, well, I guess, several of these, because it recurred reasonably quick, started to show up, why, we had some quick and fast solutions and changed our loadings of the cars and, as I say, it disappeared.

That's one instance and we can go on into many others. Our steerable truck, as you might want to call it, which we have developed, quite apart from that done by some of the other suppliers, is at a point which we have bought a 100 car sets and - Aaron - here's my economist friend come in and he wasn't satisfied with a few sets. All of a sudden we got a reasonable proliferation of them which is a little difficult from a practical end to control but it's going to do the job, it's going to give us some thoughts, and some data from which we can make future decisions on the savings that appear evident, anyway, from the steerable truck both on our rail and wheel wear. Again, I doubt that we would have got into some of the areas that we did if we hadn't had some of the fundamental data that Bill has developed to get to work on through our own research labs and push that on. Those are two instances, and we have many more, so that there's no question in my mind that starting out from some base, as imperfect as it might be, and feeling a way ahead is sure a heck of a lot better than the old empirical way which is, you know, you tried it until you dumped a few trains in the ditch and then you really never knew what happened. So I'm a greater supporter of the work that Bill is doing. As I said earlier on, I'm a little disappointed that some of the railroads don't recognize that what we've got is a system, and some of the parts are only as good as the system to operate.

Now, Aaron referred this morning to the fact that we have the ability in Canada because we have large systems to make some of these things work better. Well, that's true up to a point, but with the large system, you've got to break it down into subsystems in order to administer things. It's just too huge. And the big thing there is how do you have local authority for initiative on that part without having so much authority that they're counterproductive to the next one. I think overall it's still better to do as an integral unit than as a bunch of separate railroads, but it isn't a sinecure for solving the problems to which Aaron referred this morning, but it can be done and I think this is an area in which we have benefited dramatically from Track/Train, and I could go into many more. Bill?

(R) MR. HARRIS: I can cite one or two other different sorts of cases just to extend the answer to the question. The mechanical division has been able to take substantial advantage of things learned in Track/Train Dynamics. David Sutliffe, for example, led the effort to put in place some fatigue guidelines in the car construction committee's arsenal of ways of specifying and designating how cars ought to be designed in the future. I'm absolutely confident that failures that now do occur early in car life will not occur as a result of the fact that from Track/Train Dynamics, we have been able to sufficiently characterize the loads that go into the car, that the fatigue guideline concept can be in place. It's a difficult one to accept and it's taken some real doing, but without the coordinated effort that Bob Parson's funding and the support from personnel at TSC and the support of RPI and from the railroads and AAR budget, we just never would have had the technical basis for making that kind of decision.

We've also changed several other specifications on couplers and other components based on work done in that program. Some railroads have gone back and rechecked all of their signal spacing based on models, analytical models, developed in Track/Train Dynamics, that will validate it with very substantial expense. We have probably spent $10 million in model validation over the last 10 years, or 8 years. And absent that model validation, you cannot apply a mathematical analytical tool. With it, it suddenly becomes an enormously powerful way to re-establish what goes on in your railroad. And the notion that you suddenly have got heavier cars and longer trains and you don't know whether your signal spacing is appropriate is a terribly frightening concept for any operating man, and yet, you can't possibly go in with experimental methods and go through and break a train under a penalty application at every signal on your railroad. You just can't afford the time or run the risks of experimental error that leads to; and so I know some railroads that have gone through and they've either changed, added aspects, or they've changed their signaling spacing as a result of what they have learned. I think it's a very powerful contribution toward effective railroading.

Many railroads are doing derailment analysis and they're proving to their own satisfaction, as Jack did in this special case, conditions that need to be changed. I know railroads that have saved as much as $3,000.00 a car in cars that they have designed and built because of errors that they found they'd made in design that they checked out by looking at dynamics before they put the car in service. And on one or two car orders, it pays for the whole program. We've tried, and it's very hard for people to take the time to develop a long set of citations of application, but these are things that have come very definitively to our attention by members of the committee and observations we've made as a result of services that we can provide to the O&M department of AAR and its mechanical department particularly.

(R) MR. CANN: I think that's a very good point, Bill, and, Ed, we let one guy loose on the simulator and he immediately ran down one of our cabooses because he didn't know how to handle a train brake. He was the Vice President of R&T for AAR.

(Q) MR. LIST: This is probably not a good question under those circumstances, but you said that there was some long range thinking going on with respect to braking, and I was wondering if you might elaborate on that a little bit. I was particularly interested... I can assume that you've given a good deal of thought to the control of the train and you made a reference a minute ago to signal spacing, but in this work, have you also considered the, what seems to me, substantial amount of time that goes into the care and feeding of the air brake system when it comes to making up a train, testing a train, and all that good stuff?

(R) MR. CANN: Well, I'll tell you what we've done about it. We've changed the whole system. We're into an air flow method of brake tests instead of the usual brake leakage. We consider it's a safer and it's a more continuous monitoring of it by measuring the flow of air that's flowing out from the front with the pressure maintaining valve and by measuring the pressure that's in the van. And certainly, it's cost us to get looking into this type of a thing. That's one area that we've got into. Bill, you probably have others that you want to speak on.

(R) MR. HARRIS: There are four issues in braking that are of concern, at least to me, and my associates in some areas, I know, are much more concerned even than I. We have looked at what happens to forces in a train as a result of brake application and we're aware that the time of propagation now and the differential braking that you get with light and heavy cars and with composition shoe and cast iron brake shoe applications, and with the differences and the variations that are possible in braking ratios, that you can get an undersirable set of combinations that can lead to excessive longitudinal forces and then into train buckling.

We are aware that the very time it takes for propagation has something to do with stopping distance and with the control of the train. We're aware that the combination of brake shoes that we now have in trains can give rise to the problems under some circumstances. We are aware that the hand brake application problem is a very troublesome issue with the kinds of cars that we have and the nature of the processes of brake application. When you look at the whole combination and then add to it the problem of delay in a yard because of train makeup, the safety issues that are not serious at the moment, but are always potential by having to have people go between the train for coupling of air hoses in the yard, all lay out a whole set of concerns that are leading us toward an attempt at a redesign of a performance specification for both a hand brake and a train service brake system. It's very hard to put the numbers on this in a way to be of service to the railroads and the industry that knows so much about air brakes, the suppliers that have been working at this problem for so very long. And so, I don't say we're going to, in 1979 or '80, begin to outline what we think the new sets of requirements ought to be, but I believe that in order to have profitable and effective railroading downstream that we have to at least reconsider and offer the options of some new approaches toward braking in response to the performance issues that we can now begin to define. And I think by 1981 or 1982 we'll be able to lay these out for the kind of consideration we're now doing in the performance specifications for dynamically more stable cars. In issuing those specifications, we're not going to just sit back and hold them like this and then say, you know, take it or leave it. We're developing a set of specs, we're going to discuss them fully with the people who may be interested in bidding on those specs, and be sure there are no surprises when something finally comes forward. And so, in an air brake performance specification, this has to be approached - or in a train brake performance specification - this has to be approached with enormous care. But nonetheless, there are enough sets of problems, some of the kind you cited, some I haven't cited at all, namely overheated wheels, that are a matter of very real concern to the industry at present. But we haven't thought our way through the problem yet. It's only as a result of these kinds of research efforts we have a chance at thinking our way through the effort, and I cited it only as one area, that I think by the mid-80's we may know enough about to be able to put something forward for reconsideration.

(R) MR. CANN: Well, we seem to have satisfied your curiosity for the moment anyway, and I hope during the day we have exercised some incentive for you to think a little bit about it. Track/Train, as you can see, is a very important part and it might be appropriate if I were just to make note that on November 27to to 29th, there's an engineering conference specifically on these items to occur in Chicago, and you might be encouraged to want to go to that session and to spend more time on details specifically related to that.

I'd like to thank the panel of speakers that I've had here this afternoon and Bob, for the opportunity that you've given me to be Chairman of these sessions, and to the audience for the very attentive time they have given us, for the questions they've asked, and so on. I hope we've provoked you into thinking about the problems of the railroads during the 80's. I hope from the thinking about those, some action will come that will evolve in solutions, at least, to some of the problems at any one moment in time, to some of the things that Aaron has raised in regard to the entrepreneurship and to the research that we need to go through. The opportunities are there. I won't be with the railroad as you go through the 80's, but I will be for part of it, and to that extent, I propose on my railroad to the extent that my President will allow me to keep current and to turn that railroad into the best there is around in North America and to try and make it even more profitable than what it is today. Thank you all for your attention. I thank my panel and the panel that was here this morning. I was most appreciative of your efforts and happy to be your Chairman. Bob?

(R) MR. PARSONS: Representing the participants at the conference, I'd like to also extend our appreciation to your speakers of this morning and Lou Thompson and his speakers of yesterday morning. Let us give them a big hand. Jim, we appreciate you being host for the group. I think we've found it different this year and very convenient and satisfying. On behalf of all of us that have partaken in some of the social amenities, I'd like to again thank American Steel Foundries, Griffin Wheel Company, National Castings Division of Midland Ross Corporation, Dresser Industries, and the Railway Supply Association. I think without the social adjustment periods, we wouldn't have been able to have the good dialogue we've had both during the day and off the day.

Lastly, I'd like to thank each of you personally for attending, giving your time up. I hope the conference has been worth your trip. We'll see you possibly at the 16th Engineering Conference. The bags are available. I would suggest the ones that have tight connections get on the first bus. There's coffee and perhaps those that could wait until the second bus could have a cup of coffee before departing. With that, I wish you all a safe trip home and hope you enjoyed the conference.

[Whereupon the conference was adjourned.]

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Transportation Systems Center — October 22-23, 1979

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