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RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT ON ADVANCED RAILROAD BRAKING AND COUPLING SYSTEMS

E.K. Bender, L.E. Wittig, and H.A. Wright
Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, MA 02238

March 1981

Final Report

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
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16. Abstract

This report presents a set of recommendations for a research and development program on advanced railroad braking and coupling systems. Programs are developed for the following four systems: 1) a brake condition monitor, 2) a hybrid electropneumatic brake operating valve, 3) a multi-purpose coupler system, and 4) a system that embodies the beneficial features of all three systems previously mentioned. Estimated R&D costs for these systems range from 2 to 7 million dollars and would require 5 years to perform. Considerations of institutional factors lead to the conclusion that there are vital roles for government and industry participants. It is recommended that the Federal Railroad Administration provide overall technical direction, a major portion of the funding, and a limited waiver of certain regulations to facilitate experimentation. The Association of American Railroads would play a review and advisory role, while a railroad and an equipment supplier would conduct appropriate testing. A systems contractor would coordinate the R&D, develop hardware, and acquire and analyze test data.

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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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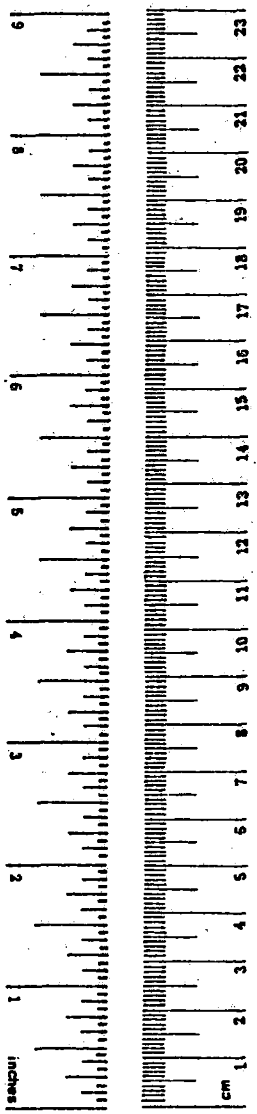
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
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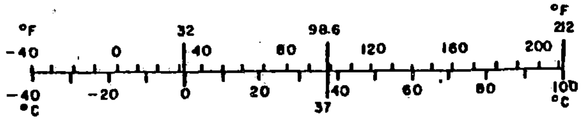
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
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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*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

PREFACE

This is the third in a five-volume series of reports on advanced braking and coupling systems. The first, "Methodology for Evaluating the Cost and Benefit of Advanced Braking and Coupling Systems" [*1*], established the techniques that were intended for use in evaluating a broad range of candidate systems. The second, "Evaluation of the Costs and Benefits of Advanced Braking and Coupling Systems" [*2*], applies these techniques to 16 such systems to identify those that appear most favorable. This report structures a set of alternative R&D plans to bring the three most promising systems, as well as a composite of these systems, from the concept stage through hardware demonstrated to be technologically and economically feasible. The fourth and fifth reports [*3*,*4*] document computer models of yard operations and the cash flow associated with railroad investment.

The authors express their appreciation to the people and organizations that have helped considerably throughout this project. The FRA COTRs, Ms. Marilynne Jacobs and subsequently Dr. N. Thomas Tsai, have provided invaluable guidance and direction. In addition, an industry committee composed of Messrs. Geoffrey Cope of Dresser Industries, John Punwani of the Association of American Railroads, Bruce Shute of the New York Air Brake Co., Donald Whitney of the Burlington Northern Railroad, and Carl Wright of Westinghouse Air Brake Co. have performed important review and consultation. The American railroad industry, in particular the Southern Railway, Boston and Maine, Conrail, and several other railroads, has graciously provided information and an opportunity to observe railroad operations. The Union Internationale Des Chemins De Fer provided valuable information on the design and costs of a coupler proposed for eventual use on European railroads.

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1. Introduction

A broad study of the probable costs and benefits of advanced railroad braking and coupling systems has shown that several systems have considerable potential to improve railroad productivity [2]. Most of these systems exist only at the conceptual stage; they have not yet been developed and demonstrated. Accordingly, a research, development, and demonstration (RD&D) program is needed to carry this technology from the concept stage to functional and reliable hardware.

The results of the study are summarized in Table 1. The table shows that wide gathering range couplers and many of the electronic systems designed to improve operations not only show very favorable cost/benefit ratios but also have the potential to provide a substantial net benefit* to American railroads. The findings lead one to expect that an RD&D program for these systems will show a particularly high return on investment and thus will be a profitable undertaking.

In assessing the various ways in which one could structure an RD&D program, risk and allocation of limited resources must be considered. RD&D could, for example, be performed on each of the favorable systems shown in Table 1. However, one runs the obvious risk of spreading resources so thin that no single project has a good chance of success. At the other extreme, resources could be focused on the single system that shows the most favorable cost/benefit ratio and the greatest net benefit. Here, too, one runs a clear risk of failing by selecting the wrong system because of uncertainties in data underlying the results in Table 1.

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*For purposes of this study, "net benefit" is defined as the gross annual benefits accrued from a system less than annual maintenance costs.

TABLE 1. SUMMARY RESULTS OF SYSTEM EVALUATION [2].

System	Net Benefits ($M)	Allowable Cost Per Car ($)	Estimated Cost Per Car ($)	Cost/Benefit Ratio:† Estimated Cost / Allowable Cost
Mechanical: Improved Operations				
Wide-range couplers	503	2157	874	0.33
Automatic airline connector	101	318	765	2.4
Incompatible coupler	597	1717	10,248	5.97
Mechanical: Improved Dynamics				
Truck-mounted brakes	*	*	*	*
Disk brakes	*	*	11,700	*
E couplers with shelves	12	58	112	1.9
High-strength draw gear				
knuckle	18	20.71	8.90	0.43
coupler body	35	6.43	15.25	2.37
yoke	13	1.77	5.75	3.25
Zero slack systems	31	91	*	*
Mechanical load sensor	38	51	405	7.94
Electrical: Improved Operations				
System framework	0	0	135	*
Remote-controlled coupler:				
a) time savings only	31	87	1,060	12.2
b) crew size reduction	493	1373	1,060	0.77
Remote-controlled brake lock	703	1957	346	0.18
Ultrasonic brake control (on 5% of cars)	198	5340	2,000	0.37
Brake condition monitor	479	1334	221	0.17
Electrical: Improved Dynamics				
Electronic brakes (direct control)	*	1275	917	0.72
Electrical load sensor	54	73	120	1.6
Electro-pneumatic brakes	(300)	*	6,225	*

*It was either infeasible or inappropriate to estimate values for these elements. Further discussion is provided in Ref. 2.

†The smaller the ratio in this column, the more attractive the system.

There are also clear, and unnecessarily large, risks associated with an approach based too heavily on a single perspective. The "engineering" approach might be to spend considerable resources developing and field testing a technologically exciting system, only to find later that it is financially unattractive. In contrast, an analyst might collect substantially more data and construct analytical models, improved far beyond those that presently exist, in an effort to reduce the uncertainty associated with the present results. But data and models are only a means to an end; alone, they do not provide needed cash flow and usually do not provide the kind of realistic information that is available from prototype hardware.

The RD&D program that we recommend here is intended to provide a balance among the factors discussed above. It involves the development of several different types of systems and the simultaneous generation of improved data and analytical tools for refining the assessmeent of their costs and benefits. Incorporated, too, are decision points that permit the curtailment of R&D investments if it appears that the cost/benefit ratio will become unattractive.

The remainder of this report is organized in three sections. In Sec. 2 we present the recommended six-phase general approach for the engineering development of several systems and discuss our approach to scheduling and costing. Section 3 presents three systems for research, development, and demonstration. They are 1) a brake condition monitor, 2) a hybrid electropneumatic brake operating valve, and 3) a multipurpose coupler system. For each of these systems we discuss the engineering effort, schedule, and required resources. In addition, a program that integrates the development of these systems into a more comprehensive program on advanced braking and coupling systems is discussed. In Sec. 4, we suggest what we believe are appropriate roles for government and industry participation.

2. GENERAL APPROACH

The approach to the development of any of the systems evaluated earlier [2] may be generalized in terms of an RD&D plan and a discussion of schedule and resource requirements. The RD&D aspects involve a step-by-step engineering effort to take systems from their present conceptual stages to the points at which they are ready for widespread implementation. Here we will discuss the engineering, schedule, and cost elements that are common to the specific systems that will be described later.

2.1 Engineering

For each of the three systems that will be discussed subsequently, the RD&D plan is composed of the follwing basic phases:

I. Design
II. Prototype Development and Laboratory Testing
III. Limited Field Testing
IV. Cost/Benefit Analysis
V. Review and Decision
VI. Extended Field Test

During the *design* phase, competing concepts are crystallized and evaluated, with the most promising embodied in a set of engineering drawings for a prototype system. As part of this process, measures of performance relating to such factors as weight, size, anticipated reliability, power consumption, and dynamic response are evaluated quantitatively wherever possible. Subsystems and components are identified that may be purchased off the shelf or custom-designed for the application at hand.

Prototype development and laboratory testing involves fabricating a small number of units and testing them under carefully controlled laboratory conditions. Because of the small numbers, mechanical parts would often be machined or fabricated from stock items rather than cast. Similarly, electronic systems would be breadboarded from basic components (e.g., transistors, amplifiers, counters) rather than developed on a single semiconductor chip typified by quantity production. Electromechanical brake systems would be tested for dynamic response and possibly to ensure proper functioning over a range of temperatures that might be encountered in the field. Couplers would be tested for strength and to ensure that proper coupling takes place over a range of impact speeds and misalignments.

In the *limited field testing* phase, a number of systems are installed in freight cars for three purposes. First, it is necessary to verify that the laboratory-proven systems are also capable of functioning satisfactorily in an operating train. Second, it is important to obtain information on their durability and sustained performance under actual operating conditions. Third, operational and maintenance data must be acquired for purposes of a subsequent cost/benefit analysis.

A *cost/benefit analysis* performed at this stage would be based firmly on the specific experience acquired during prototype development and limited field testing. This analysis should consider the future stream of costs and benefits, as was done earlier [2] in a somewhat broader treatment.

A *review and decision* point follows logically from the previous phases, particularly the cost/benefit analysis. Participating government and industrial organizations should convene and decide whether to continue with the system implementation through an extended field test, refine the system design, acquire additional cost and benefit data, abort the program, or follow some other course of action.

An *extended field test* would be warranted if the cost/benefit analysis and results of limited testing are sufficiently encouraging. This phase involves the placement of more components in service for extensive testing. These components may be configured to resemble quantity production units more closely than the original prototypes used for limited field testing.

2.2 Schedule and Costs

For each system, and for the set of integrated-systems, a five year schedule is developed to show the estimated time to perform each task of each phase of work. At least two control points are incorporated in each schedule; at each, the FRA can decide to curtail further development or redirect the program, thereby avoiding a wasteful expenditure of resources if the program does not proceed as expected. One such point occurs during Phase II, after a single system has been built and laboratory-tested to demonstrate technological feasibility. The other occurs after the completion of Phase IV, at which time a favorable cost/benefit relation is shown to be favorable or unfavorable.

Costing is performed by estimating labor and direct costs by phase. Labor categories are Project Manager, Electrical or Mechanical Engineer, Analyst, and Technician or Draftsman. An assumed average rate of $80k per man year is used to obtain a labor cost estimate. Other direct costs involve travel and subsistence, hardware procurement, and miscellaneous (e.g., computer, report copying, laboratory utilization). The total cost is then computed for each phase and the entire project.

The estimates given are in constant dollars, with no account taken for inflation. This assumption builds a downward bias into estimates, particularly for five-year programs. However, it gives the reader a reasonable feel for the cost in terms of 1980/81 dollars. It is also assumed that a participating railroad would not charge for the use of its equipment, facilities, or manpower. The rationale is that the contribution of these resources is a mechanism for cost sharing in a program that promises to be of considerable benefit to the participating railroad and subsequently to the railroad industry.

3. SYSTEMS RECOMMENDED FOR DEVELOPMENT

3.1 Brake Condition Monitor

A brake condition monitoring system is designed for partial automation of brake testing as currently required by the Power Brake Law. The law requires that certain procedures and conditions be met before a train leaves an initial terminal or after it has travelled 500 miles. The brake pipe pressure at the rear of the train must be at a minimum of 60 psi and within 15 psi of the locomotive feed valve pressure. The leakage rate with the brakes applied must be less than 5 psi/min. After a full service reduction is made, the brakes must be inspected to ensure that all brakes have indeed applied and that piston travel is correct. When brakes are released, the train is inspected again to ensure that all brakes have released. All of this requires a significant amount of time, which could be reduced substantially by a brake condition monitoring system.

As shown in Fig.3.1, the brake condition monitoring system is composed of three subsystems: a locomotive-based monitoring unit, a car condition monitoring module, and a brake pipe pressure module. The locomotive monitoring unit interrogates each car and displays the status to the engineer or head-end brakeman. The module will indicate the specific cars on which the brake piston is not extended properly or an angle cock is closed. It will also show whether the brake pipe pressure at the caboose is adequate. The car condition monitoring module and associated sensors determine whether angle cocks are open and piston travel is correct and supplies this information in digitally coded form to the locomotive-based monitoring unit. The brake pipe pressure module monitors the brake pipe pressure in the caboose and similarly transmits pressure information to the locomotive monitoring unit.

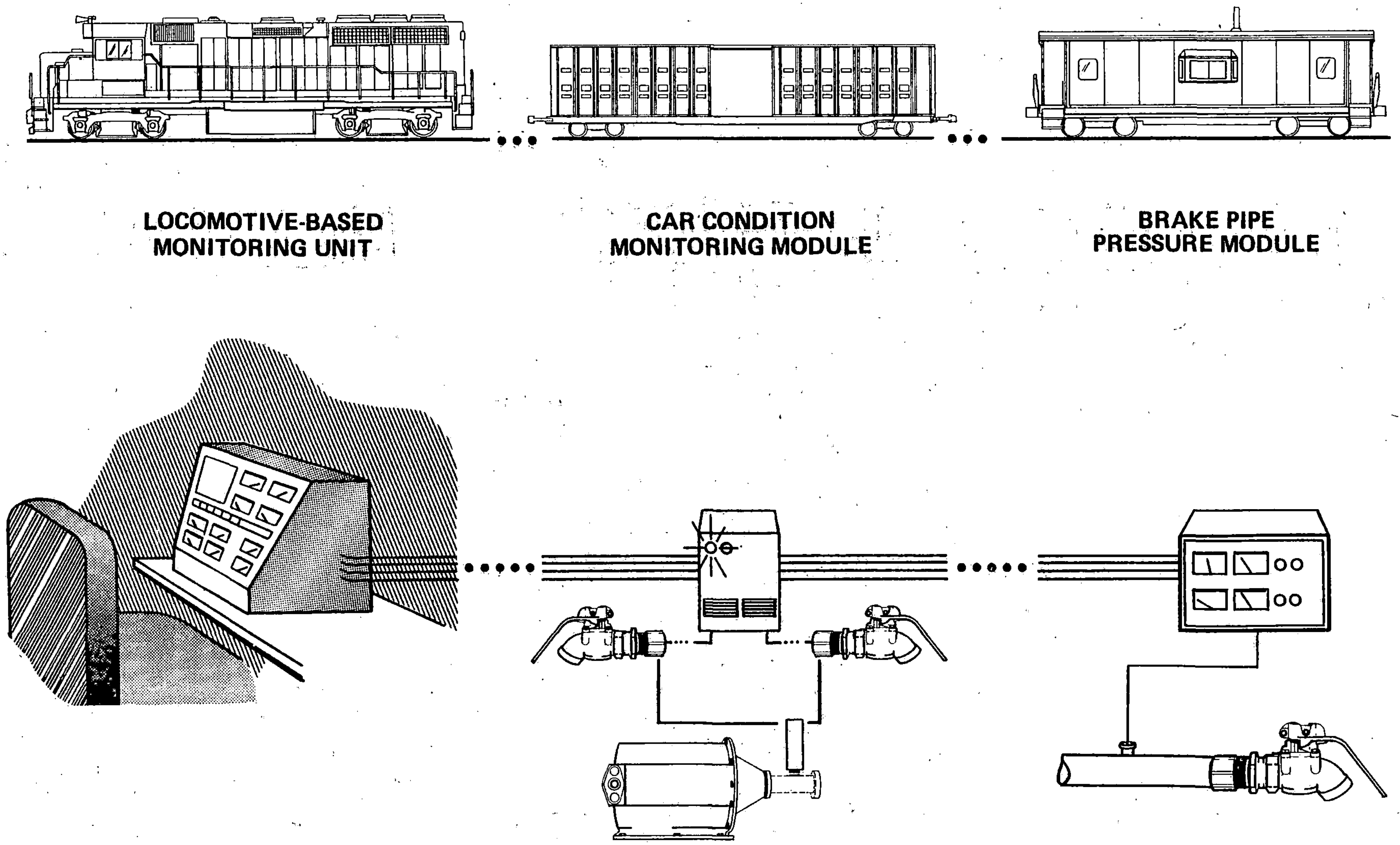


FIG. 3.1 BRAKE CONDITION MONITORING SYSTEM .

If the brake monitoring system were successful and proven reliable, it could be left operational while a train is running. A malfunctioning component could be detected immediately and steps taken for its repair. This system might then obviate the need for routine power brake tests at 500-mile intervals.

3.1.1 Engineering

The six-phase engineering program is as follows.

Phase I: Design

The overall system and major components would be designed or selected. Major components are:

- locomotive-based monitoring unit
- angle cock position sensors
- brake piston travel sensor
- electronic car condition monitoring module
- intercar connectors
- brake pipe pressure sensor

Phase II: Prototype Development and Laboratory Testing

Task 1 Component development

After each component is designed, it should be fabricated and laboratory-tested to ensure that it functions properly, especially under the range of environmental conditions found on American railroads. Of particular concern would be the effect of temperature extremes on electronics and dirt, dust, and precipitation on position-monitoring switches. Laboratory tests should be conducted on the three major components connected together to form a basic system. These tests constitute a critical control point at which the FRA can decide whether to proceed with the program as planned or proceed with an alternate course of action.

Task 2. Ten-car system development

A 10-car monitoring system should then be assembled and laboratory-tested in preparation for subsequent field testing. Starting with 10 cars provides the opportunity to test, evaluate, and modify the system before incurring the expense associated with equipping a complete train. Refinements to the system should be made as appropriate.

Phase III: Limited Field Testing

Field testing should be performed on a unit train rather than on cars used in general interchange service. At this stage of development, it is necessary to keep the cars connected electrically and monitor the system from a locomotive. This can be done on a unit train that remains intact for extended periods, but not on general commodity trains, which are repeatedly broken down and reassembled. Moreover, unit trains are highly utilized and would probably benefit most from a brake condition monitoring system.

Task 1 Unit train identification and baseline evaluation

Since the brake condition monitoring system would be implemented first on a unit train, it is necessary to identify the train (or route) and begin the acquisition of baseline data. These data would include measures of the time and costs presently allocable to power brake tests, and an assessment of delays caused by initial noncompliance with the test requirements.

Task 2 Develop an implementation and test plan

An implementation and test plan must be developed that addresses two functions. The first is the physical installation of the limited monitoring system on a unit train and the subsequent acquisition of test data. The second is the provision for inspection procedures required by the Power Brake Law that are not amenable to instrumentation. This would likely involve a visual inspection to ensure that brake rigging is not fouled and that brake equipment is properly secured. This inspection might be performed on an outbound roll-by or as part of a general inbound inspection.

Task 3 Limited unit train implementation

The system should be implemented on a unit train for service test and evaluation. This system would be comprised of the locomotive-based monitoring and display unit, 10 cars instrumented to detect angle cock and piston travel, and one car instrumented to monitor brake pipe pressure.

Task 4 Field test

The 10-car monitoring system described above should be tested during a period of approximately one year. Moreover, the route through which the train operates should preferably be in a part of the country that experiences extremes in climate to subject the system to a full range of environmental conditions. During this test phase, system performance should be monitored and recorded. Since the train is only partially instrumented, it would, of course, be required to undergo normal power brake testing during this field test stage.

Phase IV: Cost/Benefit Analysis

On the basis of the prototype design and the data acquired before and during the field test, a cost/benefit analysis should be performed. This analysis should focus on unit train operation for which the acquired data are most relevant. Since a monitoring system is likely to be significantly more cost-effective for a unit train than for general interchange service, the outcome of this analysis determines a minimum threshold for project continuation.

Phase V: Review and Decision

The results of Phase IV would be reviewed and a decision made to continue into Phase VI, abort the program, or restructure it.

Phase VI: Extended Field Test

Task 1 System fabrication and laboratory testing

A monitoring system for an entire train should be fabricated and laboratory-tested. This system would be sufficient for a unit train plus a group of cars that would normally replace those removed from the train for maintenance.

Task 2 Full train testing

A unit train would be equipped and tested for about a one-year period. If, after an initial shakedown period, the system is proven to be reliable, conversion of power brake testing from conventional methods to reliance on the monitoring system should take place. This would result in immediate and measurable benefits to the railroad participating in the test.

Task 3 General service evaluation

Once it has been decided to proceed with full train testing, a detailed study of implementing the monitoring system in general interchange should be undertaken. This study would involve detailed yard and road modeling and would be based in large part on the field experience generated in Phase VI. The results of the program should be reviewed and recommendations made as to whether to proceed with the general implementation of a monitoring system.

3.1.2 Schedule

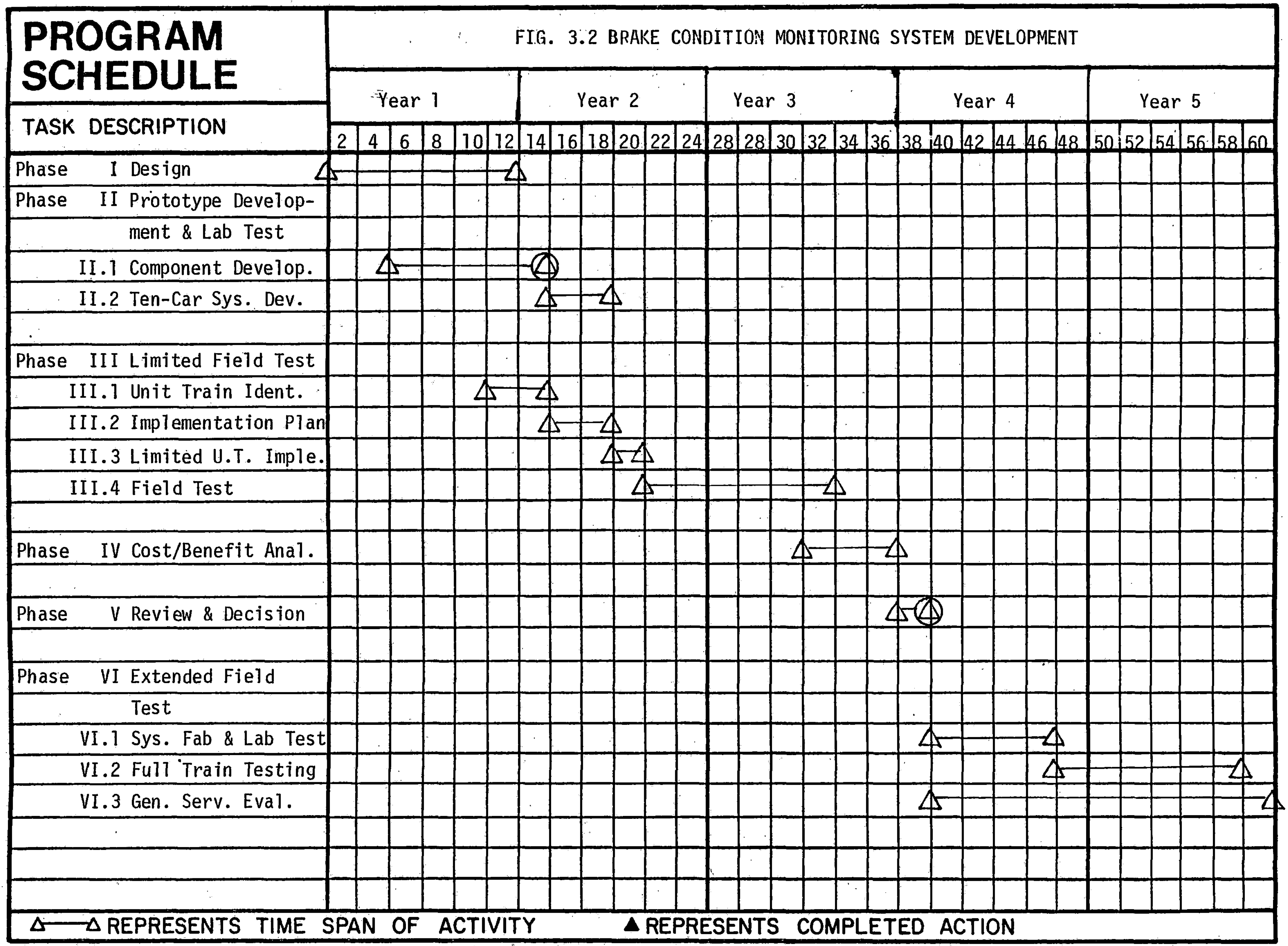
Figure 3.2 presents a recommended schedule for the six-phase RD&D program described in Sec. 3.1.1. The program encompasses five years and extends from the present conceptual stage through a thorough demonstration of a complete system.

The Phase I design stage begins immediately and lasts for one year. Four months later, Phase II starts with the development (or acquisition) of basic components. These would probably be electrical connectors, angle cock position sensors, and the brake piston travel sensor. Following would be the development of more complex components, such as the locomotive-based monitoring unit and car monitoring modules. Subsequently, a 10-car system is developed and checked.

The Phase III limited field testing begins eight months before the 10-car system is ready. This allows time for planning and the acquisition of baseline operational and cost data. Two months are allowed to implement and check out the system, followed by a one-year field test. The Phase IV cost/benefit analysis begins shortly before the field test is complete and ends six months later.

At the beginning of the fourth year, the critical Phase V review and decision takes place, based on an evaluation of the prior three year effort, with special emphasis on the cost/benefit results. If it is decided to proceed with Phase VI, a full unit train system is built, checked, and implemented for a full year

FIG. 3.2 BRAKE CONDITION MONITORING SYSTEM DEVELOPMENT



of testing. The program concludes with an evaluation of the suitability of the system for general interchange service.

3.1.3 Cost

A cost estimate for developing the brake condition monitoring system is shown in Table 3.1. The table illustrates that the most intensive effort is for the development and laboratory testing of the initial 10-car system (Phase II) and for the extended field test (Phase VI), which includes the fabrication of a system for a complete unit train.

Figure 3.3 shows the costs in Table 3.1 projected over the five-year course of the program. Two control points are shown at the beginning of the 15th month (after a basic system has been built and laboratory-tested) and the 39th month (after a cost/benefit analysis) points. By these points, $830k and $1,600k will have been spent. If the system appears unpromising at either point, the program can be aborted and future expenditures avoided.

3.2 Hybrid Electropneumatic Brake

As discussed in Ref. 1, a hybrid electropneumatic operating valve has the potential to bridge the gap from the present pneumatic operating valves to a future electronically controlled valve. The hybrid valve contains an electronic logic system to control a set of solenoid valves, has a self-contained electrical power supply, and responds to brake pipe pressure changes in the same way as the present ABDW valve. The system can be incorporated on cars used in interchange service. After new cars equipped with this system have naturally replaced old cars, they can be connected with an electrical train line. The result is a brake system that responds rapidly and simultaneously throughout the train, and may be less expensive than existing systems.

TABLE 3.1 COST ESTIMATE FOR DEVELOPMENT OF BRAKE CONDITION MONITORING SYSTEM.

	Phase I Design	Phase II Prototype Development and Laboratory Test	Phase III Limited Field Test	Phase IV Cost/ Benefit Analysis	Phase V Review and Decision	Phase VI Extended Field Test	Total
Labor							
Program Manager	0.5 m-yr	0.5 m-yr	1.5 m-yr	0.5 m-yr	0.2 m-yr	1.8 m-yr	5.0 m-yr
Elec/Mech Engineer	2.0	3.0	1.0	0.5	0.2	3.0	9.7
Analyst	-	-	1.0	0.5	0.2	2.0	3.7
Technician/Draftsman	1.0	3.0	1.0	0.5	-	5.0	10.5
Total Labor	3.5 m-yr	6.5 m-yr	4.5 m-yr	2.0 m-yr	0.6 m-yr	11.8 m-yr	28.9 m-yr
Assumed Rate	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr
Total Labor Cost	$280k	$520k	$360k	$160k	$48k	$ 944k	$2312k
Other Direct Costs							
Travel & Subsistence	$ 10k	$ 20k	$ 30k	$ 10k	$10k	$ 50k	$ 130k
Hardware	-	50k	20k	-	-	300k	370k
Miscellaneous	10k	50k	20k	10k	2k	50k	142k
Total ODC's	$ 20k	$120k	$ 70k	$ 20k	$12k	$ 400k	$ 642k
TOTAL COST	$300k	$640k	$430k	$180k	$60k	$1244k	$2954k

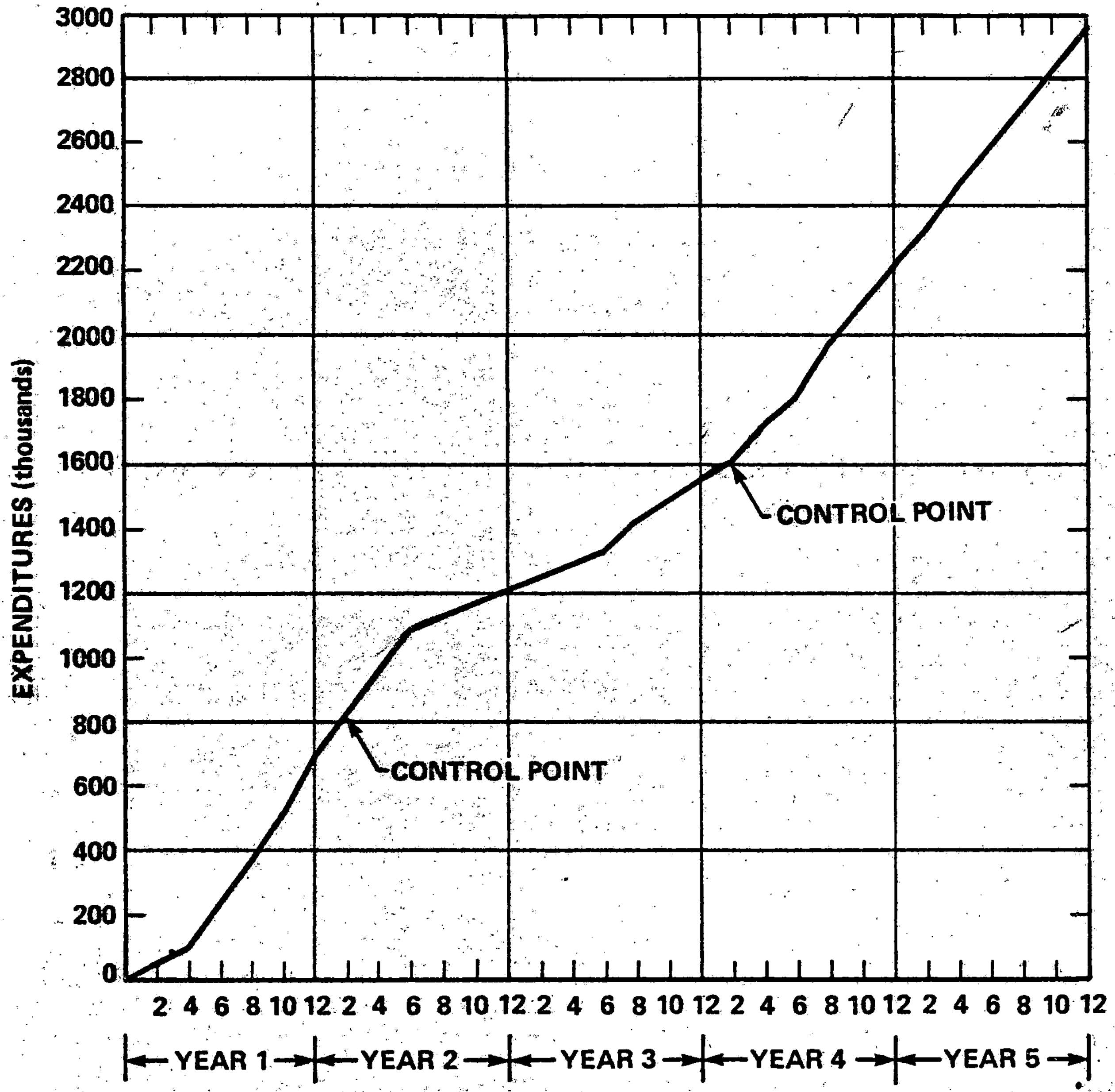


FIG. 3.3 PROJECTED EXPENDITURES FOR THE DEVELOPMENT OF A BRAKE CONDITION MONITORING SYSTEM.

Figure 3.4 shows that the main new elements of this valve are a charger, battery, a logic/control module, and an electropneumatic switching module. As with the ABDW control valve, the hybrid valve responds to brake pipe pressure changes to deliver stored air to the brake cylinder at service or emergency rates.

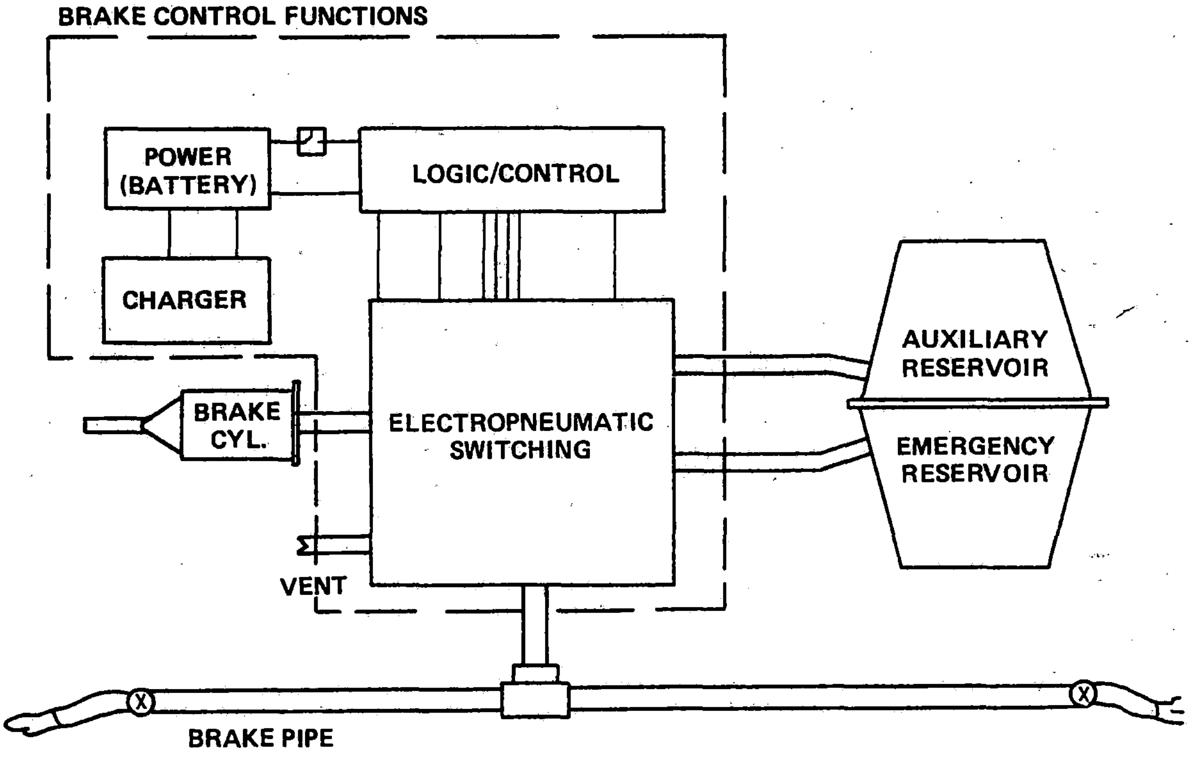


FIG. 3.4 OVERVIEW OF A HYBRID ELECTROPNEUMATIC BRAKING SYSTEM.

3.2.1 Engineering

The development of this system would proceed according to the six basic phases discussed in Sec. 2.

Phase I: Design

The design of the unit should begin with the logic/control and electropneumatic switching modules. These should incorporate the response features of the present ABDW valve but should also be sufficiently flexible to improve upon that valve as appropriate.

The design properties of these modules will determine battery and subsequently charger capacities. The battery will have to be long lasting and reliable. The source of energy for the charger could be mechanical (e.g., an axle-mounted generator), pneumatic (an air motor and generator operated while the brake reservoirs are charged), or photo-voltaic.

The system must clearly be designed to be failsafe. If the electrical components fail, the system should be able to respond in some measure to a brake pipe pressure reduction. Conversely, a failure should not initiate a brake application. Such an application on a running train might not be detected by the train crew and could cause overheating and catastrophic failure of a wheel.

Phase II: Prototype Development and Laboratory Testing

Task 1 Single unit development

A single prototype unit should be developed and laboratory-tested to ensure proper functioning during normal and abnormal circumstances and under a variety of temperatures. The response requirements, as set forth in 49 CFR 232, should be met. Moreover, the impact of the system response on train braking dynamics (stopping distance and intercar forces) should be evaluated.

Task 2 Ten-car system

If the single unit tests and the train dynamic evaluation are acceptable, work should proceed to fabricate 10 units for service testing. These units should be laboratory-tested on a simulator similar to the 150-car brake system test racks currently used by major air brake system suppliers.

Phase III: Limited Field Testing

Task 1 Preparation

Prior to the completion of the 10-car system, a unit train should be identified and a test plan prepared. A unit train is selected because it remains intact and is more readily monitored than a general service train.

If Phase II laboratory testing proves successful, the system should be re-configured as necessary for service operation. This could involve design modifications to ensure that the equipment will perform under the range of temperatures, electromagnetic interference, and vibration encountered on operating railroads as well as in the presence of rain, snow, and other contaminants.

Task 2 Installation

The 10-unit system should be installed on a dedicated consist of 10 freight cars, replacing the conventional ABDW valves on those cars. Key brake system components on each car should be instrumented for subsequent testing. The variables to be measured are:

- brake pipe pressure
- auxiliary reservoir pressure
- emergency reservoir pressure
- brake cylinder pressure.

Tests should then be conducted under stationary conditions in a yard to ensure that all cars are performing properly. As a minimum, these tests would consist of

- charging
- partial service reduction
- full service reduction
- emergency application.

After the yard tests have been performed successfully, the freight cars should be installed at the rear end of a unit train. The rear end (rather than the head end or some other location) is recommended for two reasons. First, if the systems fail, they are not likely to degrade stopping distance as much as if they are at the head end. If the cars were at the head end and failed, an emergency brake application would probably not propagate through them to trigger an emergency application on subsequent cars. (It would, however, trigger a full service application.) Second, the rear 10 cars are adjacent to the caboose, which could carry recording instruments. The performance of the brake systems should be monitored and recorded throughout the test.

Phase IV: Cost/Benefit Analysis

On the basis of the results of Phases I to III, a cost/benefit analysis would be performed to assess the probable financial benefit of the hybrid system on railroad productivity. This assessment would encompass unit train and general interchange services.

Phase V: Review and Decision

The results of Phase IV would be reviewed and a decision made to continue into Phase VI, abort the program, or restructure it.

Phase VI: Extended Field Test

Task 1 System fabrication and laboratory testing

A monitoring system for an entire train should be fabricated and laboratory-tested. This system would be sufficient for a unit train plus a group of cars that would normally replace those removed from the train for maintenance.

Task 2 Full train testing

A unit train would be equipped and tested for about a one-year period. If, after an initial test period, the system is proven to be reliable, the addition of an electrical train line should be considered, accompanied by conversion of the electronic modules and the development of a new brake controller to be installed in the locomotive. This system would permit the operation of the train with a rapidly responding braking system and the accumulation of concomitant experience.

Task 3 General service evaluation

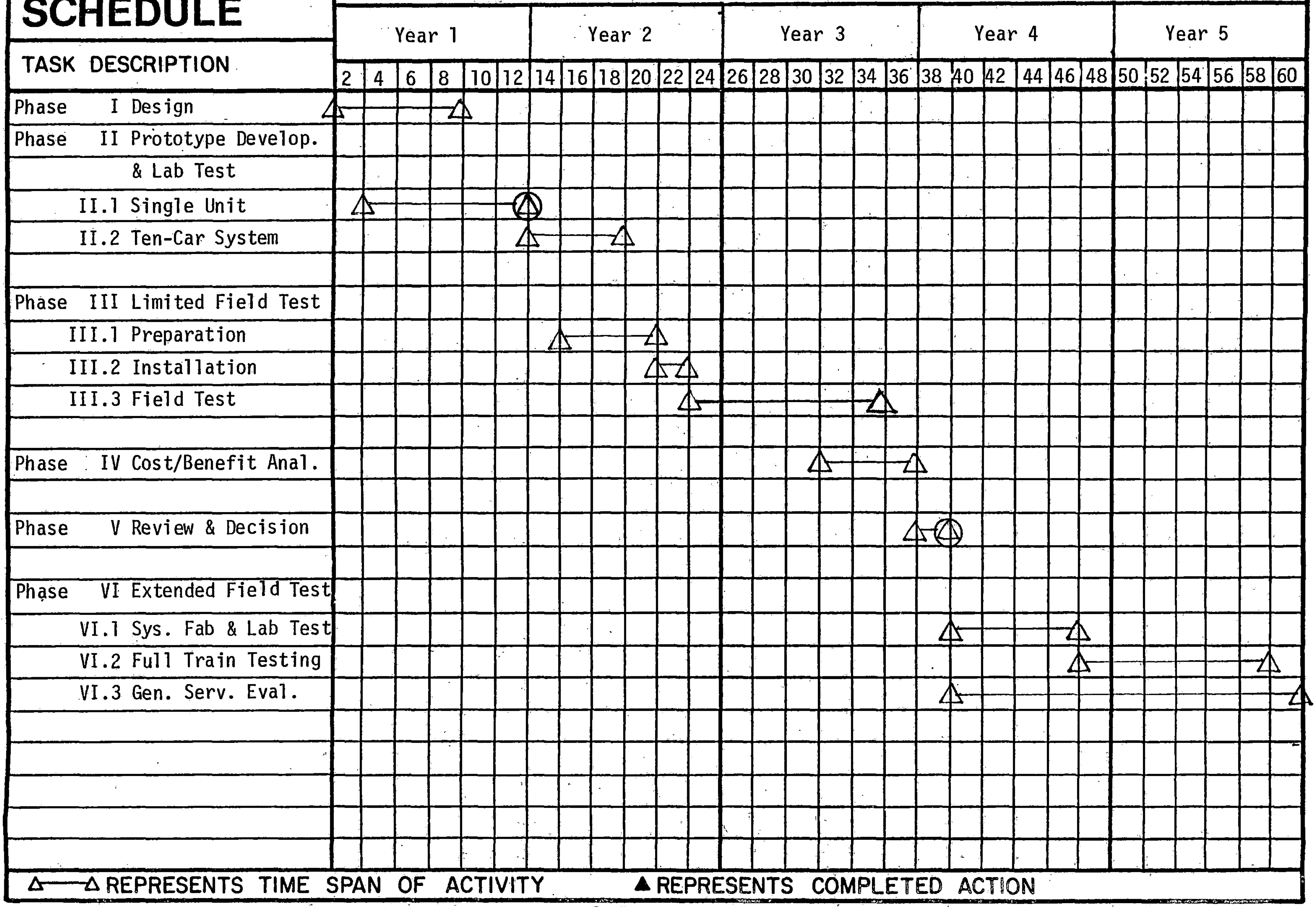
Once it has been decided to proceed with full train testing, a detailed study of implementing the hybrid brake system in general interchange should be undertaken. This study would be based in large part on the field experience generated in Phase VI. The results of the program should be reviewed and conclusions drawn as to whether to proceed with the general implementation of the hybrid system.

3.2.2 Schedule

Figure 3.5 presents a recommended schedule for the six-phase RD&D program described in Sec. 3.2.1. The program encompasses five years and extends from the present conceptual stage through a thorough demonstration of a complete system.

PROGRAM SCHEDULE

FIG. 3.5 HYBRID ELECTROPNEUMATIC BRAKE OPERATING VALVE



The Phase I design stage begins immediately and lasts for eight months. Two months later, Phase II starts with the development (and acquisition) of basic components. By the end of one year, a single system will be built and tested. This represents a control point at which the technological feasibility of the system is determined. If the system proves feasible, an instrumented 10-car system is developed and checked.

The Phase III limited field testing begins four months before the 10-car system is ready. This allows time for the preparation of a test plan, followed by the adaptation of the 10-car system for field service. Two months are allowed to implement and check out the system, followed by a one-year field test. The Phase IV cost/benefit analysis begins shortly before the field test is complete and extends two months beyond the end of the field test.

At the beginning of the fourth year, the critical Phase V review and decision takes place, based on an evaluation of the prior three-year effort, with special emphasis on the cost/benefit results. If it is decided to proceed with Phase VI, a full unit train system is built, checked, and implemented for a full year of testing. The program concludes with an evaluation of the suitability of the system for general interchange service.

3.2.3 Cost

A cost estimate for the brake condition monitoring system is shown in Table 3.2. The table illustrates that the most intensive parts of the effort are the limited and extended field tests (Phases III and VI).

Figure 3.6 shows the costs in Table 3.2 projected over the five-year course of the program. Two control points are shown at the beginning of the 16th month (after a basic system has been

TABLE 3.2 COST ESTIMATE FOR DEVELOPMENT OF A HYBRID ELECTROPNEUMATIC BRAKE CONTROL SYSTEM.

	Phase I Design	Phase II Prototype Development and Laboratory Test	Phase III Limited Field Test	Phase IV Cost/ Benefit Analysis	Phase V Review and Decision	Phase VI Extended Field Test	Total
Labor							
Program Manager	0.5 m-yr	0.5 m-yr	1.0 m-yr	0.5 m-yr	0.2 m-yr	1.3 m-yr	4.0 m-yr
Elec/Mech Engineer	1.0	1.0	1.0	0.5	0.2	2.5	6.2
Analyst	-	-	0.5	0.5	0.2	1.5	2.7
Technician/Draftsman	0.5	1.0	0.5	-	-	4.0	6.0
Total Labor	2.0 m-yr	2.5 m-yr	3.0 m-yr	1.5 m-yr	0.6 m-yr	9.3 m-yr	18.9 m-yr
Assumed Rate	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr
Total Labor Cost	$160k	$200k	$240k	$120k	$48k	$744k	$1512k
Other Direct Costs							
Travel & Subsistence	$ 10k	$ 15k	$ 25k	$ 10k	$10k	$ 50k	$ 120k
Hardware	-	30k	15k	-	-	250k	295k
Miscellaneous	10k	20k	15k	10k	2k	50k	107k
Total ODC's	$ 20k	$ 65k	$ 55k	$ 20k	$12k	$ 350k	$ 522k
TOTAL COST	$180k	$265k	$295k	$140k	$60k	$1094k	$2034k

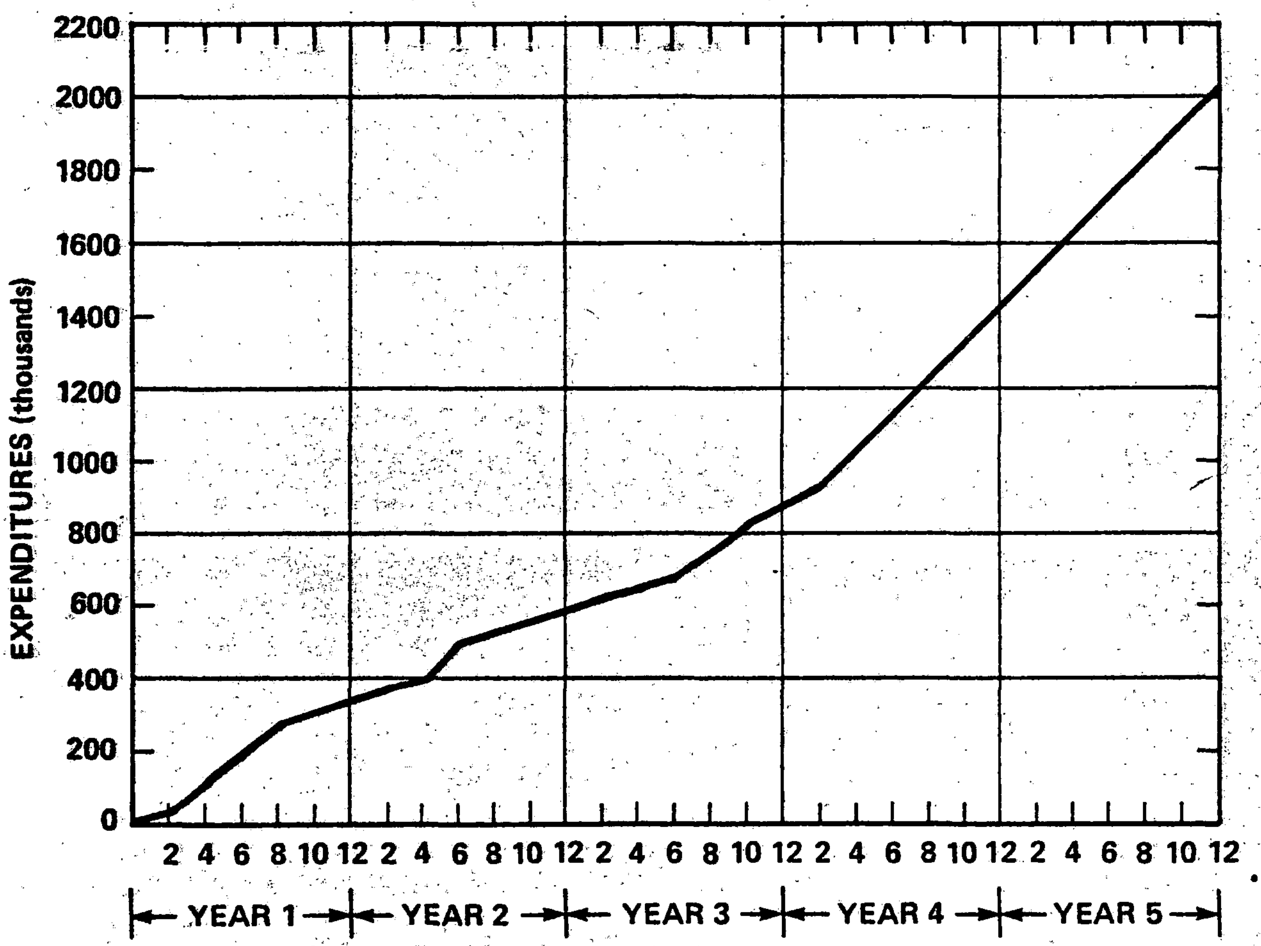


FIG. 3.6 PROJECTED COSTS FOR HYBRID ELECTROPNEUMATIC BRAKE CONTROL SYSTEM.

built and laboratory-tested) and 40th month (after a cost/benefit analysis). By these points, approximately $400k and $950k will have been spent. If the system appears unpromising at either point, the program can be aborted and future expenditures avoided.

3.3 Multi-purpose Coupler System

The railroad industry could benefit enormously from a multi-purpose coupler system which embodies automatic mechanical, air line, and electrical couplers. Through a wide gathering range mechanical coupler, bypasses could be reduced during coupling operations. This would obviate the need to "trim" cars on classification tracks, thereby saving time and money. An automatic air line connector would reduce waiting time while a carman walks the length of a train to couple air hoses manually. Moreover, an automatic air hose connector would substantially reduce the present hazard associated with stepping between cars to connect air lines. The value of an automatic electrical connector lies in the future. When cars are equipped with an electrical connector, train communication, monitoring, and control will be significantly enhanced.

The best way to design a reliable and economically feasible multi-purpose coupler is not clear. An automatic air line connector that can be added to a conventional coupler is shown in Fig. 3.7. The connector has its own gathering arms and several degrees of freedom of motion to ensure alignment with a similar connector on a mating coupler. However, as shown in Ref. 2, the unfavorable cost ratio of 2.4 precludes the implementation of this connector in its present form.

An alternative coupler, which incorporates the functions of the desired multi-purpose coupling system, is illustrated in Fig. 3.8. This type of coupler is presently used on rail transit cars and costs several thousand dollars per car set. These costs are

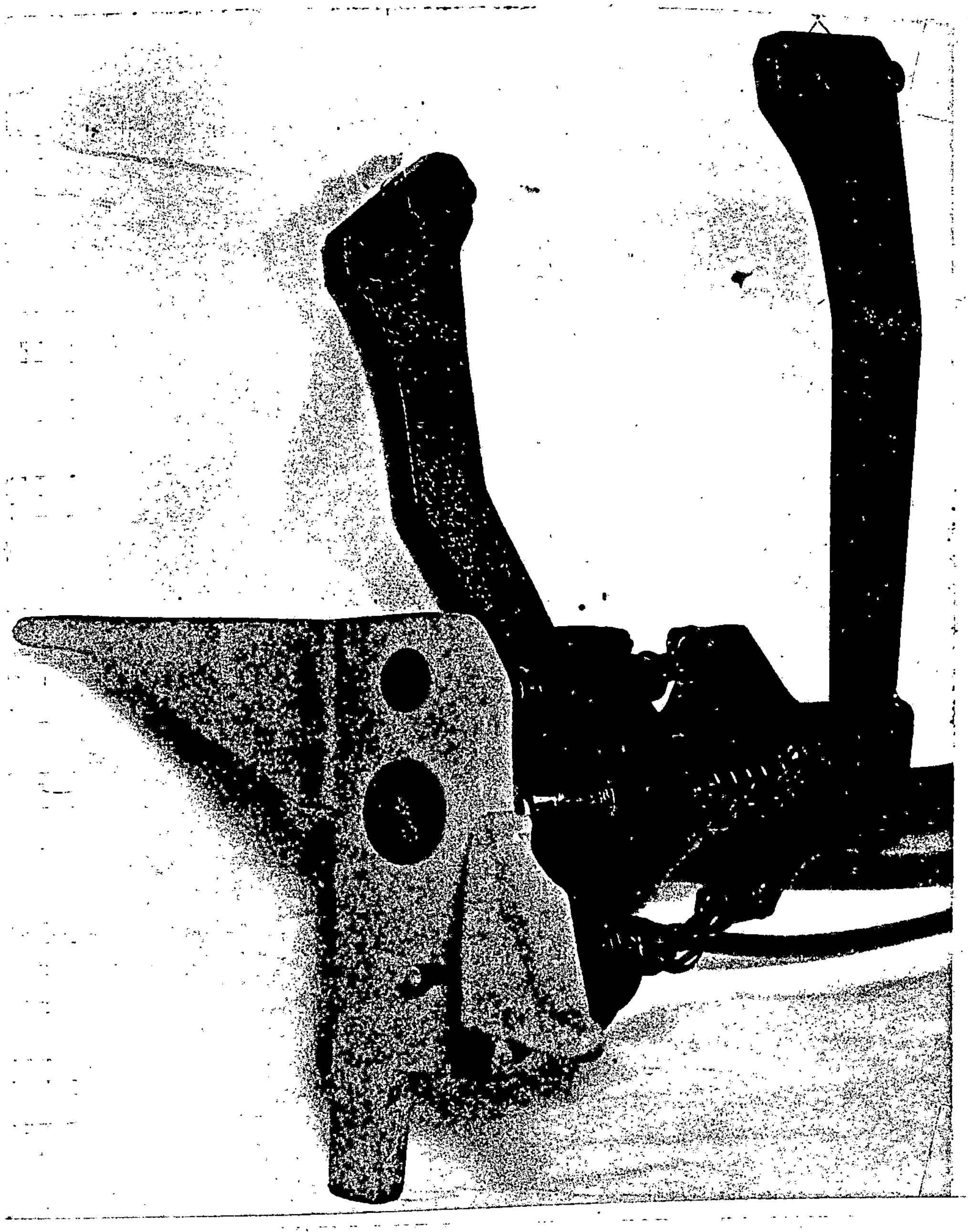


FIG. 3.7 AUTOMATIC AIR LINE CONNECTOR SUITABLE FOR RETROFIT TO EXISTING COUPLERS.

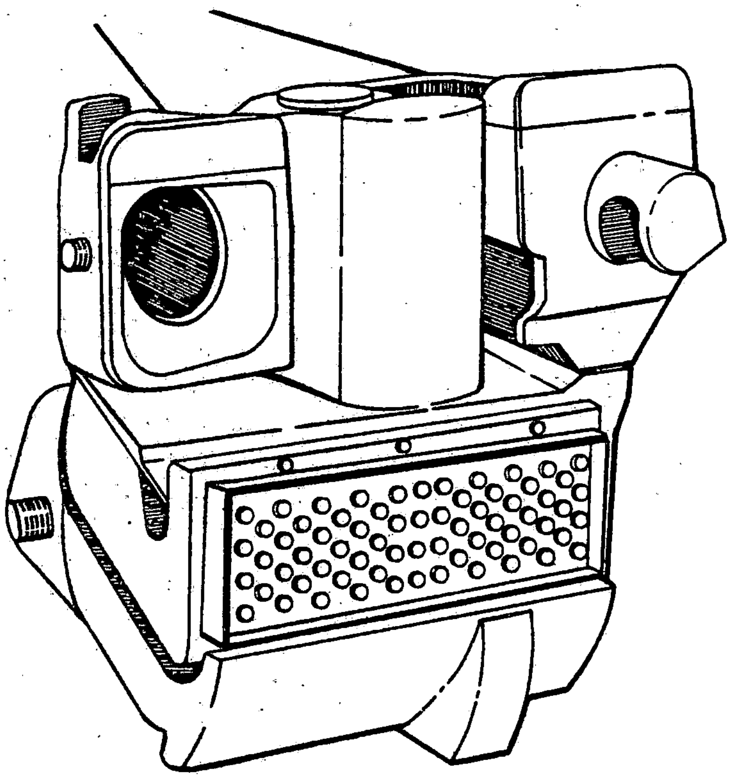


FIG. 3.8 KNUCKLE TYPE COUPLER INCLUDING AUTOMATIC AIR AND ELECTRICAL CONNECTORS (Adapted from design by the Ohio Brass Co. for transit cars.)

too high to be justified for a freight car application. Costs could be reduced by using fewer electrical connectors and through economies of scale associated with the freight car industry.

3.3.1 Engineering

Phase I: Design

During this phase, several alternate concepts should be designed and evaluated. The coupling systems must satisfy a number of objectives. They should be compatible with existing knuckle couplers and air line connectors. They should have a wide gathering range (perhaps ±8 inches horizontally and ±3 inches vertically) and be capable of coupling throughout a reasonable range of angular misalignments. It is also essential for the couplers to exhibit the strength, fatigue resistance, and energy absorption qualities of present couplers.

Phase II: Prototype Development and Laboratory Testing

Task 1 Coupler pair development

After the coupler system is designed, a pair of couplers should be fabricated and laboratory tested. The testing should involve coupling under various speeds of approach, and misalignments in the horizontal, vertical, and angular directions. Refinements should be made as necessary until mechanical, air line, and electrical coupling occurs consistently under these various conditions. Strength tests in buff and draft should also be performed to ensure that the coupler meets current requirements. Again, refinements should be made if necessary.

Task 2 Ten car set fabrication

Ten car sets of coupler systems should be built and laboratory-tested in preparation for subsequent field testing. This testing would be more limited than the developmental testing performed in

Task 1, the primary objective being the assurance of proper functioning in service.

Phase III: Limited Field Testing

The 10 car sets of multi-purpose couplers should be field tested with cars that are frequently coupled and uncoupled but that are assigned to a limited district or portion of a railroad. In contrast to the braking systems described in Secs. 3.1 and 3.2, testing on a unit train is inappropriate because its cars are uncoupled only infrequently. Testing on cars assigned to interchange service is also inappropriate because of the difficulty in maintaining control over such cars.

Task 1 Identification of an experimental district

The first step in Phase III is the identification of a district on which couplers can be tested. The cars on which the couplers are installed should be confined to a controllable section of a railroad.

Task 2 Develop an implementation and test plan

A plan to implement and test the couplers should be developed. It must address the initial issue of monitoring the couplers in service to determine their performance reliability. This could be accomplished either through on-board instrumentation, physical inspection by properly trained field crew, or a combination thereof.

Task 3 Limited implementation

Coupler systems (and any concomitant instrumentation) should be installed on a set of 10 cars that will be used in the limited field test. The couplers should be checked to ensure proper functioning before the cars are released for service.

Task 4 Field test

The 10-car set should be field tested for a period of approximately one year. During this interval cars should be monitored and inspected periodically to evaluate their performance over the course of time, and under a variety of weather conditions. Any design deficiencies identified during this test ought to be corrected. During this phase, field studies should be performed to estimate the time savings, other benefits, and costs associated with the system.

Phase IV: Cost/Benefit Analysis

On the basis, primarily, of the results of Phase III, an analysis of the costs and benefits of the system ought to be made. The analysis would be limited to the application that had been evaluated in Phase III, for which reliable data should now be available.

Phase V: Review and Decision

The results of the previous tasks should be reviewed and a decision made to continue the program into Phase VI, or stop or restructure it.

Phase VI: Extended Field Test

Task 1 System fabrication and bench testing

Enough couplers for an extended field test should be fabricated and bench tested. The appropriate number (perhaps 100 to 200 car sets) would be selected to ensure that, again in a limited district, entire trains using only these couplers could be assembled and operated. Each coupler would be inspected and bench tested to ensure that it conforms to specification and functions properly.

Task 2 Extended testing

Cars should be equipped with the advanced system and tested over an extended period of time (about one year), again in a limited district. During this period data should be gathered to determine the real costs and benefits of the system.

Task 3 General service evaluation

In parallel with Tasks 1 and 2 of this phase, a detailed study of implementing this coupler fleet-wide should be undertaken. This study would use the data acquired in the other tasks and phases and also would involve detailed analysis of yard and road operation. The results of the entire program would be reviewed and recommendations made about the general adaptation of a multi-purpose coupling system.

3.3.2 Schedule

Figure 3.9 presents a recommended schedule for the six-phase RD&D program described above. The program encompasses five years and extends from the present conceptual stage through an extensive demonstration of a complete multi-purpose coupler system.

The Phase I design stage begins immediately and lasts for one year. Four months later, Phase II starts with the development (and acquisition) of basic components. By the end of fourteen months, a coupler pair will be built and tested. This represents a control point at which the technological feasibility of the system is determined. If the system proves feasible, 10 car sets are developed and checked.

The Phase III limited field testing begins four months before the 10 car sets are ready. This allows time for the preparation of a test plan, followed by the adaptation of the 10 car sets for field service. One month is allowed to implement and check out the couplers, followed by a one-year field test. The Phase IV cost/benefit analysis begins shortly before the field test is complete and extends two months beyond.

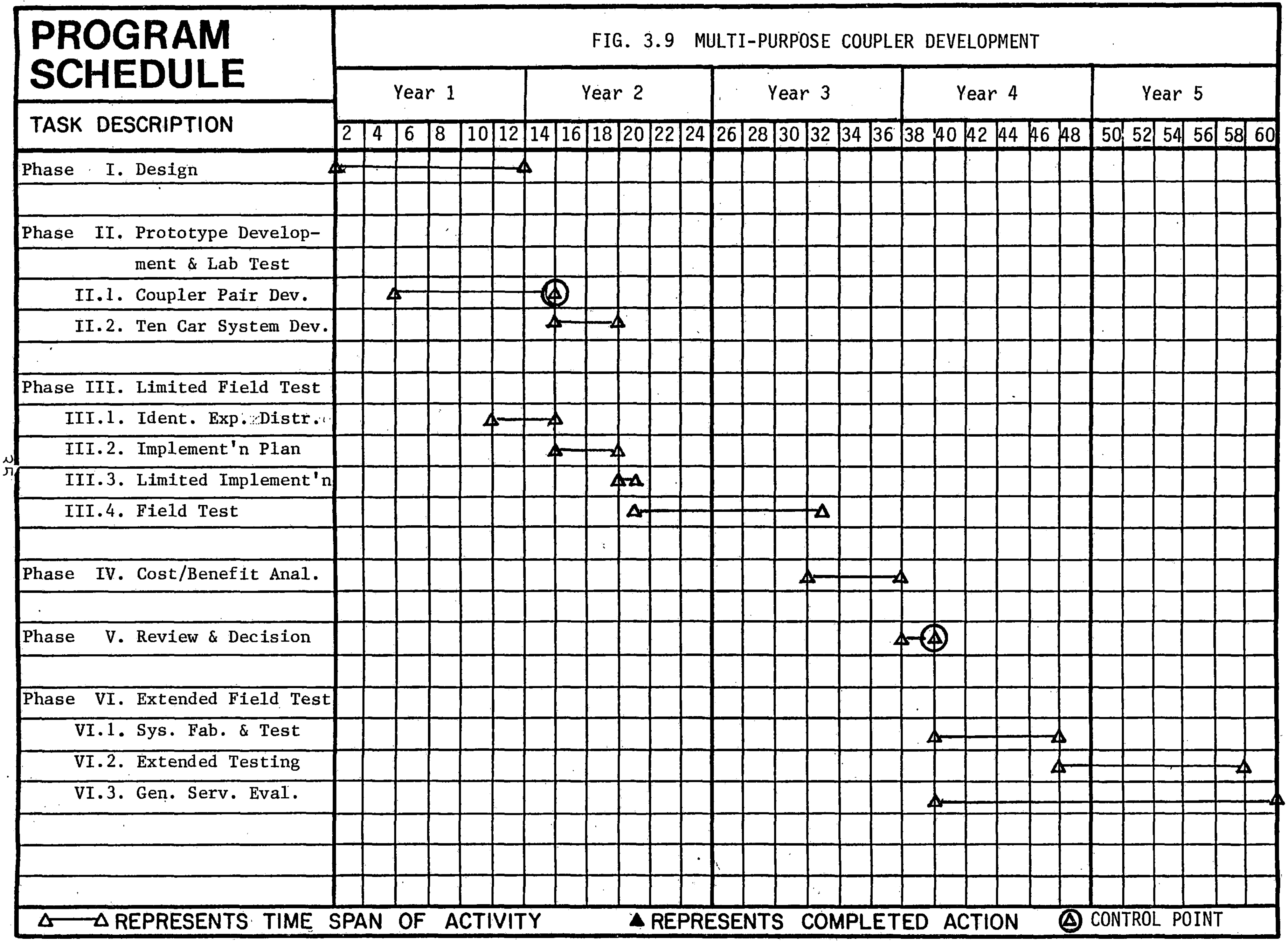


FIG. 3.9 MULTI-PURPOSE COUPLER DEVELOPMENT

At the beginning of the fourth year, the critical Phase V review and decision takes place, based on an evaluation of the prior three-year effort, with special emphasis on the cost/benefit results. If it is decided to proceed with Phase VI, a large number of couplers are built, checked, and implemented for a full year of testing. The program concludes with an evaluation of the suitability of the system for general interchange service.

3.3.3 Cost

A cost estimate for the multi-purpose coupler system is shown in Table 3.3. The table illustrates that the most intensive parts of the effort are the prototype development and extended field tests (Phases II and VI). It is anticipated that the hardware costs for couplers will be significantly higher than for the electro-mechanical systems treated elsewhere.

Figure 3.10 shows the costs in Table 3.3 projected over the five-year course of the program. Two control points are shown at the beginning of the 16th month (after a basic system has been built and laboratory-tested) and 40th month (after a cost/benefit analysis). By these points, approximately $750k and $1450 k will have been spent. If the system appears unpromising at either point, the program can be aborted and future expenditures avoided.

3.4 Integrated-system Development

The three systems discussed above are obviously related and would work better together than individually. It also appears that there would be synergism in a development program in two respects. First, systems could be tested together, thereby saving labor. Second, all three systems could be available after a five-year development period, thereby hastening the implementation of these systems in the railroad fleet.

TABLE 3.3 COST ESTIMATE FOR DEVELOPMENT OF A MULTI-PURPOSE COUPLER.

	Phase I Design	Phase II Prototype Development and Laboratory Test	Phase III Limited Field Test	Phase IV Cost/ Benefit Analysis	Phase V Review and Decision	Phase VI Extended Field Test	Total
Labor							
Program Manager	0.5 m-yr	0.5 m-yr	1.5 m-yr	0.5 m-yr	0.2 m-yr	1.8 m-yr	5.0 m-yr
Elec/Mech Engineer	2.0	2.0	1.0	0.5	0.2	3.0	8.7
Analyst	-	-	0.5	0.5	0.2	2.0	3.2
Technician/Draftsman	1.0	2.0	1.0	-	-	4.0	8.0
Total Labor	3.5 m-yr	4.5 m-yr	4.0 m-yr	1.5 m-yr	0.6 m-yr	10.8 m-yr	24.9 m-yr
Assumed Rate	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr
Total Labor Cost	$280k	$360k	$320k	$120k	$48k	$864k	$1992k
Other Direct Costs							
Travel & Subsistence	$ 10k	$ 20k	$ 25k	$ 20k	$48k	$ 50k	$ 125k
Hardware	-	100k	50k	-	-	1000k	1150k
Miscellaneous	10k	30k	25k	10k	2k	100k	177k
Total ODC's	$ 20k	$150k	$100k	$ 20k	$12k	$1150k	$1452k
TOTAL COST	$300k	$510k	$420k	$140k	$60k	$2014k	$3444k

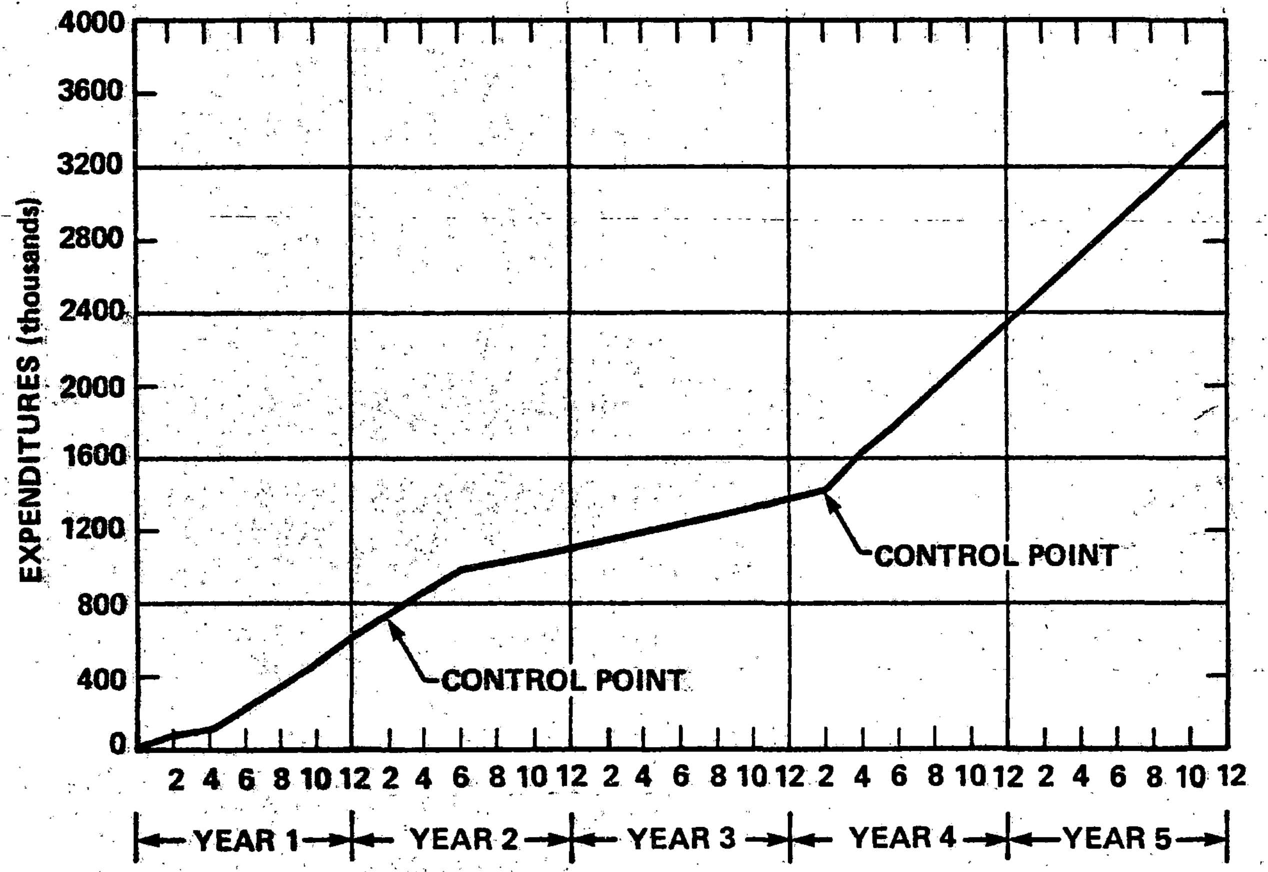


FIG. 3.10 PROJECTED COSTS FOR DEVELOPMENT OF A MULTI-PURPOSE COUPLER SYSTEM.

3.4.1 Engineering

The engineering effort needed to develop these systems would be similar to that discussed above and will not be repeated here. However, we shall consider the structure of a program that integrates the development of a brake monitoring system, an electronic operating valve, and a multi-purpose coupler.

Figure 3.11 is an elementary PERT chart that illustrates the structure of a program to develop an integrated system. During the first 1½ years, design and development would proceed along parallel paths as described for Phases I and II for each of the three systems. At the end of this interval, the electronic monitoring system and the electronic operating valves would be installed on the 10 cars selected for unit train testing. The cars would then be tested for approximately one year. Simultaneously, multi-purpose couplers would be tested on cars that are frequently coupled and uncoupled, and are confined to a limited district of a railroad.

A cost/benefit analysis would be performed on all of the systems and a decision made about entering into the extended field test or restructuring the program. If it is decided to conduct an extended field test, sufficient cars would be equipped with the integrated system to test complete trains during running and classification operations.

3.4.2 Costs

A cost estimate for this program is presented in Table 3.4. The total value of $7,164k is more than one million dollars less than the $8,432k found by adding the cost for the three individual programs. These savings accrue primarily from efficiencies associated with the use of a single program manager and Phase III and VI field testing.

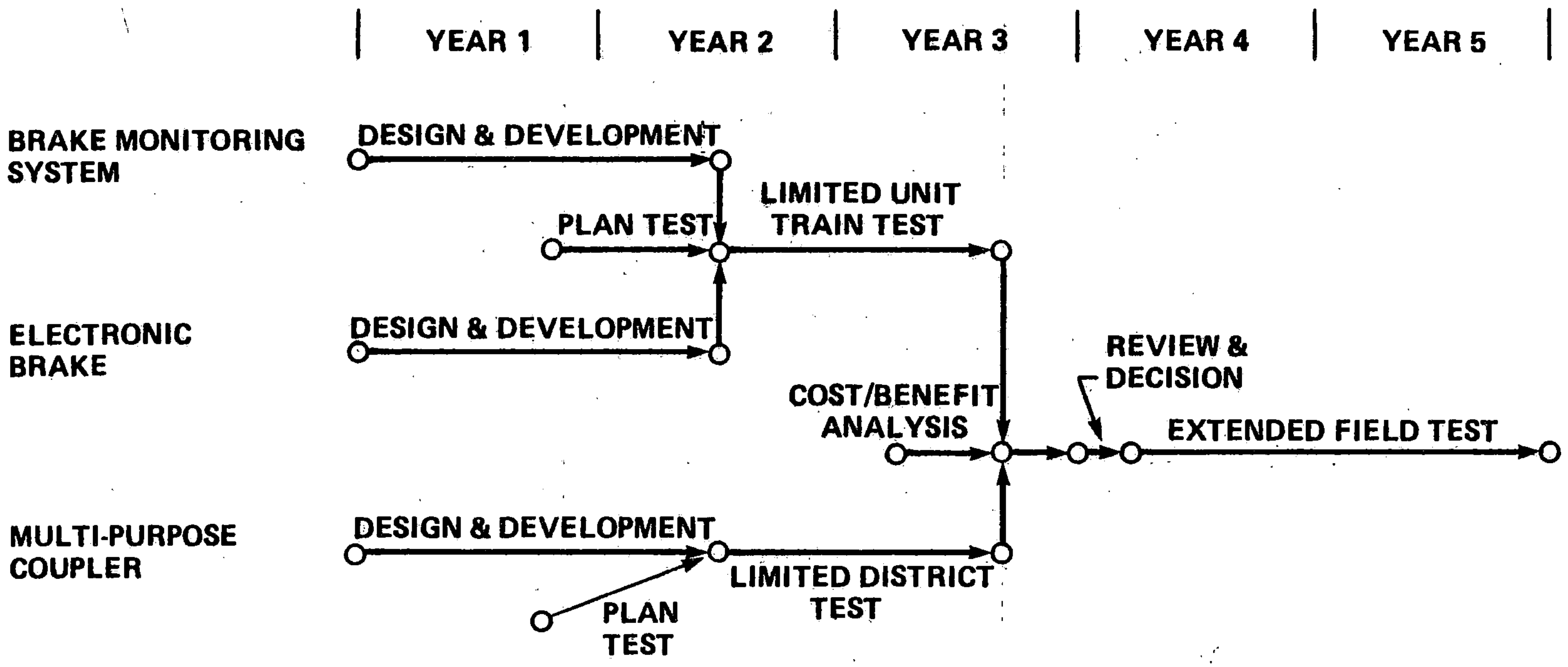


FIG. 3.11 PERT CHART FOR INTEGRATED-SYSTEM DEVELOPMENT

TABLE 3.4 COST ESTIMATE FOR INTEGRATED-SYSTEM DEVELOPMENT

	Phase I Design	Phase II Prototype Development and Laboratory Test	Phase III Limited Field Test	Phase IV Cost/ Benefit Analysis	Phase V Review and Decision	Phase VI Extended Field Test	Total
Labor							
Program Manager	0.5 m-yr	0.5 m-yr	1.5 m-yr	0.5 m-yr	0.2 m-yr	1.8 m-yr	5.0 m-yr
Elec/Mech Engineer	5.0	6.0	2.5	1.0	0.5	7.0	22.0
Analyst	-	-	1.5	1.0	0.5	5.0	8.0
Technician/Draftsman	2.5	6.0	2.5	0.5	-	12.0	23.5
Total Labor	8.0 m-yr	12.5 m-yr	8.0 m-yr	3.0 m-yr	1.2 m-yr	25.8 m-yr	58.5 m-yr
Assumed Rate	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr	×$80k/m-yr
Total Labor Cost	$640k	$1000k	$640k	$240k	$ 96k	$2004k	$4680k
Other Direct Costs							
Travel & Subsistence	$ 30k	$ 50k	$ 70k	$ 25k	$ 20k	$ 100k	$ 295k
Hardware	-	180k	100k	-	-	1500k	1780k
Miscellaneous	30k	100k	50k	25k	4k	200k	409k
Total ODC's	$ 60k	$ 330k	$220k	$ 50k	$ 24k	$1800k	$2484k
TOTAL COST	$700k	$1330k	$860k	$290k	$120k	$3864k	$7164k

A graph of expenditures versus time shown in Fig. 3.12 illustrates the two control points at which the program can be readily redirected as necessary.

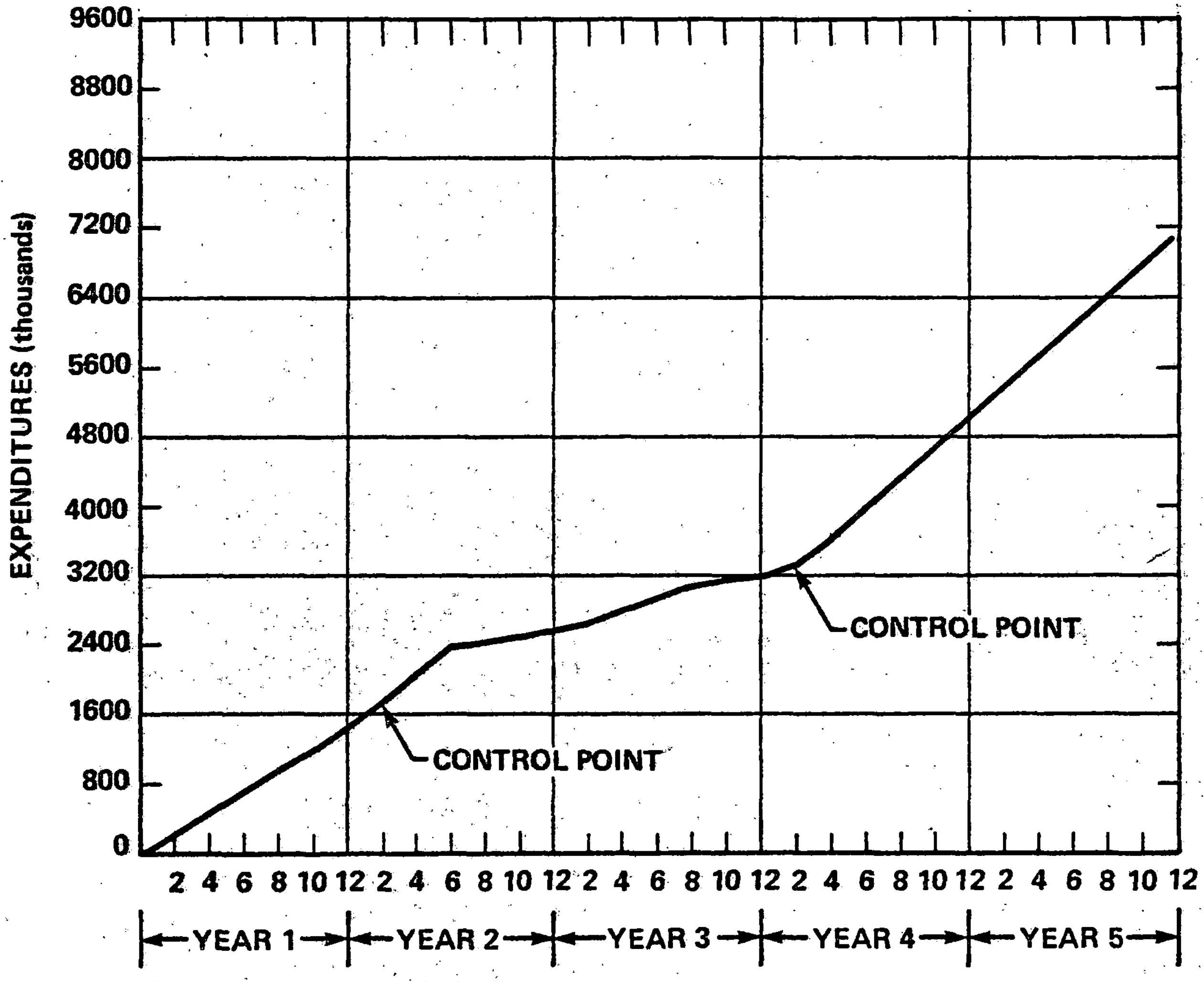


FIG. 3.12 PROJECTED COSTS FOR INTEGRATED SYSTEM DEVELOPMENT.

4. GOVERNMENT AND INDUSTRY PARTICIPATION

4.1 Background

Throughout all parts of the industrial sector, creative people constantly produce new technological concepts to improve productivity and safety. Even in the most fertile industries, only a fraction of these concepts are transformed into products that achieve marketplace acceptance. The remaining ideas fall by the wayside for a variety of reasons. Initial development or product manufacturing costs may be excessive, various unforeseen technological problems become overwhelming, or marketplace demand may have initially been overestimated. Nevertheless, when sufficient resources are available, institutional constraints are minimal, and the profit potential is sufficiently high, enough good ideas will survive development to enrich both supply and user members of the industry.

The conditions in the freight railroad industry have not been conducive to the development of advanced braking and coupling systems which differ radically from their progenitors. The best evidence of this is displayed in the history of existing systems. The present ABDW control valve is an evolved form of the Triple valve invented by George Westinghouse more than 100 years ago. Similarly, present E and F knuckle couplers are descended from the Janney-type coupler installed on American railroads just after the Civil War.

This evolution through a sequence of perturbations and expansions of older designs has taken place in spite of numerous relevant inventions within the railroad industry and advances in the closely allied rail rapid transit and passenger train technologies. As shown in Ref. 5, hundreds of patents exist for such advanced systems as automatic air line connectors and fluid-actuated uncoupling mechanisms for railroad cars. Electrically controlled valves and couplers incorporating electrical and air line connectors exist in rail transit systems.

It is important to consider some of the factors that have inhibited the development of advanced railroad braking and coupling systems prior to recommending an organizational structure for carrying out their development. Otherwise, the development of these systems may not be undertaken, or, worse, systems will be developed but never integrated into the railroad industry.

Some of the most apparent reasons that passenger train technologies have never been adapted for the railroad industry relate to fundamental differences in needs between freight and passenger equipment. Many passenger train requirements have virtually dictated the use of electrical braking from an early stage. Passenger trains travel at high speeds and need to stop quickly and smoothly. Passenger trains generally remain intact in contrast to the frequent reclassification that occurs in freight transport. When passenger cars are coupled, it is generally done slowly, with visual supervision of the coupling process. Moreover, passenger cars are substantially more expensive than freight cars. The economics of passenger train operation is correspondingly less sensitive to the absolute costs of braking and coupling systems. Most importantly, lives of approximately 1,000 passengers in each train depend on the performance of brake systems which obviously cannot be compromised. For these and other reasons, one cannot expect simply to transfer passenger technology to freight systems.

Compatibility of new technologies with existing equipment has been another major and apparent constraint on innovation that is virtually unique to railroads. The interchange of cars among all railroads has traditionally required that each new car operate in consort with each of the 1.7 million cars that comprise the American railroad fleet. It would be difficult to imagine, for example, how the electronic data processing industry could have grown in recent decades if digital computers had to be compatible with analog computers or if pocket calculators had to work with adding machines.

There are other, more subtle innovation-limiting factors that relate to the general health and structure of railroads and their suppliers. It is widely agreed that railroads are generally in a financially unhealthy condition, with few resources available for high risk ventures, even if the long term return is attractive. The industry's 1979 net operating income of $794 million represents only a 2.58% rate of return on its $28.8 billion net investment in plant and equipment [6]. In October of 1978, a report submitted by the Secretary of Transportation to the Congress pointed out other major problems [7]. By that time, deferred maintenance expenditures had amounted to $5.4 billion. It was estimated that during the 1976 to 1985 decade, the railroad industry (exclusive of Conrail and the Long Island Railroad) would be unable to raise $13 to $16 billion for needed investments. Several railroads are in a state of bankruptcy, and the Eastern division as a whole has shown an operating deficit for the past five years. Railroads in this condition will naturally focus their resources on capital improvements and short run problems of survival before addressing the future gains afforded by advanced braking and coupling systems.

Railroad equipment suppliers face a number of barriers to the introduction of innovative technologies. In addition to the above-mentioned constraints, suppliers find it difficult to introduce freight car products quickly and realize a return on investment in a reasonably short time frame for two reasons. First, a generally necessary, but time consuming, testing and review period is required by the Association of American Railroads for new products that will be used in interchange service. Then, if products are to be incorporated on new cars only, their introduction will be rather slow. Since freight cars last about thirty years, only about 3% of the car population changes in a year. Accordingly, a long development period coupled with market size limitations tends to inhibit R&D investment in the supply industry.

4.2 Organizations and Roles

In our judgement, the successful development and implementation of advanced braking and coupling systems depends on the following organizations working in close collaboration:

- Federal Railroad Administration
- Association of American Railroads
- Systems contractor
- Railroad
- Railroad supplier.

The FRA would play a key role by providing funding, overall technical direction, and waivers for existing regulations. The several million dollars of support needed to develop any of the systems identified in Sec. 3 will overcome present financial limitations for R&D in the industry. This funding is really an investment for which the government can expect an indirect future payback from a vital industry through improved productivity and reduced need for continued financial assistance. Because the FRA has relevant technical expertise and an overview of the entire railroad industry, it is in an ideal position to provide technical guidance for the development of systems. Moreover, this type of direction is a necessary concomitant of funding. Finally, the FRA must, on a limited basis, release railroads from complying with existing regulations to facilitate experimentation with certain systems (e.g., brake condition monitors). It should also provide assurances to the industry that it would be willing to change regulations permanently, contingent on the successful demonstration of certain technologies. In this way the FRA will make a major contribution to overcoming existing financial limitations, uncertainties in technological performance and marketplace demand, and regulatory constraints.

This research should be coordinated with the Association of American Railroads for several reasons. As an industry association, the AAR represents diverse technical perspectives that can be brought to bear on the research. Conversely, members of the AAR that review the research can communicate their findings to their respective railroads. In the long run, one would expect this communication to enable the railroads to adapt research results more quickly. The AAR also has a research organization that could conduct R&D in this area as well. Coordination should help to avoid wasteful duplication of effort.

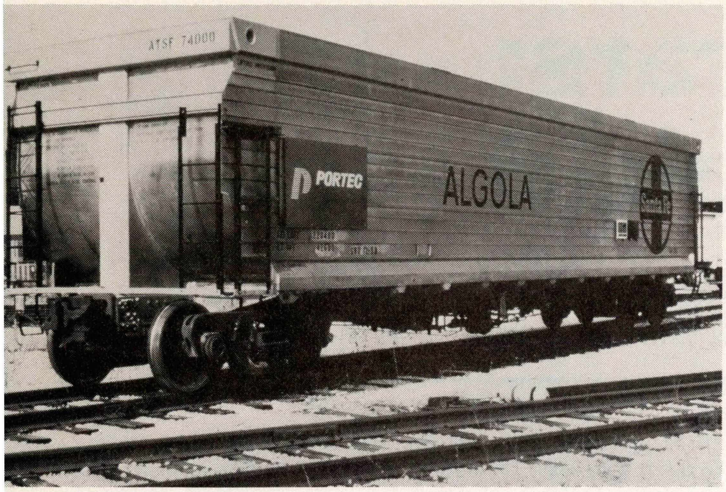
A systems contractor, working under the direction of the FRA Office of Research and Development, would assume responsibility for a carefully constructed R&D program, and would perform the bulk of the work. It would provide its own expertise in mechanical and electrical engineering, and cost and systems analyses, while drawing on expertise within railroad and supplier sides of the industry. A systems contractor, rather than one of the other organizations, provides some unique advantages, but has some limitations. The other organizations have capabilities that are matched to existing technologies, but may not have the breadth in electronics, computer control, or economics needed to perform some of the candidate projects. Also, this type of R&D is usually the primary business of a systems contractor and will receive its undivided attention. In contrast, the primary business of a railroad is moving freight for its customers, and the primary business of a supplier is providing the hardware needed to satisfy the (generally immediate) needs of its railroad customers. Accordingly, these organizations will often find themselves torn between assigning their key staff to solve primary business problems versus meeting commitments for a long-range R&D program. They often welcome a program in which they can participate without significantly diverting their key staff.

The limitations of a systems contractor are that it does not operate trains or design railroad equipment. These are compensated for by complimentary capabilities among railroads and equipment suppliers, both of which must participate to give any program even a chance of success. The railroad would operate equipment on its trains during limited and extended field testing (Phase III and VI) while the equipment supplier might conduct tests (in Phase II) requiring laboratory equipment unique to his product line. This participation of both supplier and members of the industry sets the stage for production and implementation of systems that have been proven successful.

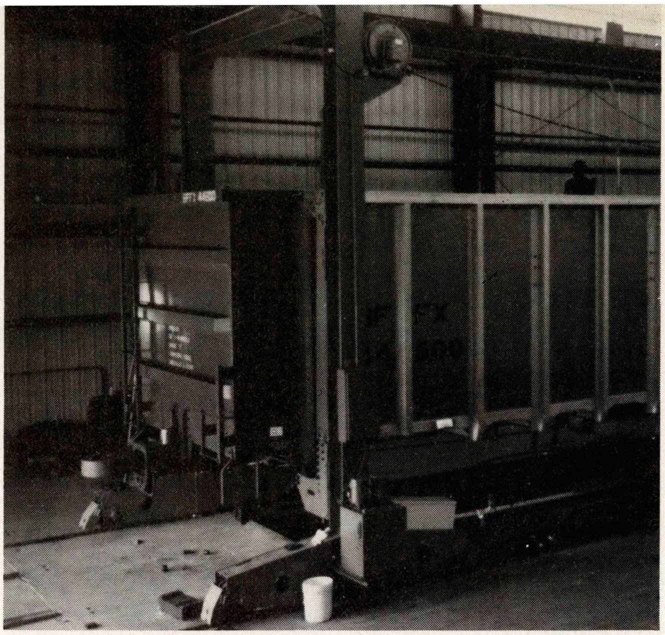
A summary of the principal contributions that would be made by each organization for each phase of a program is illustrated in Table 4.1. The FRA Office of Research and Development provides an overview throughout the program and makes decisions on how best to proceed (if at all) during Phases II and V. The role of the FRA Office of Safety is to grant a waiver for testing prior to field testing experimental hardware in Phase III and VI. Throughout the program, the AAR will review activities and provide advice as appropriate. The systems contractor will perform Phases I and IV in their entirety. It will develop and test prototype hardware (Phase II), relying on the equipment supplier for tests that require specialized facilities. During the field tests (Phases III and VI), the systems contractor will work closely with

TABLE 4.1 PRINCIPAL CONTRIBUTION OF EACH ORGANIZATION BY PHASE

	Organization					
Phase	FRA Office of R&D	FRA Office of Safety	AAR	Systems Contractor	Railroad	Equipment Supplier
I. Design	Overview	-	Review and Advise	Complete Task	Review and Advise	Review and Advise
II. Prototype Development & Lab Testing	Decision	-	Review and Advise	Development and some testing	Review and Advise	Laboratory Testing
III. Limited Field Testing	Overview	Grant Waiver if Needed	Review and Advise	Data Acquisition and Analysis	Conduct Tests	Review and Advise
IV. Cost/Benefit Analysis	Overview	-	Review and Advise	Complete Task	Provide Data	Provide Data
V. Review and Decision	Decision	-	Review and Advise	Data and Advice	Review and Advise	Review and Advise
VI. Extended Field Test	Overview	Grant Waiver if Needed	Review and Advise	Data Acquisition and Analysis	Conduct Tests	Review and Advise



Portec's modified Algola car, now going into production for Santee Cooper, has end sheets that are rounded rather than vertical.



Berwick's prototype aluminum-body gondola car is shown being connected to railcar load simulator at Houston Area Research Center.

as modification of the interior bracing will produce still greater efficiencies.

• **The aluminum contenders.** But, while the aerodynamics are getting more study, this is what's happening with the new designs already in service or under test or about to be:

—Engineers at Portec's Railcar Division have done a bit of redesigning on the Algola prototype, and the car today looks like the production models that will be coming out for delivery to the South Carolina utility, Santee Cooper. Several modifications have been made, the most obvious of which is that the car now has a rounded end, with end sheets that are rounded instead of vertical.

Portec made the modifications while the car was in its shop for repair of damage caused by a derailment (which wasn't the Algola's fault). That gave Portec employees their first shot at working with aluminum, an experience that was not traumatic at all. And the derailment may have proved something else about aluminum cars: Portec engineers are convinced that the Algola came out of the derailment in relatively better condition than a steel car would have under comparable circumstances. In the derailment, the trucks stopped moving before the carbody did, so the underside was torn up, and the Algola eventually wound up being dragged on its side. Portec straightened the side panels, replaced some of the side sill extrusions, several crossbearers and floor sheets, and the car was ready to go back into service.

What the accident illustrated was that aluminum, when it reaches its yield point, will tear. Steel, the engineers note, will take on a permanent set when it reaches that point, and twisting results. Once the repairs to the Algola were made, it was remounted on trucks and there was no twist damage to repair in order to get the car to ride properly.

—Greenville Steel Car, with prototypes in the works for many months, will be turning out a composite car, tub-type, with aluminum centersill and steel bolsters and draft sills, and with aluminum superstructure. Light weight is estimated at between 41,000 and 41,500 pounds, although the stencil could come in at under 41,000. Greenville has worked with Reynolds on this particular prototype, which will go to Miner Enterprises' test facility for its AAR tests and then probably go to one of the most taxing unit-train operations for road testing.

In the meantime, Greenville is working with Alcoa on its second prototype, the automatic-dump hopper car. This one will be somewhat heavier, in the range of 47,000 to 48,000 pounds, because it will be built with steel centersill, bolsters and dumping mechanism.

—Pullman Standard Manufacturing's car, about which PSM hasn't said much yet, is a tub-type car with steel stub sills, with aluminum used elsewhere in the structures and with design changes aimed at improving aerodynamic characteristics. It came in at 41,500 pounds tare weight and could go lower if equipped with different trucks. It has passed its AAR-approval tests, and it has passed a dumping test.

—Berwick's car, meanwhile, has gone through some of the most extensive testing of any new design, not just the standard AAR tests but also a fatigue test on the load simulator at the Houston Area Research Center at Conroe, Tex. There, the simulation involved what's described as one of the toughest unit-train operations in the country. Through computer-controlled hydraulic load cells, varying force levels in a wide range of sequences were applied to produce the buff and draft effects of more than 300,000 pounds that a car would experience over this route. The result: The car was judged able to survive without failure for the equivalent of more than 18 years at a mileage-equivalent of 120,000 miles per year. This isn't the lightest-weight car in the competition, coming in at 44,800 pounds in prototype and built with steel bolsters and draft sills as well as steel for handholds and other safety-appliance items for replacement ease. But Berwick engineers believe they have a car that's practical, in operating and maintenance terms, in the real world.

—Ortner and its component suppliers have been having their problems getting the Santee Cooper cars to operate derailment-free, and the road over which the cars operate, Seaboard System, is also obviously concerned. But the evidence thus far seems to indicate that the problems have nothing to do with the use of aluminum as a major carbuilding material, except for the fact that aluminum is lighter in weight, and, therefore, if there are going to be problems with truck stiffness or with suspension or braking systems, they're going to be accentuated with a lighter-weight car.

Meanwhile, Ortner, which has had a prototype aluminum Rapid Discharge car in service since the mid-1970s, is working on what it's calling an optimized design for such a car, using more aluminum (the original car was, essentially, a steel-car design with aluminum substituted) but still using steel for sills and bolsters and discharge-mechanism castings.

• **A slow market.** Where does the lightweight race go from here? Only as far as the market will carry it. And the market, at this point, looks to be slow in developing. Demand for coal and, therefore, for coal transportation, is not growing as early and rosy forecasts said it would, mainly because demand for electric power is not growing as early and rosy forecasts said it would; nor are industrial-plant conversions to coal taking place as early and rosy forecasts said they would. And besides, there is a surplus of coal cars, hoppers and gondolas, railroad-owned and utility-owned. Those surpluses won't be worked off until demand picks up. In the meantime, cars are sitting out there—cars with useful life still left in them, cars still on lease, cars still not paid for.

Still, the lure of aluminum is unmistakable.

Aluminum cars cost more in the beginning, 25% or so more. But when the time comes for sending a car to scrap, the residual value of an aluminum car will be quite a bit higher. And,

Coal cars: The lightweight race

The contenders are off and running—the mostly-aluminum car; the aluminum and steel car; the lighter-weight all-steel car. But any winner must compete with an oversupply of older, heavier cars.

Carbuilders have not yet come up with as many new designs for coal cars as they have for intermodal cars—but the field is getting more and more crowded, and aluminum is looking more and more like the material of the future.

Here's the current lineup:

—Portec was set to start production late last month on its order for 100 almost-all-aluminum Algola gondolas for Santee Cooper, with deliveries scheduled to be completed by mid-year.

—Greenville Steel Car expected to complete construction of an aluminum-steel composite tub-car prototype this month, and it was planning to have a second prototype, this one an automatic-dump car, ready for test by about the end of August.

—Pullman Standard Manufacturing division of Trinity Industries has its mostly-aluminum prototype undergoing tests, and thus far it has passed the tests required for AAR approval; like a number of the other new designs, this one will be exhibited at the Railway Supply Association's RAILEXPO '84 in Chicago in September.

—Berwick's entry in the lightweight competition has been through an extensive test program, including one test that simulated years of operation in a tough environment, and it should be going into road testing right about now.

—Ortner has completed delivery of 200 aluminum-steel composite cars for Santee Cooper, and, while certain problems have developed with these cars, Ortner is confident that it and its component suppliers can solve them. Later this year, Ortner will be delivering the first 91 cars of a 273-car order to Intermountain Power (with the remaining trainsets scheduled for 1986 delivery). And Ortner will be building yet another prototype, a Rapid Discharge car with aerodynamic improvements added to use of weight-reducing aluminum for still further gains in operating efficiency.

Santee Cooper's aluminum-and-steel cars have encountered problems, but they're not related to use of the lightweight metal. Intermountain Power has ordered a fleet of similar cars.

- **Don't count steel out.** Portec, Greenville Steel Car, Pullman Standard Manufacturing, Berwick, Ortner—all are making extensive use of aluminum. So where does that leave steel? Still with a place, as Chessie System has set out to prove with two all-steel rotary-dump cars that don't get the tare weight down to that of an aluminum car but that do weigh in at quite a bit less than a conventional steel car.

Also with a "place," it appears, will be aerodynamic styling for coal cars. Ortner's new prototype will have it, and the car designed by Pullman Standard Manufacturing already does. And, while large-scale-model wind-tunnel tests have not been run, as they have been with several configurations of intermodal cars, trailers and containers, the builders are convinced that drag can be reduced and operating efficiency helped by modest design changes. Ortner, for example, has worked with Airflow Sciences on computer analyses of changes to improve the aerodynamics on unit-train Rapid Discharge cars, and the computer seems to be saying that there are ways to reduce drag by about one-half on empty unit-train operation and by about one-third on loaded-train operation. Interestingly, hopper cars seem to behave better than gondolas in an aerodynamic sense, probably because of the air-channeling effect of the slope sheets, and it's expected that further design treatment of the slope sheets as well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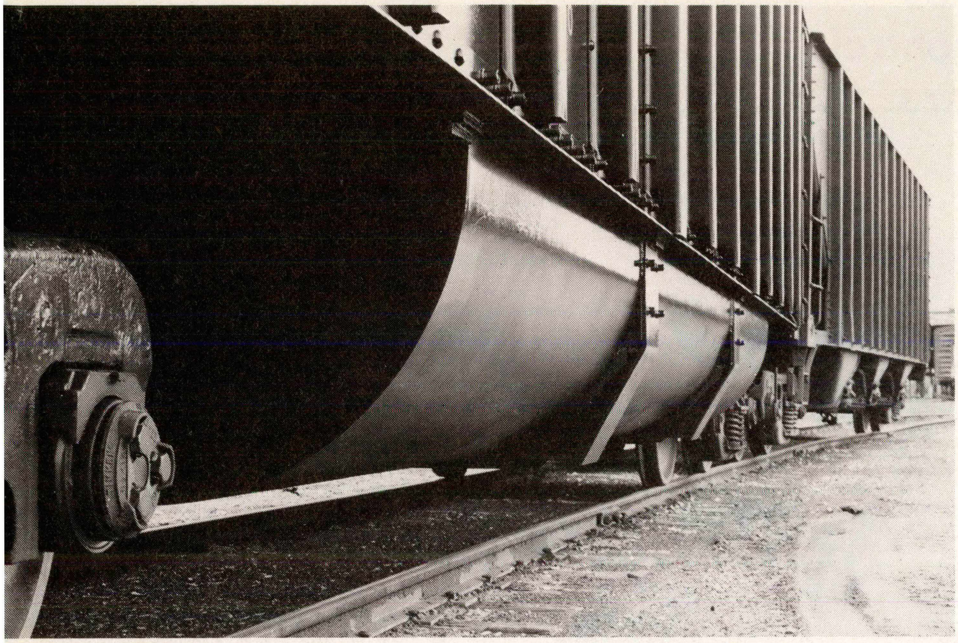


Sticking with steel is Chessie, which has developed a lighterweight steel car that has a twin-pod round bottom for easier dumping.

while the aluminum car is in service, it's going to be hauling much more tonnage than its steel counterpart, with the lightest-weight aluminum cars pegged at 111 tons lading capacity vs 100 tons for a standard steel car; Chessie's steel prototypes are lighter, but they still come in at about 54,000 pounds tare weight.

The new aluminum cars also may have some proving to do in applications where they may be subjected to car-heaters or car-shakers. Aluminum can't be heated too much, and if a thawing shed applies temperatures of above about 250 degrees F, then there could be problems. Car-shakers could pose another problem, which is why some carbuilders are looking at riveted structures as opposed to the welded carbodies used on other prototypes.

The use of extrusions is another item still open to debate. The Portec Algola, for example, uses aluminum extrusions in just about every place that extrusions could be used. Ortner, for example, takes another tack, working with about a 50-50 split between extrusions and plate, figuring (among other things) that it's going to be better off if it has a number of operators of smaller presses available as suppliers rather than relying upon the few manufacturers who can supply the big extrusions used in an Algola-type car.

- **Wait-and-see.** As for the railroads, they're staying out of the whole thing, at least for now. Seaboard System, naturally, is concerned with the way the Santee Cooper cars will operate, both the Ortner cars in service and the Portec Algolas to come. Other major coal-haulers are waiting to see how utilities will respond to the aluminum-car push (and thus far, none has except for SC and Intermountain Power). Santa Fe and Burlington Northern have been gaining experience with operation of aluminum cars of the new generation, and the experience generally has been good—but neither road, nor any other railroad, is taking the plunge.

And, in fact, no true test of the new aluminum cars can be made unless complete unit trains of those cars are being operated: Prototypes can say something about a given car, but they cannot say much about a whole train made up of such cars. That's why the Santee Cooper runs via Seaboard System are so important. That's why it's so important, for the promoters of the lightweight cars, that Ortner correct the problems its cars have encountered and that the Algolas have none.

It should be noted, too, that some engineers are concerned that not enough testing has been done on the new aluminum designs—specifically, not enough fatigue-type testing—and that there is not really an adequate, complete testing facility available to do such tests.

Then, there may be other interests coming into the market, such as Alcan of Canada, which is about to begin a marketing program aimed at the U.S. (see page 11). And never to be forgotten are the commercial carbuilders who already have steel car designs in the 105-ton-capacity area, among them FMC, ACF, Bethlehem, and Thrall Car—which is strengthening its hand in both the intermodal and coal-car markets with an agreement in principle to acquire Lamson & Sessions' United American operation and the rights to the Teoli coal car design held by another L&S company, Youngstown Steel Door.

But, it all comes down to the market, and this is the way the coal market looks—the coal market, and the market for coal cars.

A few years ago, the coal markets looked great. They don't, now.

For example, coal exports from South Africa, Australia and Poland doubled between 1972 and 1983, and the Peoples Republic of China will be getting into the market. U.S. coal exports will continue to suffer, from increased foreign competition and from the strength of the U.S. dollar.

Overall, there are problems on the horizon for both domestic and export coal demand.

In its most recent forecast, the National Coal Association forecasts total coal consumption, domestic and export, at 1.1 billion tons by 1995. A few years ago, NCA was predicting demand for 1.5 billion tons of coal by '95. That's a reduction in the projected growth rate of 27%, and it looks toward an annual growth rate in demand of only 2.6%. And for railroads, while coal represents something more than 40% in tonnage, it accounts for much less in revenues per ton-mile, something like 2.5 cents per ton-mile as compared with about 3.2 cents per ton-mile for the average of all rail-transported commodities for the most recent year for which figures are available.

- **Sharp pencils.** Given these revenue results and these forecasts, railroads are going to be using sharp pencils when they make decisions on coal rates and on acquisition of coal-hauling equipment. Utilities and other coal users are going to be doing the same. Contracts are going to be executed very carefully, by all parties, since some of them will be stretching out for 25 or 30 years.

And, waiting in the wings somewhere, is the AAR's program for suppliers to design the high-productivity integral train, to concepts that could change the ways in which bulk commodities as well as general freight are moved.

The object of that program is reduction in operating costs, through use of more efficient equipment, the motive power as well as the freight-carrying vehicle. The object of what carbuilders and a railroad or two are doing right now is the reduction in operating costs, through use of more efficient equipment.

The question is, where—and when—will the payoff come?

Carbuilders and component suppliers can't forever put money into research-and-development efforts if what they come up with are products, cars and components, that nobody is really ready to buy. And yet railroads, with a couple of exceptions, are not set up to do the same kind of work themselves.

The coal-car market, actually, is more than just a microcosm of what's going on. But it's a situation that everybody—suppliers and railroads alike—will be watching closely. Railroads and utilities, the users of coal-carrying cars, have a lot at stake. So do Portec, Greenville, Pullman Standard Manufacturing, Berwick and Ortner—as well as a few other companies that may be joining the race.

The products may need to be fine-tuned.

It's the market that needs to be tuned up.

And then, maybe, things will take care of themselves. ■

Table I. Snapshot of Improved Freight Car Truck Aspirations — December 1983

Truck/sponsor[1]	Basic Frame Type	Characteristic design features	Principal performance-improvement factors	Status	Remarks/ development plans
[2]ASF Ride-Control (American Steel Foundries)	3-Piece	Constant-column-load friction damping	Baseline designs—center plate extension pads or constant-contact side bearings, supplementary spring group snubbers used as add-ons to control hunting, rock & roll in many applications	In almost universal use on N. American freight car fleet	Extended-life, reduced-maintenance designs based on detail refinements such as more extensive use of wear plates
[2]Barber S-2 (Standard Car Truck Co.)	3-Piece	Load-variable friction damping			
RDI (Railroad Dynamics, Inc.)	3-Piece	Split friction wedge in angled pocket spreads sidewise to take up clearances in bolster/side frame	Increased truck stiffness in tram raises hunting threshold speed with minimum modification to basic truck	Experimental quantities in service on several railroads	Can be retrofitted to existing bolster pockets
UTDC Frame-Braced (Urban Transit Development Corp.)	3-Piece	Diagonal rods connected to side frames to increase interaxle shear stiffness; shear pads over axle bearings	Shear pads and frame braces provide some radial-axle curving improvement with minimum mods; frame bracing controls hunting	Single c/s tested; in-service wear test continuing	
Primary-Aligned Truck (American Steel Foundries)	3-Piece	Close-tolerance steel/elastomer pads over bearings stiffen truck in tram, provide some cushioning, empty/load side/center brgs. assembly adjusts car/truck yaw stiffness, load path	Tram stiffness allows use of higher conicity wheels for better curving w/o hunting problems; better rock & roll control without supplementary spring-group snubbing	In test under THETA-80 Track Train Dynamics High-Performance Covered Hopper	Envisioned as family of trucks of increasing performance level tailored to meet specific requirements at minimum cost
[3]National Swing-Motion (Midland Ross-Nat'l Castings Div.)	3-Piece	Transom-stabilized side frames pivoted to act as swing hangers; dual-rate coil spring suspension	Higher hunting threshold speed, cushioning of lateral impact forces	Extensive service history, mostly in caboose & other premium service	
[3]Maxiride (Evans Products/ SOCIMI)	Rigid	Fabricated H-frame "European" truck with special-coil friction damped primary suspension	Reduced unsprung weight, high tram stiffness for high hunting speed threshold	Single 100-ton c/s tested in TDOP FAST & wear tests	
[3]DR-1 (Dresser Industries/ DOFASCO)	3-Piece	Self-steering radial truck, steering arms, bearing shear pad retrofittable to standard truck	Radial-axle action for reduced angle of attack curving with high hunting threshold speed	Several hundred c/s in service on unit coal trains.	DR-2 over-bolster design (compatible with truck-mounted brakes) prototypes in service
[3]Barber-Scheffel (Standard Car Truck Co.)	3-Piece	Self-steering cross-braced radial truck, modified side frames with dual shear pads, standard secondary suspension	Radial-axle action for reduced angle of attack curving, high hunting threshold with high conicity wheels	Several hundred c/s in service on unit coal trains.	Lower-cost, single-shear-pad design completed
[3]Devine-Scales (Devine Mfg. Co.)	Rigid	Fabricated-frame carbody - steered radial truck with friction-damped, standard-coil spring primary suspension over sliding pads	Radial-axle action for reduced angle of attack curving, high hunting threshold; reduced unsprung weight.	Single c/s tested in TDOP FAST, service wear tests.	Cast-bolster "equalized" primary-suspension & retrofittable secondary — suspension designs with same steering linkage have been prepared.

[1] Listed in approximate order of increasing degree of deviation from baseline truck
[2] TDOP "Type I" (baseline) truck
[3] Tested as TDOP "Type II" (premium) truck

"A railroad may find fixing a few sections of track (grade crossings and bridge abutments mostly) a good alternative to over-designing a lot of cars."

swering questions of everything from locomotive traction to fatigue effects of wheel contact with the gauge corner of the rail, but both analytical and experimental tools for settling most such matters have never been sharper.

- **A quicker wear evaluation?** One of the toughest matters the analysts have been tackling over the years is the matter of rail wear prediction. It is known that angle of attack between flange and rail is a major factor, along with lateral forces; both are difficult to measure accurately in the field. Recent tests at Pueblo indicate the possibility of a major shortcut in comparing wear effects between different truck designs. There is a fairly well established relationship between energy dissipated in rail/wheel contact and metal loss; on the FAST loop, railhead temperature rise during the passage of a test consist is as much as 23 degrees F, a big enough value to assure that such measurements over a single trip or so may well provide a quick but precise indication of comparative long-term wear rates.
- **The truck picture today.** One thing the current depression in sales has given the truck designer is *time to think;* another is all the shop capacity in the world for trying out ideas for which development money can be pried loose. So, what *is* cooking? Table I is a snapshot, necessarily incomplete, of the four-wheel freight-truck scene summarizing the major designs which have seen service or test to a significant extent, along with some indication of the directions in which further development is proceeding. Previous articles (*RA*, Sept. 8, 1980, p. 30; Apr. 27, 1981, p. 40; and January 1983, p. 51) include illustrations of the principal designs.

As is the case with the "baseline" ASF Ride Control and Barber S-2's representing virtually all of the high-capacity (70 and 100 ton) trucks in the North American car fleet, many variations or add-ons—such as constant-contact side bearings creating sub-classes for particular applications—are to be expected.

What sort of acceptance environment must these designs face? As a "designated devil's advocate" at Montreal, Seaboard System equipment chief L.A. McLean provided a pithy summary of potential pitfalls with any new piece of equipment—operational and maintenance considerations such as non-interchangeability or incompatibility with shop capabilities which, if not addressed, could generate costs far beyond anticipated savings. In the harsh world of reality where 100- and 125-ton side frames two inches different in wheelbase have actually been concocted into a truck which (rather briefly—until the third derailment) got out onto the road, the experienced designer taking precautions against such eventualities will still refer to his product as "rip-track resistant" rather than "rip-track proof."

As the summary indicates, continuing design and development is aiming at: (1) retrofittable improvements making maximum use of the investment (both in design confidence and hardware) in present trucks and (2) the age-old and worthy goal of the minor change with the big benefits. The "standard" three-piece truck is not a stationary target, either—during the decade, its longevity, simplicity and versatility has been steadily improving with such seemingly minor but important changes as spring group rearrangements, snubbing and squaring augmentation and more efficient placement of metal in general.

- **Boxing-in truck economics.** To realign economic possibilities with today's conditions, an analysis presented by AAR economist M.E. Hargrove seeks to put realistic bounds on the principal categories of possible savings from the use of AAR costing programs being developed as assists in such matters as optimizing train routing, makeup, and scheduling. These programs are increasingly fine-grained, to the extent of attempting to quantify and reflect current thinking on such items as the additional track maintenance costs resulting from dynamic vertical and lateral loads. Figures generated concentrate on what a set of "really super" trucks might save in general service and high-utilization unit-train scenarios.

Since the analysis indicated that under current energy-cost conditions *tare weight reduction* had by far the best potential for justifying increased investment, it was assumed that a car set would weigh two tons less, in addition to reducing truck-action-caused costs. Results confirm that low-mileage general service cannot support premium-truck investment. In the high-mileage situation, the pay-off window is still open for the super-truck inventor if he can squeeze out the weight—if he can't, the tangent-greaser may turn out to be the smart buyer.

Is it possible to sweat out that much weight? Those who have been trying for years sincerely doubt it, but what will certainly be a strong psychological push is at hand: The aluminum-body gondolas have more than 50% of their total weight in the trucks and that's going to cause pressure.

A Canadian Pacific study by E.R. McIlveen and M.D. Roney demonstrates effects of trains on tracks in terms of annual rail renewals required to maintain track quality. Planned upgrading including installation of cwr, direct rail-tie fixation (in this case seen as reducing low-rail head flow by eliminating "false flange" contact with worn wheels because dynamic gauge widening is less), better-designed rail-grinding programs, expanded lubricator installations, and use of premium or improved rail is seen as increasing rail life by a factor of four or more. This must correspondingly decrease opportunities for achieving major savings from the introduction of steering trucks unless they can be put into service well before track upgrading is completed.

Rather clearly, the alternatives—some of them very route-specific—among the ways of saving and making money with capital investments came across loud and clear. As Track Train Dynamics manager K.L. Hawthorne pointed out, in an 11,000-mile recording of vertical dynamic loads conducted in connection with the fatigue-load car design criteria determination program it was found that loads over 1.8 times static occurred only 0.006% of the time—once every 50 miles. Since the test car is now equipped to mark such spots with paint, a railroad may find fixing a few segments of track (grade crossings and bridge abutments mostly) a good alternative to over-designing a lot of cars.

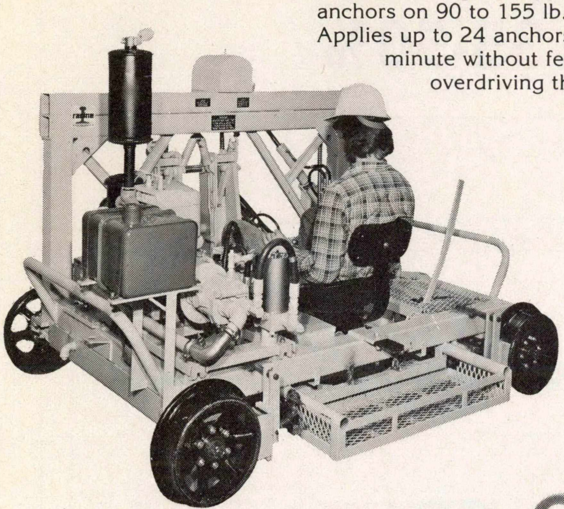
- **Single axles—the right stuff?** Trailer Train's analysis of the single-axle truck concludes that a continuing market for the routing flexibility of single-trailer intermodal cars will warrant development of minimum-tare four wheelers and that the right design has the potential for achieving *per trailer* truck costs and tare weights somewhat lower than those for articulated cars with four-wheel trucks. Among its recent test cars are a pair based on the standardized European (UIC) suspension, modified to meet AAR standards with the use of as many available North American components as practical.

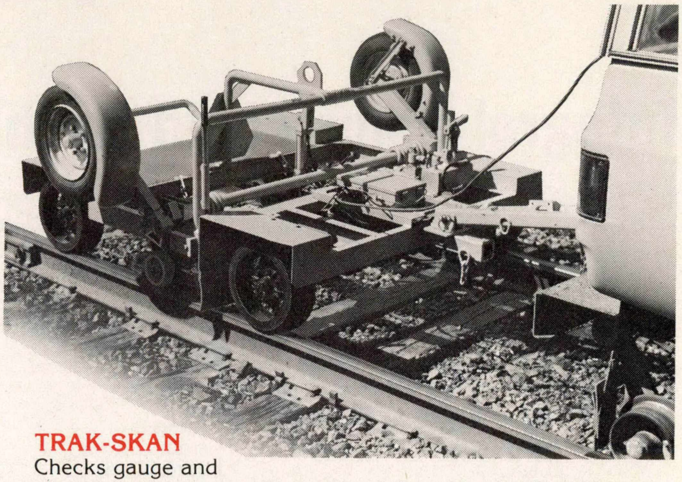
The resulting assembly includes some features attractive in the American scene, including lateral motion totaling about ¾-inch cushioned by three stages of increasing resistance, somewhat lower upsprung weight, and two-stage springing for a soft ride under light loads. They will have to continue to demonstrate their practicality under American intermodal speed, load, train weight, climatic, track and utilization conditions if they are to overcome railroad resistance ingrained by hearsay if not experience.

Car design on a *system* basis is particularly essential with the single axles; carbody twist flexibility—along with the 4¼-inch travel (leaf) springing—has allowed the car to exceed AAR requirements by keeping all wheels on the rail with any one jacked up six inches. Other single-axle trucks planned for Trailer Train evaluation include a British Rail design and an updated version of the National Castings Uni-Truck. ■

rmance and dependability.

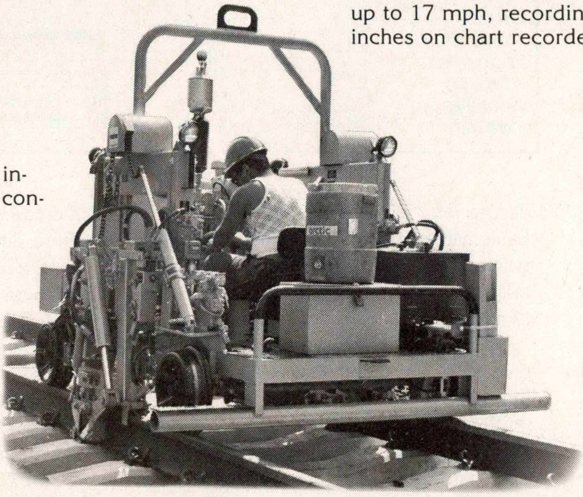
ANCHOR-FAST
Single nipper head easily handles boxing and applying anchors on 90 to 155 lb. rail. Applies up to 24 anchors per minute without fear of overdriving them.



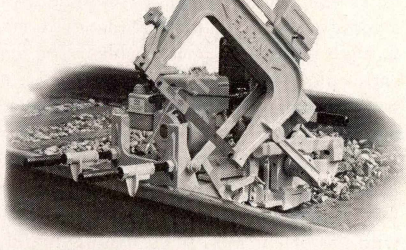


TRAK-SKAN
Checks gauge and elevation on long stretches of track from the comfortable cab of a tow vehicle. Dual sensing unit on trailer chassis is connected to electronic read-out device inside cab. Travels up to 17 mph, recording deviations as minute as ± 1½ inches on chart recorder and digital display.

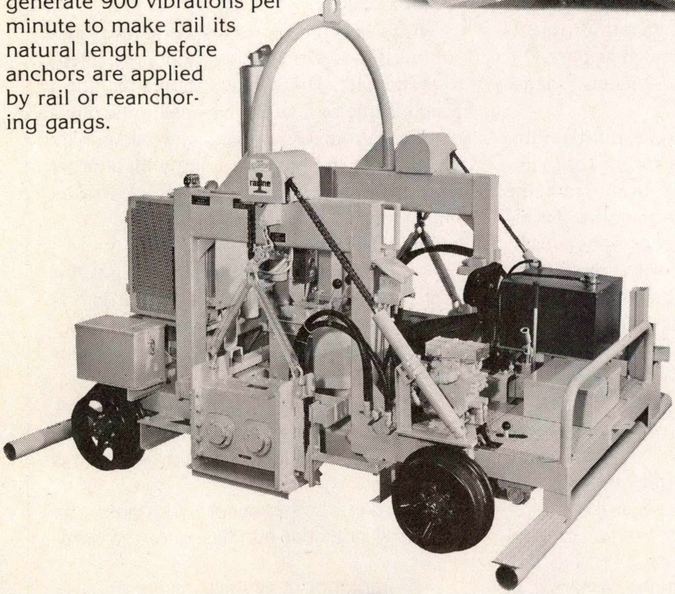
DUAL-CLIP-APPLICATOR
Self-centering work heads install clips on both rails on concrete ties insuring positive alignment even on slightly skewed ties. Automatic sensing prevents overdriving of clips.



RECIPROCATING RAIL SAWS
Powered hack saw models 140 and 155 reduce rail failure due to fractures caused by torch cutting or nick and break method. Capacity from 60 to 155 lb. Cuts in 5 to 8 minutes.



DUAL-TRAK-VIBE
Two vibrating work heads generate 900 vibrations per minute to make rail its natural length before anchors are applied by rail or reanchoring gangs.



TIE-SAVR
Revolutionary free-flowing granular compound eliminates scrapping of spike-killed ties. Restores 80% of spike-to-tie bond. Easy to apply with hand or machine applicator. Adds several years to life-span of average spike-killed tie.

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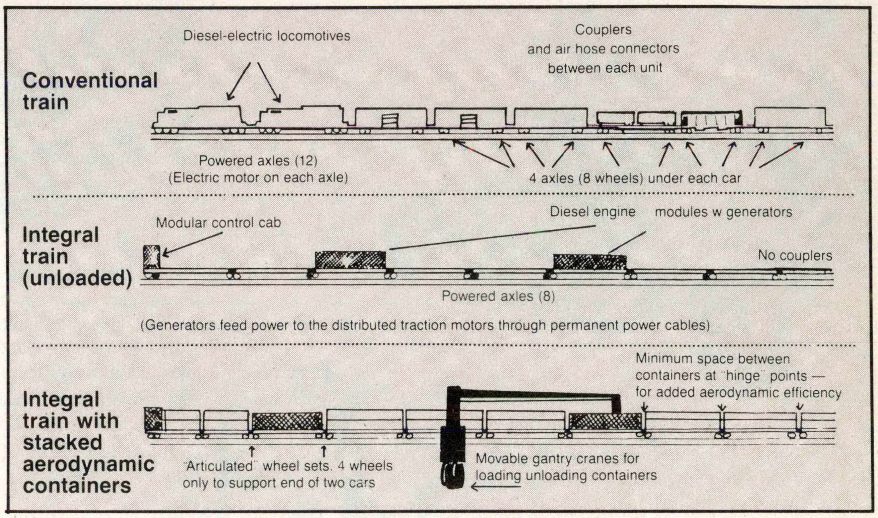
Update

Integral trains could slash costs 35-50%



July 2 is the deadline for letters of intent to participate, and Oct. 15 is the deadline for preliminary concept proposals in a bold AAR program to develop an "integral" train that would be better suited to meeting competition, especially from trucks.

October 1985 is the target for building the first such train, which AAR sees as particularly applicable for intermodal and bulk commodity traffic.

What is an integral train?

It is, says AAR, "a train that does not have to meet all interchange requirements and is designed as a system and operated as an entity to offer a high level of productivity."

More specifically, it is a train with: (1) power spread throughout rather than bunched at the front; (2) reduced tare weight, affecting fuel consumption and allowing higher net load per unit of train length; (3) an improved, load-compensating brake system; (4) greatly reduced slack action, reducing component wear, car-structure fatigue, lading damage, and likelihood of derailment.

Virtually all benefits derive from the power spread, which would take the form of diesel-engine modules with generators feeding power to distributed traction motors through permanent power cables. The lead car would have a modular control cab. Cars would be joined without couplers, perhaps on articulated wheel sets.

AAR has high hopes. Integral-train objectives include: for intermodal, a 50% cost reduction, reliable transit times competitive with motor carriers, rapid loading/unloading, and accommodation of varying container sizes; for bulk commodities, a 35% cost reduction, assurance of service reliability, and rapid loading/unloading.

AAR has identified 11 separate goals: Improve overall system reliability, optimize train-cycle time, optimize requirements for train maintenance and servicing, reduce derailment risk, improve ride and stability, improve train handling, optimize energy consumption, optimize load/tare ratio, optimize load per unit-length of train, improve utilization of fixed plant, and optimize requirements for construction and maintenance of the fixed plant.

AAR described the project at an April 3 meeting in Chicago attended by more than 200 railroaders, suppliers and consultants. Emphasizing the urgent need for a new train design was Richard L. Spence, Seaboard System executive vice president-operations, who said carrier-supplier interdependence is taking some "new and uncomfortable twists."

Spence said: "I have to tell you this—unless freight trains can be designed and built which offer a quantum decrease in the unit costs of operations, our participation in new America will be disappointingly small. And with heavy reliance on the shrinking markets of old America, growth prospects will be limited, yours as much as ours."

Spence cited these developments as lending urgency:

—A major rationalization of railroads under deregulation, with new incentives to improve service and a move away from the traditional pattern of many small railroads interchanging huge numbers of single cars.

—The worst recession since the 1930s, which has limited railroads' ability to take advantage of the deregulated situation.

—Substantial cost reductions by truckers as they move to larger trailers, often in tandem.

—Possible competition from slurry pipelines.

—The diverging economies in America, one smokestack-oriented and unlikely to return to former grandeur, the other oriented toward consumer products and services.

"The freight of this young America is growing less dense," said Spence. "Cost per unit cube is often more important than cost per ton. And, as the value of freight increases, service standards become even more demanding."

Heading the integral-train effort is Dr. William J. Harris, AAR vice president-research and test. There are two committees: Technical/engineering, headed by Ted Mason, Santa Fe chief mechanical officer; and economics/marketing, headed by Peter J. Detmold, CP Rail special consultant and chairman of the Railway Advisory Committee of Canada.

The project has six stages, beginning with submission to Dr. Harris of letters of intent to participate. These letters should include a brief outline of how the proposer (one company or a group of companies) would pursue the goals of the project, along with a target timetable for completion of "various milestones."

The other stages are:

—Submission of preliminary design concept proposal, for which the target date is Oct. 15. This should include sufficient detail to judge the economic and technical feasibility of the proposal.

—Evaluation of proposals by industry committees, using various tools such as mathematical models and train operations simulators.

—Marketing of concept by proposer, by soliciting potential purchasers of the hardware.

—Completion of detailed design and testing of individual components.

—Finally, building of the first train and AAR testing of it, in late 1985.

a participatory railroad on the installation and removal of prototype hardware and instrumentation, and will acquire and analyze all data. During the key review and decision phase (V), the systems contractor will provide data and advice as needed. Throughout the program, the railroad and equipment supplier will review and advise on the project in addition to testing as described above.

The recommended relationships among participating organizations is illustrated in Fig. 4.1. The FRA Office of R&D would interface with the AAR on the one hand and the FRA Office of Safety on the other. The Office of Safety would grant waivers directly to the

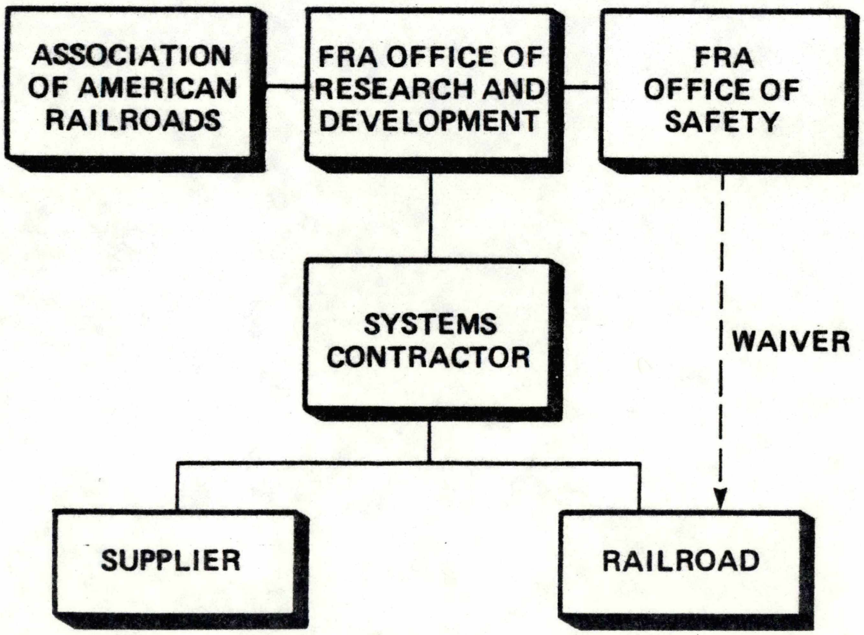


FIG. 4.1 MAJOR PARTICIPATING ORGANIZATIONS.

participating railroad. The Systems Contractor would report to and take direction from the Office of R&D. The supplier and the railroad would work with the Systems Contractor through subcontracting or other written agreements specifying commitments made by participating parties.

We believe that these organizations, working together, can overcome the barriers that have prevented the implementation of novel braking and coupling systems during the past hundred years of development of the American railroad system. Each of the various innovations presented in Sec. 3 is expected to enhance railroad productivity by itself; together, they provide an essential link in the long term conversion of braking and coupling systems from their present dependence on manual control to a high degree of automation.

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