

FUNCTIONAL REQUIREMENTS FOR A FACILITY FOR ACCELERATED SERVICE TESTING

S. K. PUNWANI
J. R. LUNDGREN
G. C. MARTIN



SEPTEMBER 1976

FINAL REPORT

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16. Abstract <p>This report describes recommendations for a proposed Facility for Accelerated Service Testing (FAST) and the rationale for the recommendations. It includes a list of proposed initial test series for railroad track research and railroad mechanical equipment research to be conducted by rapid accumulation of traffic operating continuously on proposed test track loops.</p> <p>The proposed FAST consists of three closed track loops, providing a curvature range up to 10° and a maximum speed capability up to 80 mph. In addition, a Mechanical Loop option is described</p>					
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PREFACE

The concepts and recommendations reported on herein are those of the Association of American Railroads and they do not necessarily reflect the view of policy of the Federal Railroad Administration.

This is the Final Report for Task 4, DOT-FR 30038.

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The assistance of members of the Research Committee, Engineering Division, Association of American Railroads, and the General, the Research and other Committees of the Mechanical Division, AAR in defining the nature, scope and initial test series is gratefully acknowledged.

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EXECUTIVE SUMMARY

**FUNCTIONAL REQUIREMENTS FOR A
FACILITY FOR ACCELERATED SERVICE TESTING
(FAST)**

A study of the technical design and cost of construction and operation of a test track facility to be built for the evaluation of railroad track and equipment under service loadings applied at high rates

S. K. Punwani
J. R. Lundgren
G. C. Martin

Prepared by

**THE ASSOCIATION OF AMERICAN RAILROADS, TECHNICAL CENTER
CHICAGO, ILLINOIS**

for

**THE UNITED STATES DEPARTMENT OF TRANSPORTATION,
FEDERAL RAILROAD ADMINISTRATION**

Task #4, Contract DOT-FR 30038

SEPTEMBER 1975

1. INTRODUCTION

The concept of a closed track loop facility designed to accommodate full scale testing of railroad track and equipment under controlled conditions has received considerable attention in recent years. Railroad research facilities of this type exist in Europe and in one case a facility has been in use for over 40 years.

Some facilities for closed loop and other testing of vehicles have been under construction or in operation at the DOT Pueblo, Colorado High Speed Ground Test Center* (Figure 1) for the past several years. These facilities are the Impact Track, the UMTA loop and the Track Train Dynamics Track, the LIM Track and TACV guideway. These are used for the evaluation of both conventional and advanced guided ground transport vehicles and their guideways.

However, these loops were designed primarily for studies of vehicle dynamics or testing of vehicles and guideways that are not of a conventional railroad equipment and track nature.

There is great and further need for a facility to evaluate conventional railroad track and equipment under conditions generating high traffic volume and high mileages. This report describes a facility to fill this need. This proposed facility is called a "Facility for Accelerated Service Testing" (FAST) in this report.

For discussion, it is assumed FAST will be an integral part of the Pueblo installation, and will specifically address the need for applying extremely high volumes of traffic to track structures under test. Accumulation of traffic rates on the order of a tenfold increase over that available from typical field tests is a prime goal of FAST. This basic FAST layout is shown in Figure 2.

*Now called Transportation Test Center

TEST SECTIONS	LENGTH	TEST SECTIONS	LENGTH
A (1 to 4)	4800' (1460 m)	F (1 to 4)	4800' (1460 m)
B (1 to 4)	4800' (1460 m)	G (1 to 9)	10,800' (3283 m)
C (1 to 4)	4800' (1460 m)	H (1 to 9)	10,800' (3283 m)
D (1 to 4)	4800' (1460 m)	J (1 to 4)	4800' (1460 m)
E (1 to 4)	4800' (1460 m)	K (1 to 4)	4800' (1460 m)
S (1 to 4)	600' (182 m)	L (1 to 3)	3600' (1094 m)

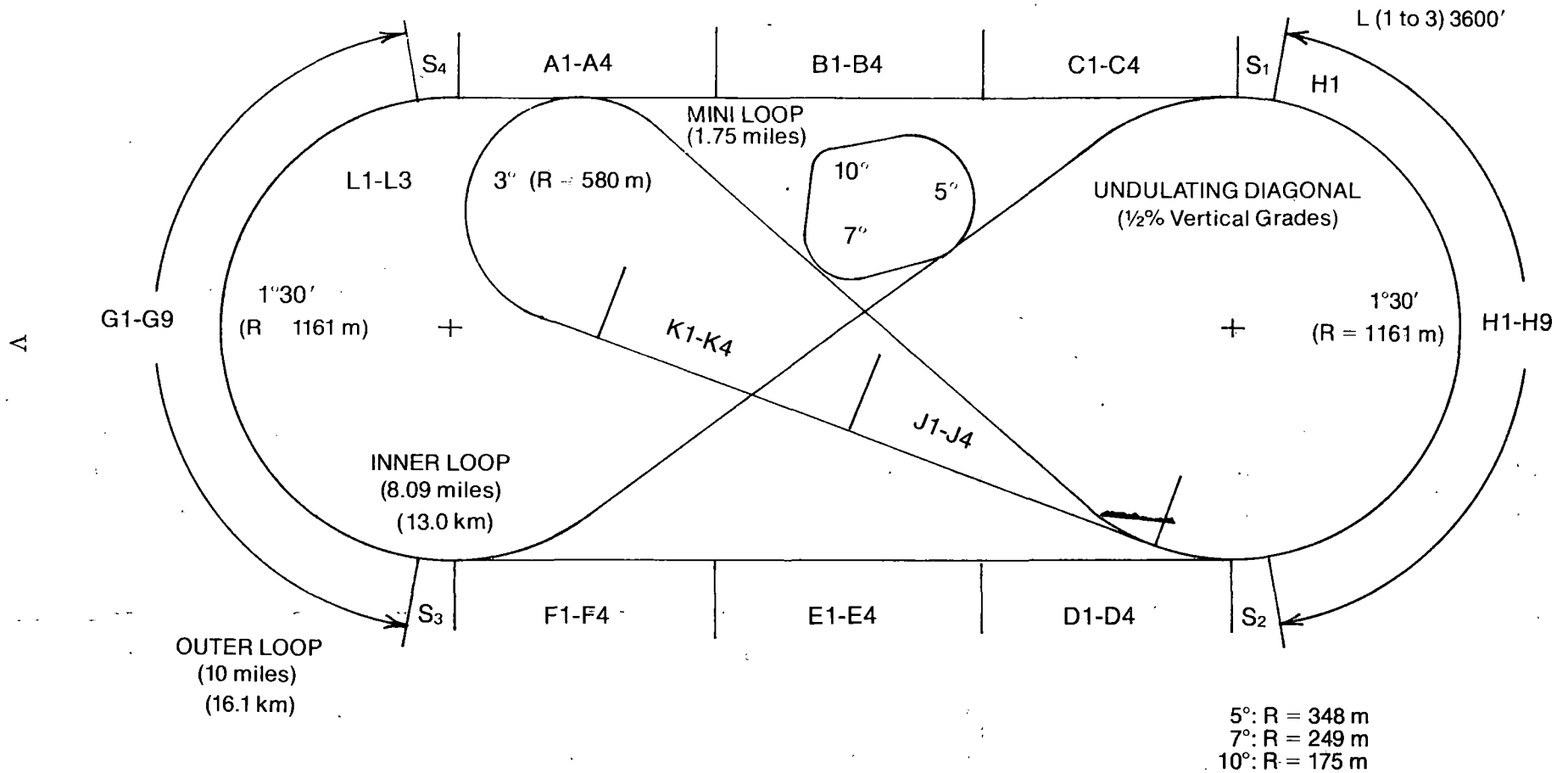


Figure 2 Proposed FAST Configuration

2. BACKGROUND

The subject facility concept started in part as a result of Task 4 studies of track structure research facility needs. The objectives of Task 4 were the development of functional specifications for a track research facility. This report is intended to meet this requirement. In addition, the mechanical tests and other tests that could be conducted are also discussed.

3. SCOPE

This final report on the functional requirements for the FAST facility is a complete review of the considerations having impact on the design features of the loop configuration, rolling stock and operations strategy.

In Part I, the report defines the proposed functional capabilities proposed for the facility.

A recommendation for facility design is presented. This design meets the essential criteria and provides acceptable compromise where several objectives must be met.

Detailed recommendations are given for each element of the loop design. Proposals for the initial test series for both track structures and car equipment are included.

Also included in Part I of the report is a preliminary cost estimate covering both initial construction of the facility and cost of operation for the duration of the proposed initial test series.

Part II explains the rationale for the recommendations and describes all concepts considered. The constraints on facility design imposed both by technical limitations and by engineering judgment are presented. Vehicle speed, climatic effects,

train length, train tonnage, space requirements, test duration and test section lengths are among the parameters evaluated. Consideration has also been given to the problems of loop configuration, interfacing mechanical and track testing and providing for inspection, maintenance and operation of the facility.

Using these inputs, a summary of the design elements impacting the FAST loop design is presented.

The potential benefits to be derived from the tests are summarized and an evaluation of the dollar savings is presented.

4. APPROACH TAKEN

The study to develop the functional specifications for an accelerated service test facility approached the design problem on the basis of establishing the essential capabilities for the facility before considering any constraints.

The test capabilities of the facility were developed on the basis of AAR experience gained through many years of direct participation in track and equipment research. This experience is tempered with suggestions and counsel from many of the chief engineering and mechanical officers in the railroad industry. Extensive questionnaires in both the areas of track structure and equipment design were submitted to major railroads. Their replies were enthusiastic and detailed. Their recommendations have guided the design and many of their suggestions have been incorporated into the design.

From this pool of experimental, theoretical and practical experience, and a careful evaluation of the technical restraints on the facility; a design providing the functional capabilities desired evolved.

5. FACILITY CONFIGURATION

The recommended initial configuration for the FAST project consists of a loop arrangement of trackage forming three basic elements (Refer to Figures 2 through 4):

1. An outer, high speed (approximately 80 mph) oval about 10 miles in length having $1^{\circ}30'$ curves.
2. An inner, 60 mph loop, created by incorporating a portion of the outer loop and adding a 3° curve and reversing diagonal.
3. A "mini-loop" incorporating sharp curvature allowing operation up to 30 mph on 5° , 7° and 10° curves.

Provision for tangent and curved track test sections 1000 feet in length with 100 foot transition sections on each end is made on each loop. Test section locations are chosen to optimize test benefits.

The traffic applied to the various test sections will consist of a random mix of popular car designs, realistically loaded to form a 6400 to 6800 ton train. It is anticipated that motive power will consist of 3 diesel-electric units of approximately 3000 HP rating on conventional 3 axle trucks. Normal train consist will be approximately 85 cars.

Operating speeds will be consistent with curve geometry and superelevation, with a daily operation period of 20 hours generating on the order of 1 million gross tons of traffic over a test section daily. A single vehicle will travel from 800 to 1600 miles per day.

The facility design also includes recommendations for operating procedure, maintenance intervals, supporting equipment and instrumentation systems.

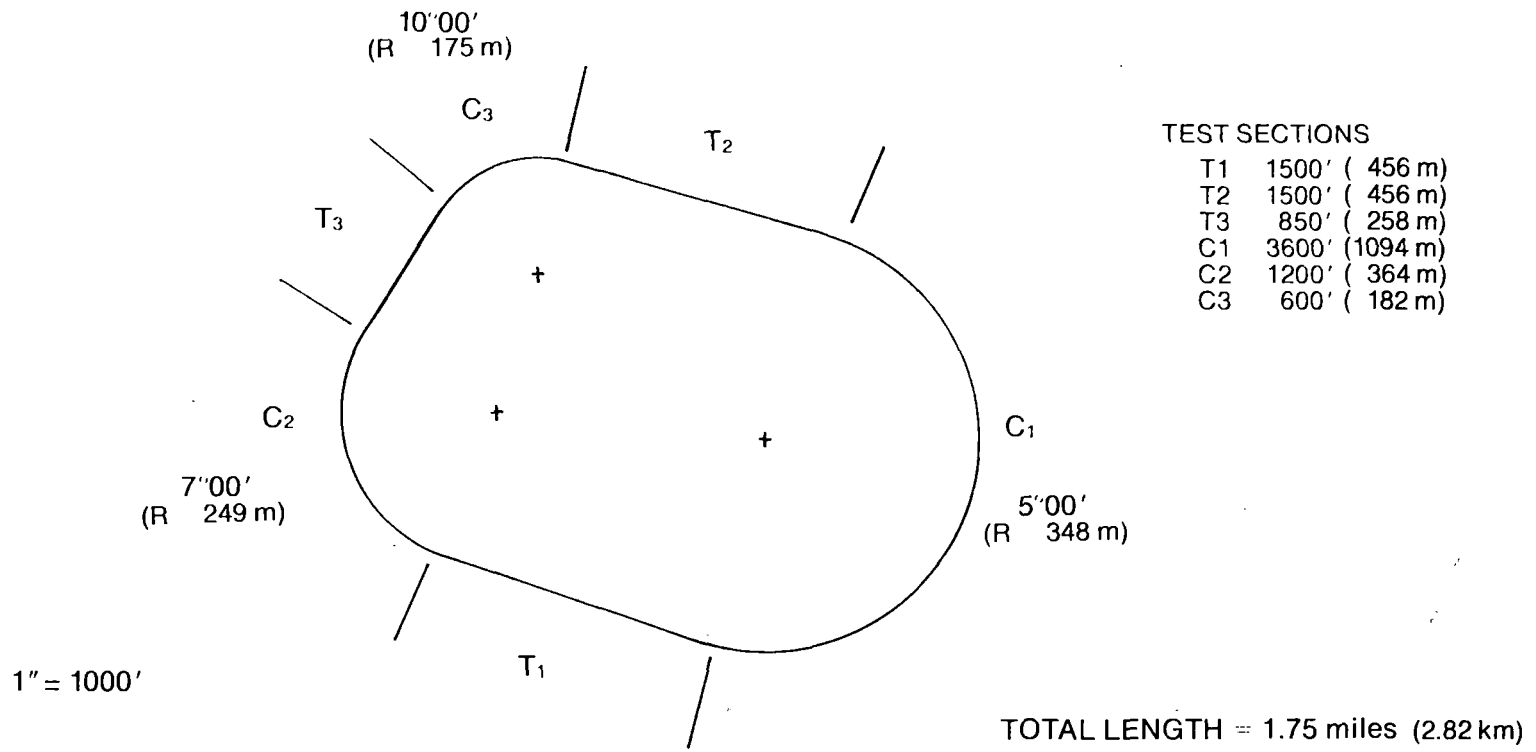


Figure 3 Proposed Mini-Loop-FAST

W-F = BROKEN WHEEL DETECTOR
 H-B = HOT BOX
 D-E = DRAGGING EQUIPMENT DETECTOR
 A.T.C. = AUTOMATIC TRAIN CONTROL

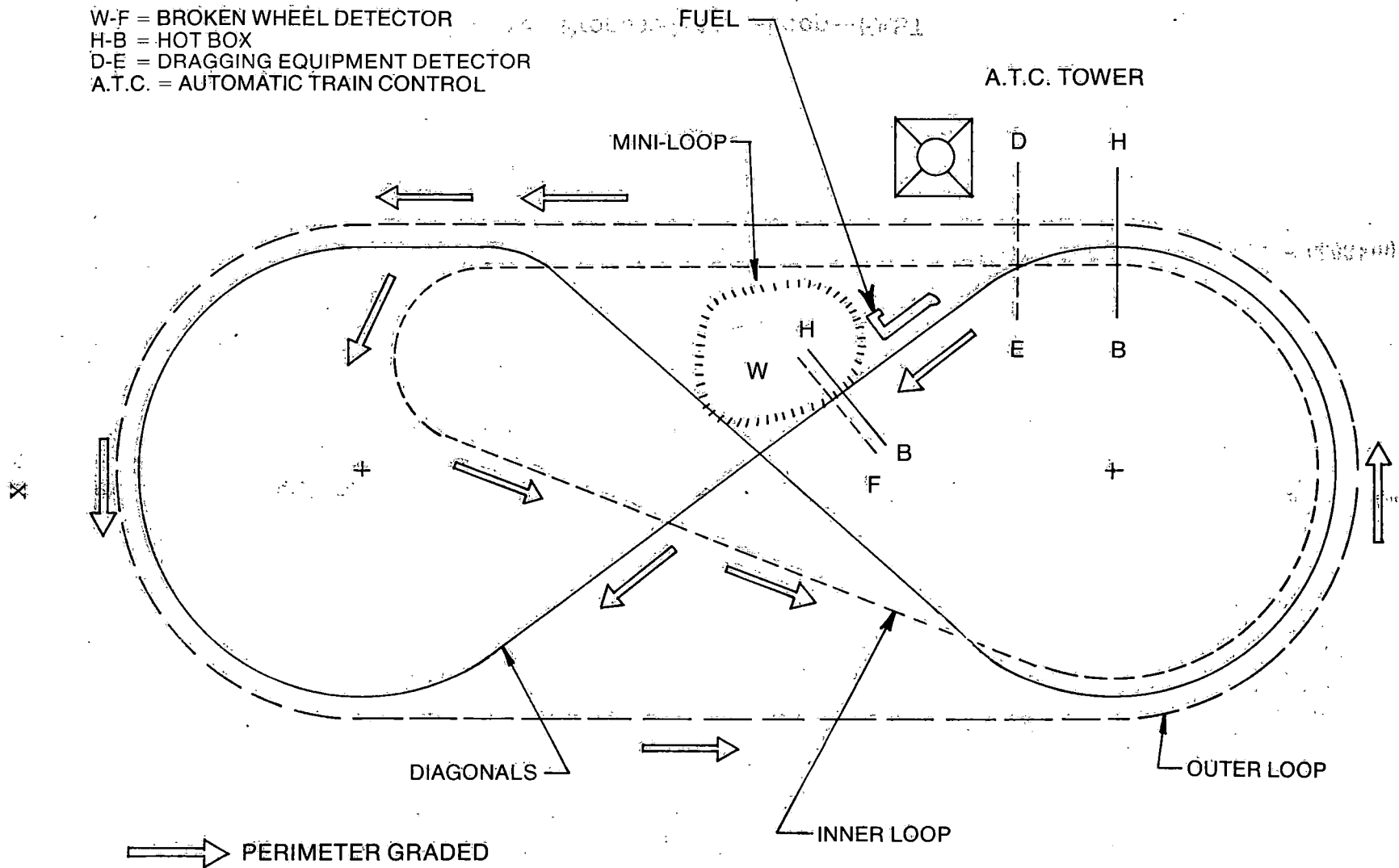


Figure 4 General FAST Layout

In addition to the basic FAST loop recommendations, a mechanical loop is also described. This additional loop, if constructed, would provide a separate test loop dedicated for mechanical equipment tests. This mechanical loop option is described in Section 4.7 of the report.

6. INITIAL TEST SERIES

The initial test series consists of two parts, recommendations for track tests and recommendations for equipment tests. The proposed initial test series extends over a period of two years, and covers twelve, 50 day test periods.

The track test series would include test sections to evaluate track settlement rates, to optimize rail cant, to investigate deviations from track gage, to evaluate tie design, and to investigate various maintenance methods and rail chemistries.

The equipment test series includes investigations on wheels, centerplates, truck design, securement methods, car design, car surveillance equipment, and packaging effectiveness.

7. ESTIMATED BENEFITS FROM THE INITIAL TEST SERIES

Preliminary estimates of some of the savings which may be derived from the initial track test series have been prepared. Based on the present worth of potential benefits over a ten year cycle and allowing a conservative estimate of time for implementation to occur, the settlement rate series has a potential for \$165 million in benefits. In a similar manner, the benefits from the cant and gage tests, the tie tests, the maintenance method series and the rail chemistry tests were estimated at \$75 million, \$50 million, \$60 million and \$32 million respectively.

Total benefits from this initial track series could reach \$382 million. A similar analysis shows considerable savings accruing from the equipment test series.

8. COST OF CONSTRUCTION

Cost to implement the recommendations given in this report for the basic FAST loop design and the equipment array have been developed. Initial capital outlay would require \$15.5 million, with an additional \$12.8 million for the mechanical loop.

9. COST OF INITIAL TEST SERIES

The operating and supporting function costs for the basic FAST loops associated with the initial two-year testing period are estimated at \$10 million.

10. SUMMARY AND CONCLUSIONS

The preliminary design presented in this report is believed to satisfy the functional specifications outlined for a viable accelerated service test facility.

The potential benefits to be derived from tests run at such a facility are great.

The cost of the facility, while considerable, may be readily retrieved from implementation of test findings. By quickly selecting effective solutions to current railroad problems, the FAST concept could show a very significant return on investment.

The FAST concept fills a serious void in the array of tools available to railroad research. With it, rapid progress in improving the efficiency of all railroad line haul operations could be effected.

PART I

FACILITY DESCRIPTION AND RECOMMENDATIONS

(Sections 1.0 through 9.0)

1.0 INTRODUCTION

This final report is the result of research conducted under the sponsorship of the Federal Railroad Administration, Department of Transportation under contract DOT-FR-30038 - Railroad Track Structures Research (Task 4).

The objectives of this task were to develop functional requirements of a Track Research Laboratory as determined by need after a review of all U. S. and Foreign facilities.

During the course of the work it was determined that a Test Track Loop Facility would be of the utmost use. Several concepts were examined, and railroad industry and other research organizations were consulted in-depth before the recommendations in this report were made. Also, presently available facilities at the High Speed Ground Test Center* were examined before making recommendations.

Due to the inherent nature of a test track loop facility it was decided that a list of proposed tests must be an integral part of the rationale for selecting the functional capabilities and the test track loop configuration concepts used. Further, it was decided that due to the inherent nature of the test track loop facility, the loop should include mechanical, track and surveillance tests, but not yard impact tests. This would add to the justification for the construction of a test track facility.

This report is structured in two sections. Part I (this part) is written in a format which could permit the preparation of a detailed facility design including engineering construction plans and specifications for the purchase of freight cars, motive power, maintenance of way equipment, general test equipment within the

*Now called Transportation Test Center

general recommendations of this report. Part II of this report provides the rationale for the recommendations made.

The specific nature of the facility recommendations justify naming it as a Facility for Accelerated Service Testing (FAST). Since this name most expediently describes the basic intent of the facility, it is used throughout this report.

2.0 LIST OF PROPOSED FUNCTIONAL CAPABILITIES

The list of proposed functional capabilities has been developed after extensive discussions with industry representatives and after extensive review of presently operating facilities and those expected to be in operation in the near future such as the DOT Rail Dynamics Laboratory, the AAR moving load facility and other test loops at the Pueblo High Speed Ground Transportation Center.

A list of all physical effects experienced by track structures that are desirable to investigate is given below. The list also includes other areas of investigation, such as mechanical equipment, which can be conveniently conducted.

1. Determination of "fatigue life" of track structures and components by accelerated testing.
2. Optimization of track structure design and maintenance parameters.
3. Comparison and validation of maintenance of way methods and equipment.
4. Determination of loading environment with present and proposed vehicles.
5. For selected cases, determination of the distribution of loads, stresses and deflections within the track structures.
6. For selected cases, determination of behavior of rail, ballast, OTM and subgrade for validation of theoretical models.
7. Determination of fatigue, wear and dynamic characteristics of freight car and locomotive components by accelerated testing.
8. Testing for reliability and fatigue endurance of other miscellaneous components such as ACI, hot box detectors, on-track or track

circuiting electro-mechanical components that require a substantial number of cars traversing same or within proximity on a time accelerated basis. Such concomitant testing, while incidental to the prime capabilities, is none the less an important capability.

Each of the functional capabilities is discussed in the sections below.

2.1 Determination of "Fatigue Life" of Track Structures and Components

The capability to evaluate the "fatigue life" of a track structure and components by test measurements is an essential requirement of the proposed facility.

Full scale "fatigue life" testing of track structures is considered a requirement for several reasons:

1. Incomplete knowledge of loads generated to use in application for small scale tests.
2. Difficulty in applying loadings in a satisfactory manner such as simulation of a moving load for application in small scale.
3. It is difficult to assemble the track structure configuration on a small scale, while maintaining the same structural relationship as in full scale.

The following capabilities for a full scale "fatigue life" evaluation for existing and future track structures are as follows:

1. It must be possible to apply a significant amount of traffic within a short period of time as time compression increases the value of the results.
2. Actual measurement of settlement rates such as loss of gage, cross level, surface, alignment and warp should be possible.
3. It should be possible to use any combination of vehicles and speed consistent with track geometry.
4. Measurement of settlement rates should be made with means that will permit conclusions to be drawn for each type of failure mode, e.g. loss of line, gage, etc.
5. Adequate sample sizes for each failure mode must be available.
6. A number of concurrent tests must be possible as this increases the cost effectiveness and provides test comparison.

2.2 Optimization of Track Structure Design and Maintenance

Parameters

It has been concluded that the performance of track construction and maintenance equipment is an important and integral part of the evaluation of track performance. Consequently, it has been concluded that capabilities for evaluation of maintenance and construction equipment and procedures is an important requirement of the capabilities of FAST.

Three types of evaluation are deemed a necessary part of the track research facility.

1. Measurement of the ability of a machine or procedure to produce a desired physical condition; for example, in-place density of ballast produced at various depths for all machine parameters.
2. Performance characteristics measurement, such as time to compact ballast per mile of track.
3. Direct correlation of track structure performance as determined by geometry measurement or lateral stiffness with machine characteristic parameters by the application of traffic to the track structure.

It should be possible within the facility to test procedures for soil stabilization. Such tests will check effectiveness of proposed alternatives with prototype loadings before on-line remedial construction is undertaken.

2.3 Determination of Loading Environment

FAST must provide facilities to measure the vertical, longitudinal and lateral loads and any combination of these that are generated by vehicles upon passage on a track structure. Such measurement capability must cover the full range of vehicles presently used and those that may conceivably be presented for evaluation. These measurement capabilities must include the full speed range up to 80 mph (128 km/hr), and cover loads generated on tangents, curves and special track work. Further, since the loadings are contingent upon the maintenance of track geometry, load measurement capabilities should include all classes of track maintenance level.

The measurement of all loads is a prime FAST requirement. These measurements must provide wave shapes, frequencies and a spectrum of

load or frequency of occurrence for each level of magnitude. The sample sizes must yield values with generally acceptable confidence levels.

The measurements of loads generated as discussed above can, in general, be accomplished by the use of instrumented wheel sets (and/or instrument rails and base plates). Such measurements can be made routinely with selected cars running within the consist.

The objectives of this load determination are: a) to ensure that non-standard vehicles under test are not imposing an unusually severe loading on the track; b) to generate knowledge of the loading environment that can be used in other research programs requiring such knowledge (track structure and rail stress programs).

2.4 Distribution of loads and Stresses within Track Structures

The determination of the load paths within the present or proposed track structures and attendant stress and deflection distribution is a capability requiring extensive and sophisticated instrumentation used in carefully controlled environments. This function can best be provided within other laboratory facilities. However, selective validation of these under real life conditions is desirable for selected cases. This capability is included as part of the functional capabilities required.

2.5 Behavior of Rail, Ballast, Ties, OTM and Subgrade Materials

Material properties, whether they reflect the strength, fatigue, wear or other physical properties are best determined in carefully controlled environments. However, in some cases, in-situ behavior

measurement is necessary to develop correlation with laboratory loading simulations. This functional capability is considered to be a part of the facility capabilities.

2.6 Determination of Fatigue, Wear and Dynamic Characteristics of Vehicles and Components

FAST should provide the capability to develop a significant number of car miles within a short period of time. A meaningful accelerated service to real time ratio such as 10 to 1 with respect to the average industry vehicle is a part of the functional capabilities.

These functional capabilities make specific demands on the design of the facility. The elements entering into that design will be considered in later sections. Succeeding sections will examine the constraints placed on the design elements by both the requirements of the functional capabilities and by practical engineering restrictions.

3.0 GENERAL NATURE OF FAST

The facility recommendations are basically for test track loops wherein near-actual service testing can be accumulated at a rapid rate. Test sections have been designated as part of each of the loops, although an entire loop can be considered for test purposes. The number of loops and their respective configurations have been carefully selected to cover all types of operation with respect to speed, curvature and traffic wherein significant increases in productivity can be realized.

The test track loop configurations should be looked upon as initial recommended configurations selected on the basis of near-term test objectives. Consideration to future changes has been given in developing facility recommendations.

The facility recommendations will provide for track research testing and tests associated with locomotive and freight car mechanical equipment, and other areas where rapid accumulation of traffic is desirable. The nature of track research testing and the need for a rapid rate of traffic accumulation places some limitations on the types of mechanical tests that can be conducted. A separate alternate is discussed and included as an additional separate loop for mechanical tests which would substantially reduce the limitations placed by a common facility intended for track research tests and mechanical tests. This alternate is described in Section 4.7.

The facility recommendations include general support facilities, instrumentation, track maintenance and mechanical maintenance equipment, motive power and freight car needs, surveillance equipment and recommendations for operation.

The design details for the loop track such as ballast type, depth, etc. and car design details should be resolved on the basis of the initial tests to be conducted since these design details themselves constitute the test specimens.

The management recommendations, described in a later section, include steps that should be taken before developing detailed engineering plans.

The facility will permit accumulation of one million gross tons (0.90 million metric tonnes) traffic daily and up to 1500 vehicle miles per day (2413 km per day).

The recommendations for the Facility for Accelerated Service Testing (FAST) includes test track loops, support facilities, track maintenance equipment, mechanical maintenance equipment, freight car lease/purchase, motive power lease/purchase and recommendations for proposed initial tests and initial operation of the facility.

The proposed initial configuration is described in Section 4. Other facility recommendations are described in Section 6.

4.0 RECOMMENDED INITIAL CONFIGURATION - FAST

Figure 4.1 shows the recommended initial configuration for the FAST. It consists of three basic elements: (1) the outer loop, (2) the inner loop, and (3) the mini-loop (Rail Test Loop). These are described below.

The recommended configuration includes an outer loop with an 91 mph maximum speed capability. The limiting curvature is $1^{\circ}30'$ (1160 m) with an equilibrium speed of 69 mph at $4-3/4''$ (120 mm) superelevation. For the heavy tonnage trains the maximum practicable speed will be 84 mph (135 km/hr). The outer loop also includes 24 tangent test sections of 1200' (364 m) each. The number of tangent sections was based on the anticipated number of concurrent tests. The facility layout, particularly the earthwork, should provide for eventual double tracking on 150' (45.6 m) track centers. The second outer track when constructed would be used for non-conventional track structures. Due to the higher risk involved in testing non-conventional structures, each individual section will require a bypass capability. The present outer loop will serve that purpose and will also be available for additional tests for further optimization of conventional track structures.

The inner loop includes a 3° (580 m) curve which limits the maximum speed to 60 mph (96.5 km/hr). The capability to test on a 3° (580 m) curve is an integral part of the functional requirements. The undulating diagonal combined with the inner loop and a second diagonal provide the reverse running capability needed to reverse traffic direction and the car and running gear orientation. The speed will be restricted on the diagonals consistent with normal safety limits.

The mini-loop (Rail Test Loop) includes 5° (348 m), 7° (249 m) and 10° (175 m) curves to permit maximum accumulation of tonnage in the least amount of time.

TEST SECTIONS	LENGTH	TEST SECTIONS	LENGTH
A (1 to 4)	4800' (1460 m)	F (1 to 4)	4800' (1460 m)
B (1 to 4)	4800' (1460 m)	G (1 to 9)	10,800' (3283 m)
C (1 to 4)	4800' (1460 m)	H (1 to 9)	10,800' (3283 m)
D (1 to 4)	4800' (1460 m)	J (1 to 4)	4800' (1460 m)
E (1 to 4)	4800' (1460 m)	K (1 to 4)	4800' (1460 m)
S (1 to 4)	600' (182 m)	L (1 to 3)	3600' (1094 m)

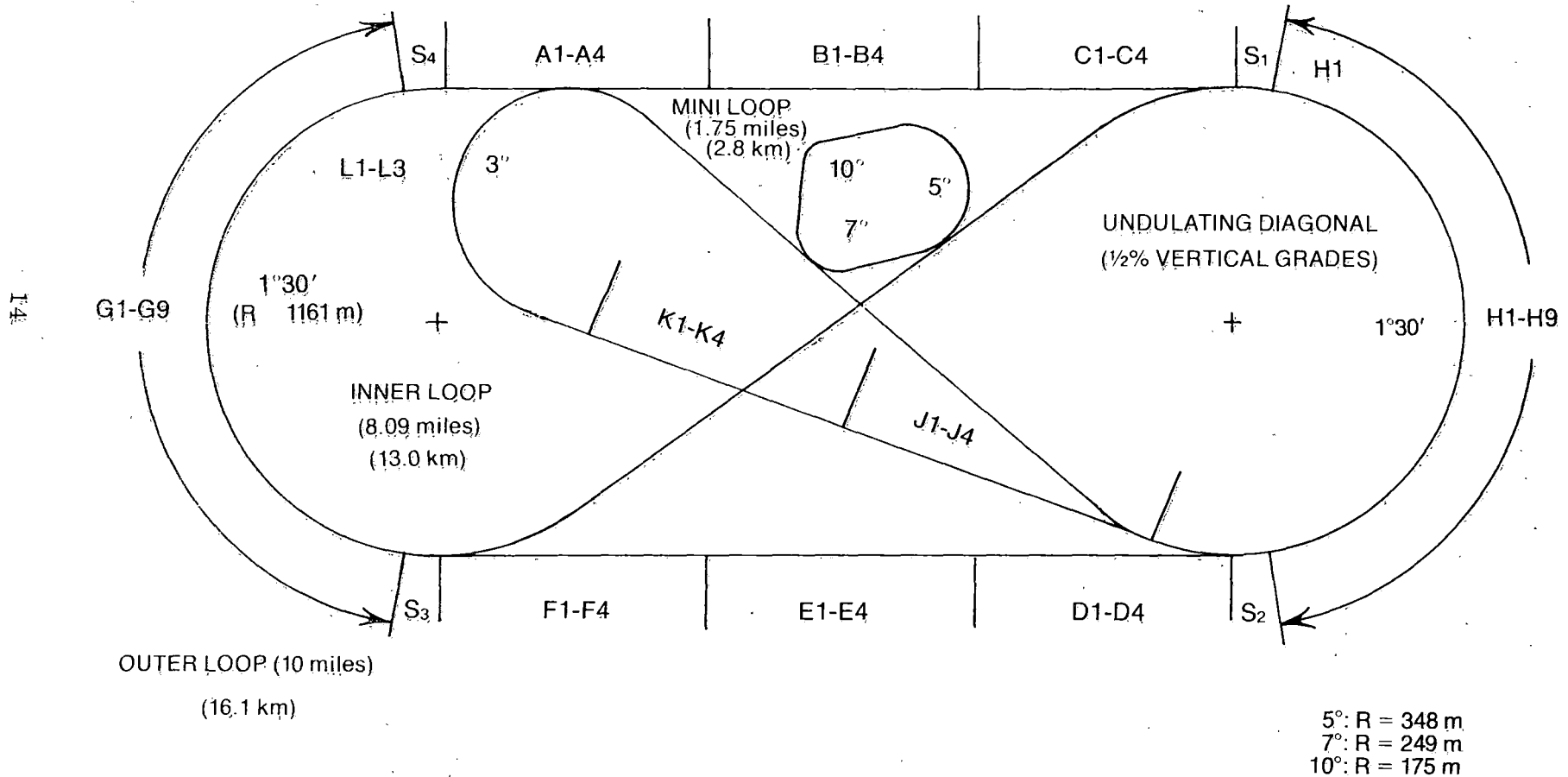


Figure 4.1 FAST—Proposed Initial Configuration

The 10° (175 m) curve limits the maximum operating speed to around 32 mph (51.5 km/hr). The 5° (348 m) and 7° (249 m) curves are initially superelevated for the 30 mph (48 km/hr) traffic. Figure 4.2 shows the mini-loop. The outer loop tangent sections are each 1200' (365 m) long with the central 1000' (304 m) constituting the actual test section. The sections are labelled in groups of four with a view to minimizing differences between adjacent sections when possible. For example, test sections B1 through B4 may all use trap rock for ballast, with only depth beneath the tie varied.

The inner loop tangent sections are also 1200' (365 m) each, with the central 1000' (304 m) test section. Extra maintenance, when necessary, will be performed on the 200' (60 m) separation between adjacent test sections to avoid a dynamic carry over that develops between adjacent sections.

Sections B1-B4 and C1-C4, should be designed to permit a change in subgrade. The depth of subgrade change should be at least 8'.

Figure 4.3 shows a general FAST layout including a location of all significant elements required for facility operation such as a hotbox detector, dragging equipment detector, broken rail detector, control tower and other features.

Figure 4.4 shows an approach to integrating the FAST with the DOT Pueblo High Speed Ground Test Center.

4.1 Traffic Recommendations

The FAST should be designed to have a full range of traffic capabilities. Passenger trains running on FAST would represent one end of the spectrum, and heavy 10,000 (9070 metric tonnes) to 15,000 ton (13605 metric tonnes) freight trains with 125 (113.4 metric tonnes) ton axle loads, the other.

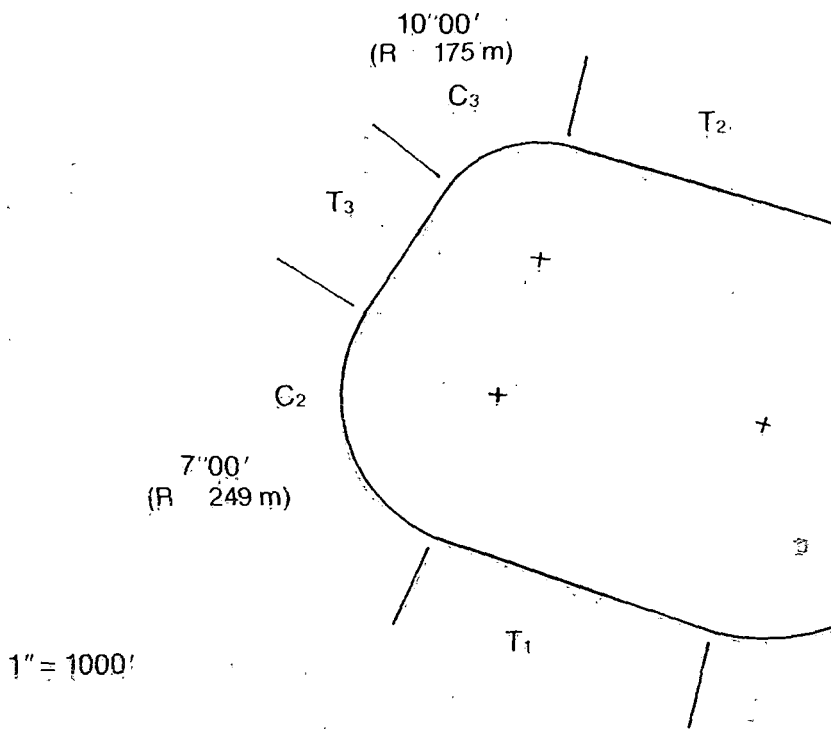
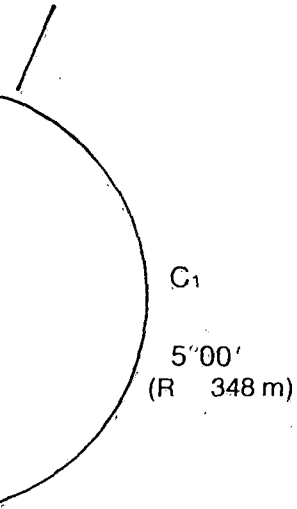


Figure 4.2 Proposed Mini—Loop

TEST SECTIONS

T1	1500'	(456 m)
T2	1500'	(456 m)
T3	850'	(258 m)
C1	3600'	(1094 m)
C2	1200'	(364 m)
C3	600'	(182 m)



TOTAL LENGTH 1.75 miles
(2.8 km)

p—FAST

W-F = WHEEL FAX
 H-B = HOT BOX
 D-E = DRAGGING EQUIPMENT DETECTOR
 A.T.C. = AUTOMATIC TRAIN CONTROL

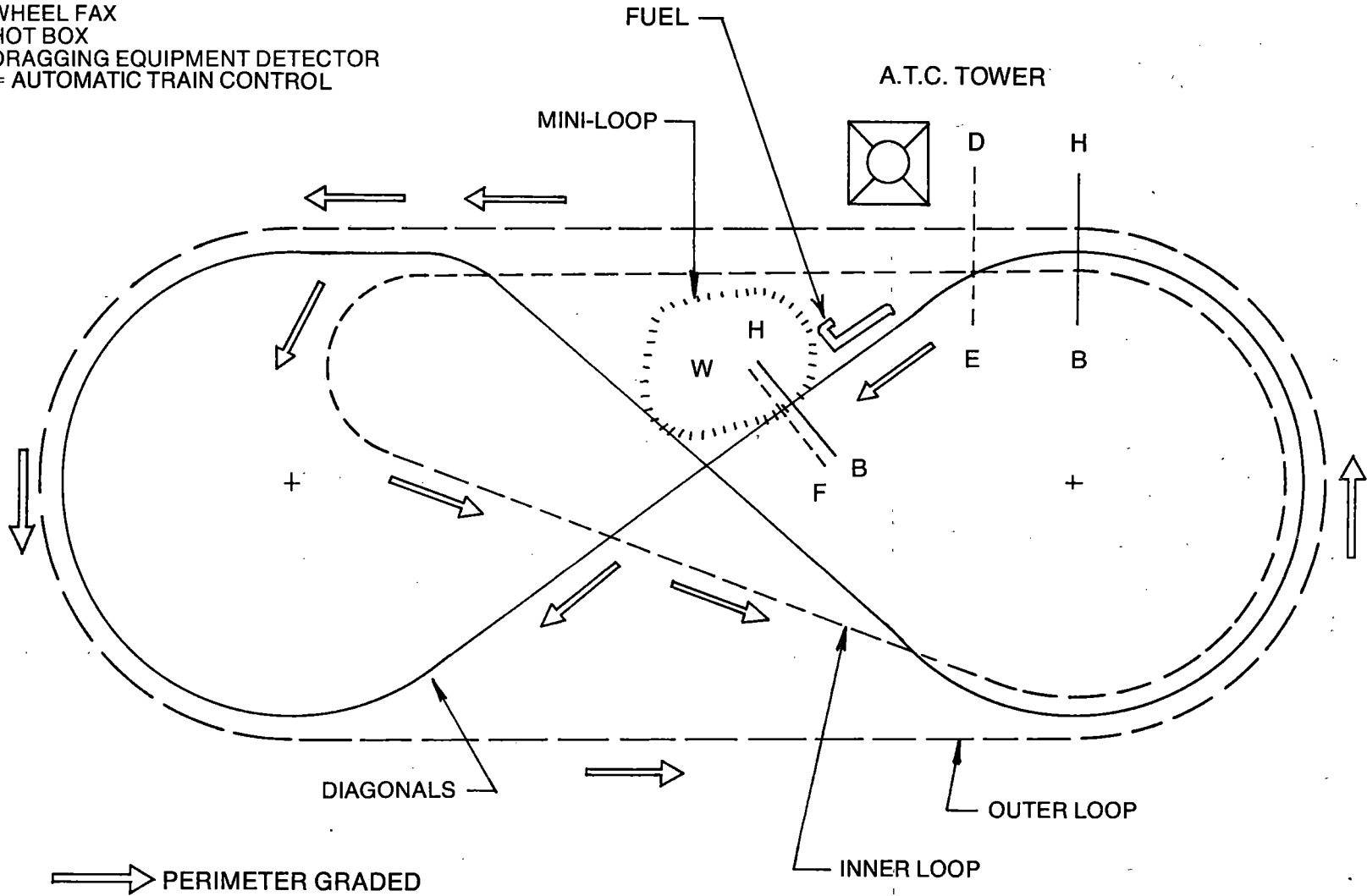


Figure 4.3 General FAST Layout

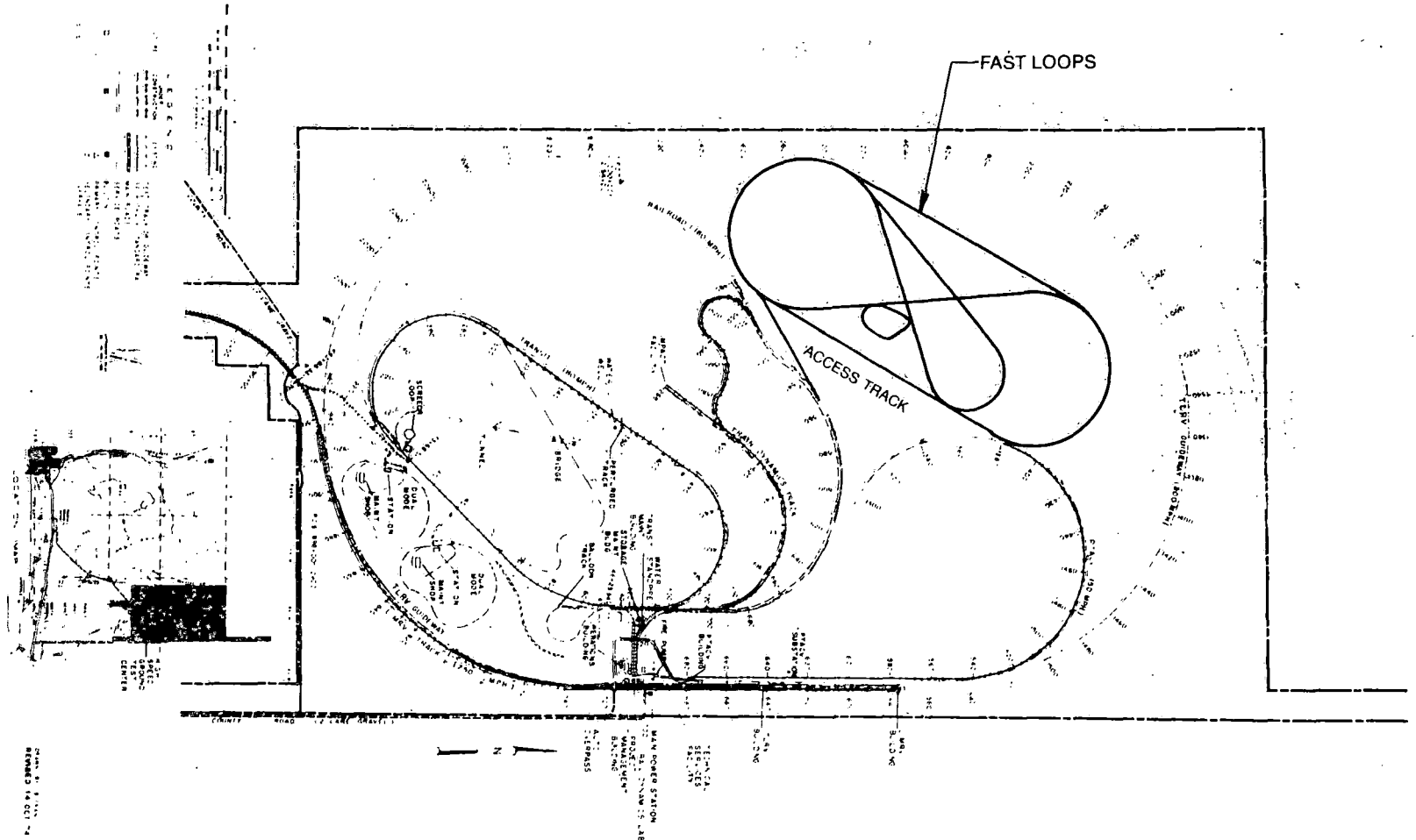


Figure 4.4 Approach To Integrating FAST With DOT/High Speed Ground Test Center

For general use, three types of traffic are recommended. A representative random mix of cars should be acquired for use with the initial test series. This random mix should be representative of average main line trains in terms of types of cars, axle loads, percent empty, percent loaded, car lengths and total train tonnage. The lateral loads applied are a function of drawbar forces and unrepresentative train sizes are not desirable except for tests where train size or axle loads are the independent variables. The representative tonnage for a random mix train has been estimated at 6500 tons (5850 metric tonnes).

The second type of traffic recommended is of the unit train type where identical 100 ton capacity cars (90.7 metric tonnes) and 10,000 ton (9070 metric tonnes) trains are common. For certain lines, this represents the predominant traffic.

The third type of traffic recommended is of the unit train type using 70 ton (63.5 metric tonnes) capacity cars.

The traffic on each of the main line segments of the national rail network can be characterized by speed (governed by curvature), train size (tonnage and length), axle loads (generally mixed except for coal or ore hauling operations), traffic density (MGT/year) and direction.

The traffic can not be applied in real time if an accelerated service test is desired. With a few exceptions 50 MGT (45 Metric MGT) per year is generally regarded as the current maximum traffic density.

A discussion of each of the functional elements follows in Sections 4.2 to 4.6 to provide some background to the test loop recommendations. The full rationale is given in Part II of this report.

4.2 Curvature

Test runs on tangent track can not be extrapolated to curve conditions due to the nature of the loading environment and the determination of the loading environment is a requirement of FAST. Acceptable confidence limits on this environment for the range of curvatures must be provided.

The range of curvature includes curves to 10° (175 m) and special track components such as turnouts and crossovers.

Table 4.1 shows the equilibrium and permissive speeds for a range of curvature. Clearly, it can be seen that except for use with short, fast trains widely differing curvatures can not be used on the same loop without restricting the speed to the allowable value for the tightest curve.

4.3 Loop Geometry

Many basic configurations were examined. Figure 4.5 shows a few of the configurations examined. Shown on Figure 4.5 are some of the attributes of each configuration.

Minimizing loop length for mechanical tests is not essential since only the train speed determines the rate of car mile accumulation. A loop for mechanical tests alone would consist of the range of curvature and grade in proportion to actual operation track mileage seen in real life. The shape of the loop would be selected to provide the right mix of curvature.

Table 4.1 Equilibrium and Permissive Speeds on Curves

<u>CURVATURE</u>	<u>EQUILIBRIUM SPEED</u>	<u>PERMISSIVE SPEED</u>
1°30' (1161 m)*	69 MPH (111 km/hr) 4 3/4" (120 mm)	84 MPH (135 km/hr) 4 3/4" (120 mm)
3°00' (580 m)	55 MPH (88 km/hr) 6 " (152 mm)	64 MPH (102 km/hr) 6 " (152 mm)
5°00' (348 m)	42 MPH (67 km/hr) 6 " (152 mm)	50 MPH (80 km/hr) 6 " (152 mm)
7°00' (249 m)	35 MPH (56 km/hr) 5 3/4" (146 mm)	41 MPH (65 km/hr) 5 3/4" (146 mm)
8°00' (217 m)	34 MPH (54 km/hr) 5 " (127 mm)	37 MPH (59 km/hr) 5 " (127 mm)
10°00' (174 m)	28 MPH (45 km/hr) 4 1/2" (114 mm)	32 MPH (51 km/hr) 4 1/2" (114 mm)

*Curve radius is metres

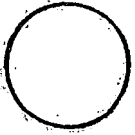
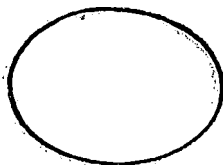


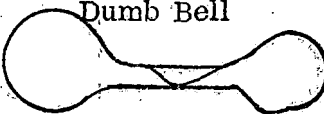
<u>Name</u>	<u>Includes</u>	<u>Excludes</u>	<u>Characteristics</u>
Circle, Ring 	One Radius	Tangent Spiral Varying Radii Turnouts Frogs Reverse Running	Rapid Traffic Accumulation
Elipse 	Varying Radii	Tangent Turnouts Frogs Reverse Running	
Race Track 	Two or More Radii	Reverse Cvs. Reverse Running	
or 			
Dumb Bell 	Variety of Curves Tangent Spiral Reverse Cv. Frogs		Max. Flexibility Lowest rate of Traffic Accumulation

Figure 4.5 Basic Loop Configurations Considered

For track research tests, the loop size must be as small as possible consistent with the demand for test sections. The ideal loop would be one that was used over its full length for tests. Test sections are required that are basically incompatible with each other due to speed limitations imposed by their very nature. It was demonstrated that widely different curves such as a $1^{\circ}30'$ (1161 m) curve and 10° (174 m) curve combined on a loop results in applying traffic to the $1^{\circ}30'$ (1161 m) curve at an unrepresentative lower speed dictated by the 10° (174 m) curve. Also, the extra length of the $1^{\circ}30'$ (1161 m) lowers the traffic rate further. Turnouts and crossings place similar speed restrictions. For this reason, the ability to test different curve test sections can only be provided by separate loops.

There is a minimum amount curve length associated with each degree of curvature. A loop must provide a central angle of at least 360° . For a given degree of curvature a Ring Track provides the shortest loop length. Table 4.2 shows Ring Track lengths for various degrees of curvature and trip times. For a $1^{\circ}30'$ (1161 m) curve, minimum loop length is 4.12 miles (6.6 km). This minimum length of curve is available for use as test sections irrespective of the needs. Addition of tangent sections decreases traffic application rate and increases trip time.

Table 4.3 shows lengths of loops for various curves combined with a $1^{\circ}30'$ (1161 m) curve on one end and associated trip times.

Figure 4.6 shows variation of trip time for various tangent lengths used with $1^{\circ}30'$ (1161 m) curves on each end. The length of tangent must be selected on the basis of the anticipated test work load. The cost per test

Table 4.2 Ring Track Lengths

Curve Radius		Degree of Curve	Total Ring Length		Superelevation Maximum		Trip Time and Permissive Speed #			Trip Time and Equilibrium Speed #			Maximum Daily Traffic*	
Feet	Mètres		Miles	km	Inches	mm	Minutes	MPH	km/hr	Minutes	MPH	km/hr	MGT	Metric MGT
5730	1740	1°	6.81	10.95	3-1/4"	57	4.49	91	145	5.83	70	112	1.02	.92
3820	1631	1°30'	4.12	6.62	4-3/4"	120	2.94	84	134	3.38	69	110	2.40	2.17
1910	580	3°	2.28	3.66	6"	152	2.13	64	102	2.48	55	88	3.08	2.79
1146	348	5°	1.36	2.18	6"	152	1.63	50	80	1.94	42	67	3.64	3.30
716	217	8°	0.85	1.36	5-1/4"	133	1.37	37	59	1.64	31	49	3.81	3.45
573	174	10°	0.68	1.09	4-1/2"	114	1.27	32	51	1.45	28	44		

Based on major railroad recommendations.

* With 5000 ton train - 50'-100 ton cars and equilibrium speed - 20 hrs/day operation.

Table 4.3 Trip Times Around Loop for Curve Combinations

Curves	Equilibrium Speed, Permissive Speeds, Superelevation	Tangent Length		Loop Length			Equilibrium Speed	Permissive Speed
		1000 ft	1000 m	Feet	Miles	km		
1° 30' (1161 m) & 1° 30' (1161 m)	E = 69 mph (110 km/hr)	4	1.21	31,989	6.06	9.69	5.27	4.33
	P = 84 mph (134 km/hr)	6	1.82	35,989	6.82	10.91	5.93	4.87
	S = 4 3/4 in (120 mm)	8	2.42	39,989	7.38	11.80	6.42	5.27
		10	3.04	43,989	8.33	13.32	7.24	5.95
		20	6.08	63,989	12.12	19.39	10.54	8.66
		31.96	9.71	87,922	16.65	26.64	14.48	11.89
3° & 1° 30'	E = 55 mph (88 km/hr)	4	1.21	27,693	5.24	8.38	5.71	4.91
	P = 64 mph (102 km/hr)	6	1.82	31,169	5.90	9.44	6.44	5.53
	S = 6 in (152 mm)	8	2.42	34,888	6.61	10.57	7.21	6.19
		10	3.04	38,712	7.33	11.72	8.00	6.87
		20	6.08	58,600	11.10	17.76	12.11	10.41
5° & 1° 30'	E = 42 mph (67 km/hr)	4	1.21	26,744	5.07	8.11	7.25	6.08
	P = 50 mph (80 km/hr)	6	1.82	29,834	5.65	9.04	8.08	6.78
	S = 6 in (152 mm)	8	2.42	33,318	6.31	10.09	9.02	7.57
		10	3.04	36,990	7.01	11.21	10.00	8.41
		20	6.08	56,000	10.60	16.96	15.15	12.71
						32	37	
8° & 1° 30'	E = 32 mph (51 km/hr)	4	1.21	26,338	4.99	7.98	9.36	8.10
	P = 37 mph (59 km/hr)	6	1.82	29,207	5.53	8.84	10.37	8.96
	S = 5 1/4 in (133 mm)	8	2.42	32,541	6.16	9.85	11.55	9.99
		10	3.04	36,113	6.84	10.94	12.81	11.10
		20	6.08	55,200	10.44	16.70	19.57	16.95
10° & 1° 30'	E = 28 mph (44 km/hr)	4	1.21	26,459	5.01	8.01	10.73	9.39
	P = 32 mph (51 km/hr)	6	1.82	29,008	5.49	8.78	11.75	10.30
	S = 4 1/4 in (107 mm)	8	2.42	32,298	6.11	9.77	13.10	11.46
		10	3.04	35,833	6.79	10.86	14.55	12.71
		20	6.08	54,500	10.31	16.49	22.12	19.35

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- 1° 30': R = 1161 m
- 3°: R = 580 m
- 5°: R = 348 m
- 8°: R = 217 m
- 10°: R = 174 m

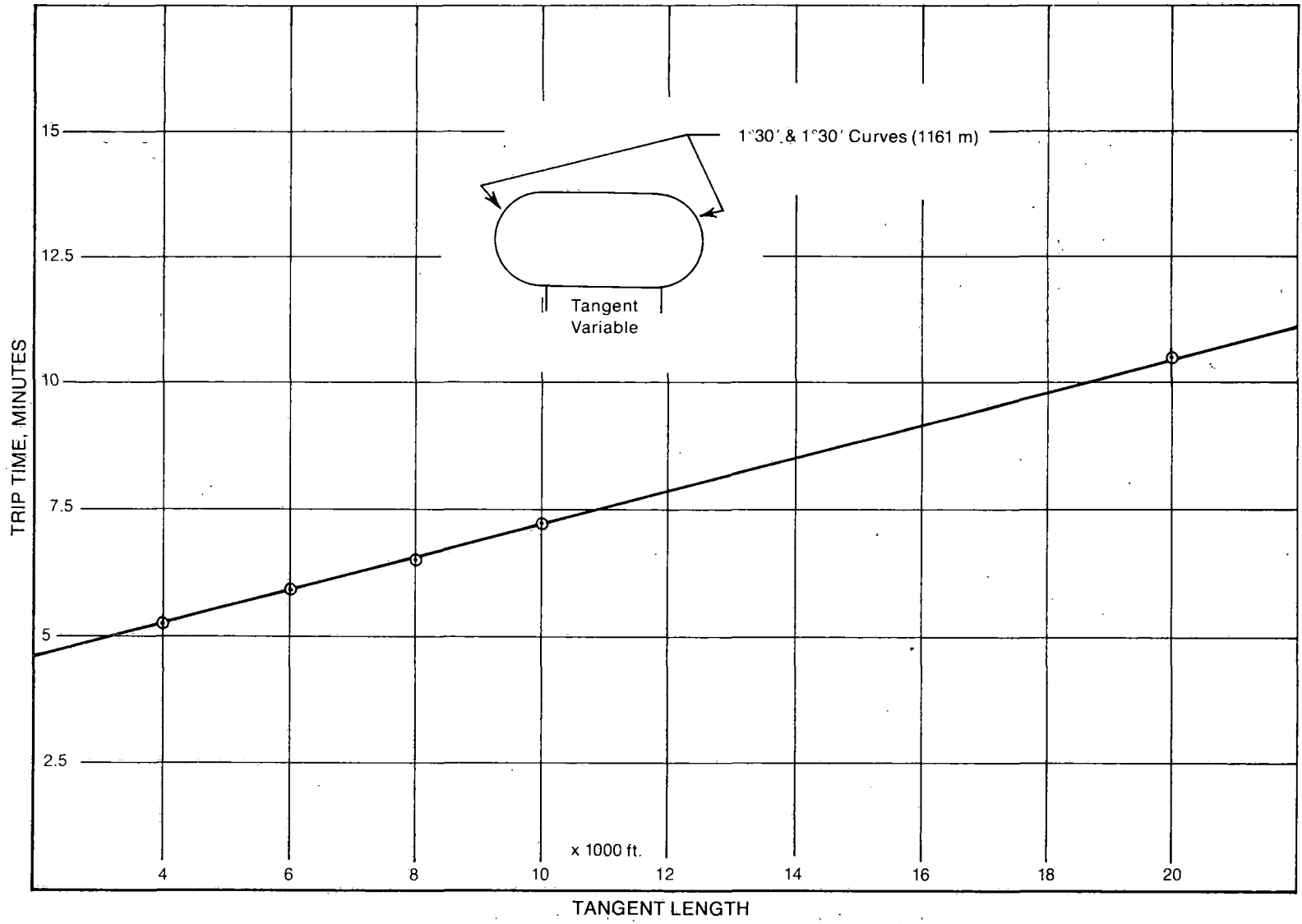


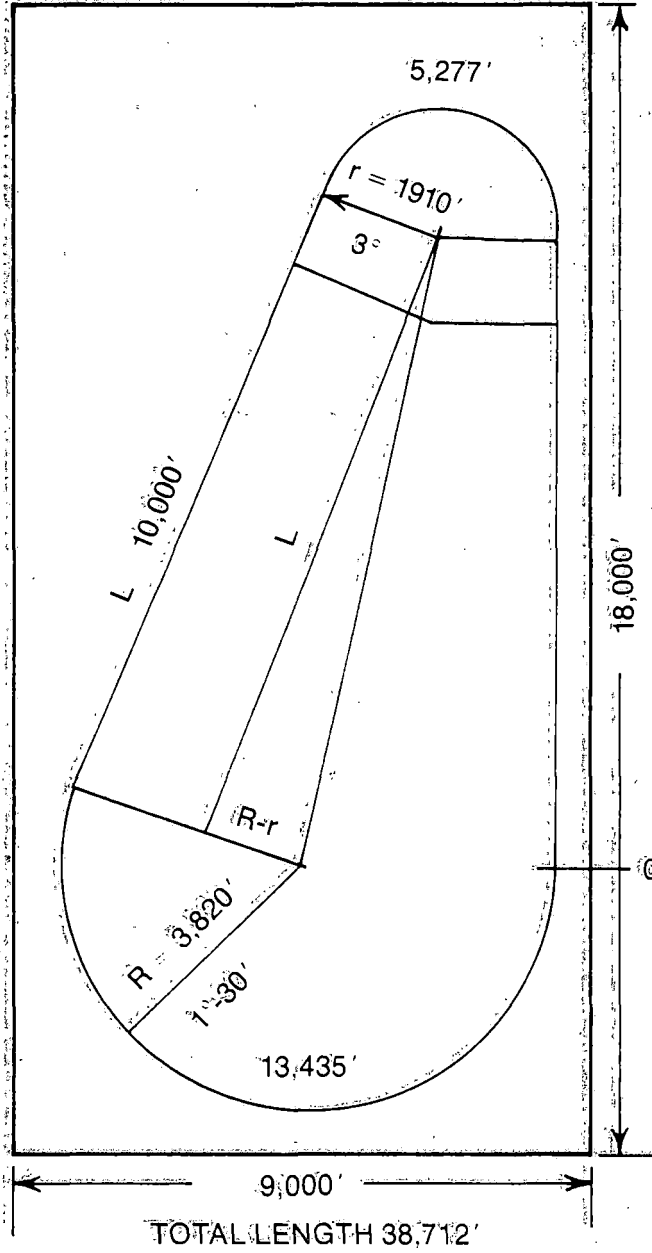
Figure 4.6 Variation In Trip Times With Tangent Length

decreases as the number of concurrent tests run are increased. The traffic application rate and consequently the duration of the test increases. While increasing the train size to compensate for increased trip time appears attractive, it is not desirable in view of the fact that unrepresentative train sizes are not representative of the loading environment.

Consider the loop in Figure 4.7 and Figure 4.8. They contain the same curves $1^{\circ}30'$ (1161 m) and 3° (580 m). These curvatures are within the limits of being compatible. The dumbbell shape (Figure 4.8) provides a greater amount of curve length than does the modified race track (Figure 4.7). The need for tangent test section lengths is far greater than those for curve test sections, consequently the modified race track configuration is preferred.

Consider the configurations again with respect to tangent sections. If no curve tests were planned and the curves used solely to reverse traffic, the end curves would be selected on the basis of the speeds desired over the tangent sections. If the maximum speed desired on the tangent sections were 60 mph (96.5 km/hr) then it would be most desirable to have a 3° (580 m) curve on each end, thereby reducing length and non-productive trip time (time on curves). If the maximum speed on tangent sections were required to be 75 mph (120.7 km/hr) the 3° (580 m) curve would have to be replaced by a $1^{\circ}30'$ (1161 m) curve.

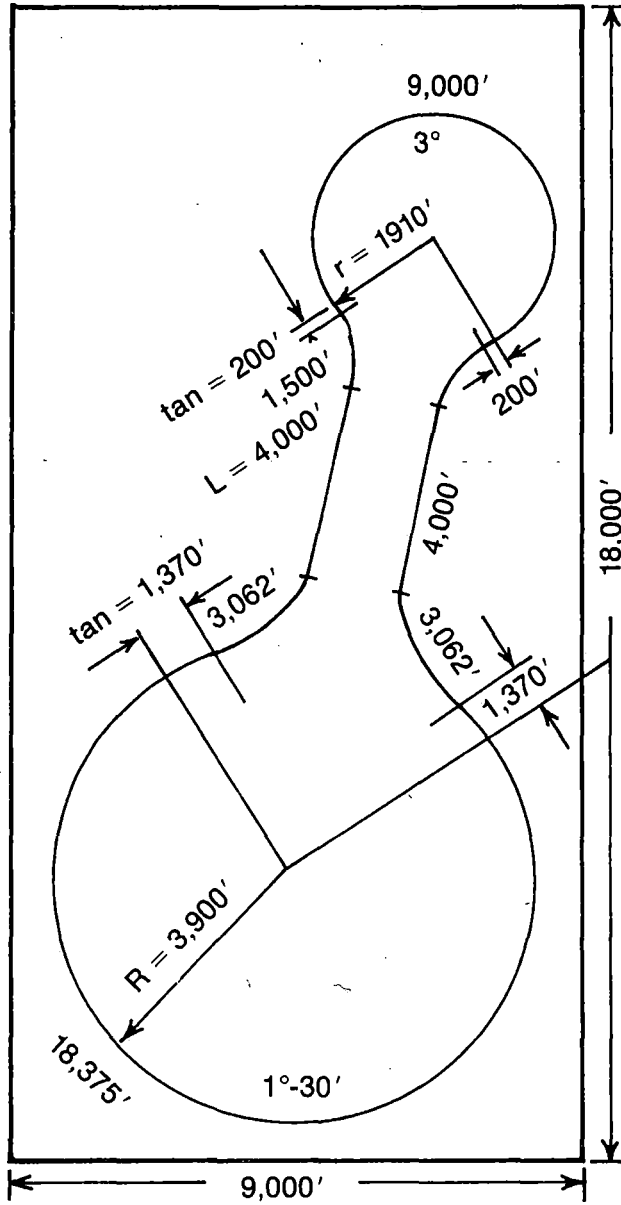
The functional requirements do require tests on curves of 3° (580 m) as well as $1^{\circ}30'$ (1161 m) along with tests at 75 mph (120.7 km/hr) speeds on tangent sections.



Scale 1" = 3,000'

$1^\circ 30'$ (R = 1161m)
 3° (R = 580m)
 $1'$ (R = 0.304m)

Figure 4.7 Modified Race Track Configuration



TOTAL LENGTH 47,639'

Scale 1" = 3,000'

1°30' (R = 1161 m)

3° (R = 580 m)

1 ft. (R = 0.304 m)

Figure 4.8 Dumbell Configuration

Tests on switch points and crossings are also required. These, however, also place speed restrictions.

Traffic reversal is necessary to simulate traffic on a single track with respect to rail creepage and shear reversals in locations such as in the rail head. The need also arises to reverse the direction of car travel and the orientation of car and running gear with respect to high side of the curves so that normal load patterns are obtained. Diagonals are necessary to provide the reverse running capability. The turnouts required place speed limitations on these operations.

4.4 Considerations for Mechanical Tests

The service environment for mechanical equipment is characterized by operation at various speeds, track curvature, empty or loaded, various temperatures, track quality and terrain. For example, the following estimate was made for a hopper car by a major railroad:

Speed Range Data

<u>Speed mph</u>	<u>% Miles Run</u>
0-9	3
10-19	10
20-29	16
30-39	24
40-49	26.5
50-60	20.5

(1 mph = 1.609 km/hr)

The empty car miles may be up to 50% of the total miles. Other characteristics to consider include the number of service brake applications per mile run, the number of 1⁰ (1741 m), 3⁰ (580 m), 5⁰ (348 m) and

10⁰ (17½ m) curves negotiated per mile run and the percentages of miles run in rainy weather or at lower temperatures.

The cumulative wear and fatigue damage to a freight car or locomotive is not accrued in the same proportion as the percentage of miles run at a given speed range. It is anticipated that over the course of the tests the full range of speeds will have been used so that a close simulation of speed ranges will be necessary on the FAST loop.

The major inadequacies of the FAST loop configuration recommended with respect to simulation of in-service operation of mechanical components are expected to be as follows:

- a. Significantly lower number of brake applications per car mile run unless programmed brake application and release is provided for at a sacrifice in the number of car miles run per test period.
- b. Absence of major terrain-induced train action.
- c. No yard impacts.

Some of these inadequacies can be overcome if the additional loop described in Section 4.7 is constructed.

A car operating on the FAST loop will, depending on the loop configuration, negotiate more curves per mile run than it would under in-service operation. Consequently, if a test is primarily concerned with wheel wear on curves, the significant portions of in-service operation may be applied with far fewer actual car miles run. Such considerations are pertinent to other car components also.

The track condition, at all times, will be fairly well defined. Track maintenance, in general, will be consistent with normal or proposed practice. Certain specific track structure tests, may in certain cases, make it advisable to include only random mixed consist cars (those not being monitored for specific mechanical tests).

4.5 Considerations for Track Tests

The loading environment to which track sections are subjected is determined by the following.

1. Geographical location (weather)
2. Nature of the track section (curve, tangent, turnout, etc.)
3. Nature of traffic axle loads, speeds, vehicle dynamic characteristics, train handling and make up.
4. Traffic density
5. Heavy braking or acceleration territory
6. Track maintenance level
7. Track modulus
8. Other track characteristics (cant, gage, tie spacing, CWR or jointed, etc.)
9. Adhesion level (curve lubrication, sanding)

The rate of traffic application of one million gross tons (MGT) per day will permit the application of up to 150 MGT of traffic without overlapping ground frost conditions.

The FAST must include many types of track section such as tangents, curves, and turnouts.

The simulation of heavy braking or acceleration territory or of locations where unusually high lateral loads occur due to run-in or run-out is not specifically within the scope of FAST.

A nominal amount of braking and acceleration will occur with normal start-up and stops. This can be augmented to provide some balance in the loading environment. This aspect can be combined with the need to balance the mechanical environment with vertical curves and lateral curves. An undulating diagonal has been provided for vertical curves.

Track maintenance requirements will be determined for each individual test section with the exception of the transition sections where track maintenance will be undertaken as necessary on a daily basis to prevent dynamic overlay of vehicle response.

The capability to add curve lubrication on the mini-loop is necessary as this reflects operating practice.

4.6 Selecting Test Section Lengths

The complete rationale of selecting test section length is covered in Part II. No permanent delineation of where a test section commences or ends is contemplated except as determined by the loop geometry. Consequently, the theoretical upper limit for a tangent test section is 14,000 ft. (4377 m). However, a 1000 ft. (304 m) length has been designated as the maximum length required. This provides suitable sample sizes for every failure mode known and for track geometry quality measurement.

All dynamic modes together with associated modal frequencies and responses to anticipated input at expected operating speeds have been examined for a variety of freight cars. In selecting test sections, lengths of 1200' (364 m) have been designated as separate test sections. One hundred feet at the end of each section will be designated as being a transition zone where test measurements will not be made and where track maintenance will be carried out as required on a daily basis to avoid dynamic interaction between adjacent sections. In addition, tests scheduled for adjacent sections by scheduling will have track dynamic stiffnesses matched as closely as possible. It is also expected that the nature of the loading environment will be monitored on a continuing basis.

4.7 Mechanical Loop

It is desirable that a mechanical loop also be built in addition to the main FAST loop.

This is a description of such a separate dedicated test track loop for mechanical tests alone. The recommendation for an additional mechanical loop should not be construed to mean that the main loops recommended are not suitable for mechanical tests. Rather, the conflicts placed on the number and types of mechanical and track tests that can be conducted will be substantially reduced if the separate mechanical and track loops are available.

The major areas where conflicts develop and compromise is required for joint use of a loop for track research and mechanical research are:

- a. programmed braking, including dynamic braking,
- b. maximum number of non-standard cars in a train consist,
- c. maximum number and length of non-conventional track section,
- d. introduction of programmed irregularities into mechanical environment,
- e. train size variation,
- f. tests with equipment outside of the normal loading bounds,
- g. number of train dynamic tests,
- h. loop down-time limitations.

Each of these is a significant limitation for any mechanical test on the main FAST loops.

It is to be remembered that the availability of a test loop for vehicle mechanical tests does not completely obviate the need for real life service testing. This will provide in many cases an opportunity for comparative testing with respect to wear and fatigue life of component parts in assembly under near actual conditions. In addition such testing will be achieved in a relatively short period of time and under controlled conditions.

Eventually the correlation of the loop environment with the actual railroad in-service environment could be possible.

Loop test types, including all types of mechanical wear and fatigue life tests fall in four basic types as follows:

1. The indirect determination of component or mechanical system life and its correlation with service life. One must remember that a one-to-one correspondence between loop mileage and in-service

mileage requiring the exact mix of track, braking, speeds, curvature will not exist.

2. Duplication on the loop facility of extreme effect seen in service with comparative tests on component and assembly variations.
3. Deterministic tests to identify and rank causal factors and to quantify impact of parametric variations on fatigue life and wear.
4. System optimization and demonstration.

All of the tests contemplated can be characterized according to one of the above types. The loop should service each type of test objective described above.

Initial mechanical test series proposed for consideration are as follows:

1. Wheel optimization series
2. Center plate series
3. Truck concept series
4. Securement test series
5. Car design series
6. Surveillance test series
7. Packaging test series
8. Fuel consumption series

An outline description is given in Section 5 of this report.

A loop configuration for mechanical tests alone, is primarily intended to provide supplemental capabilities not available on the main loops. Industry

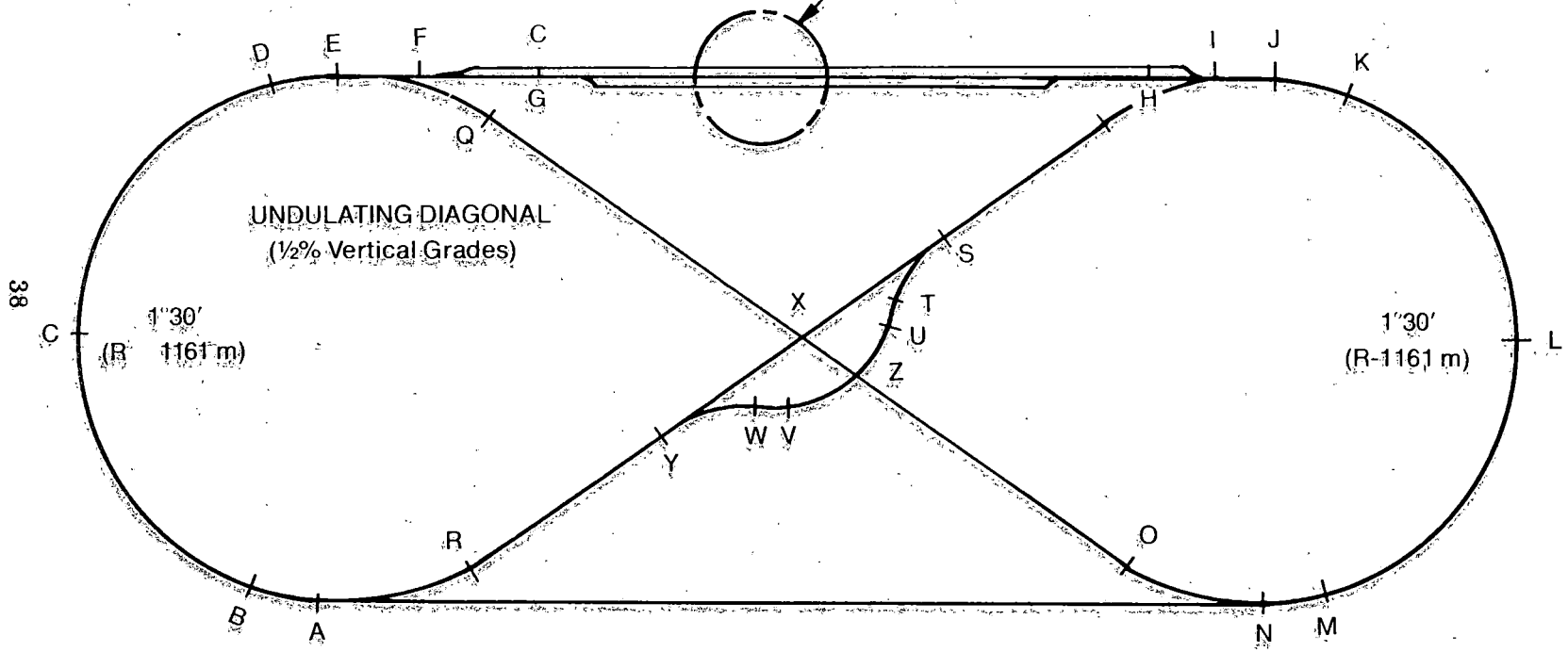
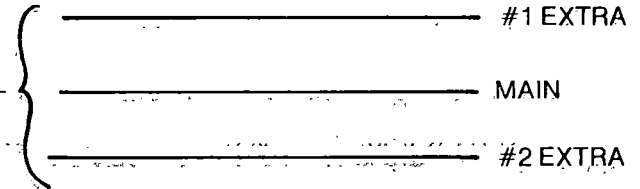
input with respect to loop configuration, anticipated mechanical tests and their objectives were all considered before making recommendations for the mechanical loop.

The mechanical loop configuration is shown in Figure 4.9. The loop curves would be superelevated for 65 mph operation. The diagonals would permit reversals in either direction without stopping. The two bypass sections can be used to program irregularities consistent with speed restrictions imposed by the turnouts for the crossovers. No. 20 turnouts used for the reversing diagonals will determine the limiting speed on the diagonals. These will permit irregularities at a higher speed. The undulating diagonals will provide vertical curves. Table 4.4 shows the specific loop geometry. A mix of main line levels of track maintenance is suggested for the mechanical loop.

Use of 132# (60 kg) CWR is recommended on most tangent sections, and 132# (60 kg) jointed rail on all other trackage. 7" x 9" x 8' 6" (177 mm x 228 mm x 2.58 m) mixed hardwood ties, on 19 1/2 inch (495 mm) centers are recommended. Six inches (151 mm) granular sub-ballast used with 9 inches (228 mm) crushed and graded traprock is recommended. These recommendations are made so that the mechanical loop will be representative of track in general use.

The mechanical loop will permit accumulation of car mileage in any desired mix of speeds, track maintenance level, consist location, and brake applications. It is anticipated that a program for brake applications will be

TRACK SECTION	GRADE	RAIL
AN,EJ	LEVEL	132#CWR
PR	LEVEL	132#CWR
AE,JN	LEVEL	132 JOINTED
#1 TRACK	LEVEL	132 JOINTED
#2 TRACK	LEVEL	132 JOINTED
OTHER	LEVEL	132 JOINTED
QO	1/2%	132 JOINTED



INDIVIDUAL SECTIONS MAINTAINED AT VARIOUS LEVELS

OUTER LOOP
(10 miles) (16.1 km)

TOTAL TRACKAGE = 21.42 miles (34.27 km)

Figure 4.9 Mechanical Loop

Table 4.4 Mechanical Loop Geometry

Track Section	Degree	Curvature		Length		Grade
		Ft.	Meters	Ft.	Meters	
A-B	Spiral/Curve			600	182	Level
B-C	1°30'	3820	1161	5400	1640	Level
C-D	1°30'	3820	1161	5400	1640	Level
D-E	1°30'	3820	1161	600	182	Level
E-F	Tangent	-	-	1300	395	Level
F-G	Tangent	-	-	2450	744	Level
G-H	Tangent	-	-	6900	2097	Level
H-I	Tangent	-	-	2450	744	Level
I-J	Tangent	-	-	1300	395	Level
J-K	Spiral/Curve	-	-	600	182	Level
K-L	1°30'	3820	1161	5400	1640	Level
L-M	1°30'	3820	1161	5400	1640	Level
M-N	Spiral/Curve	-	-	600	182	Level
N-A	Tangent	-	-	14400	4377	Level
N-O	Spiral/Curve	-	-	2000	608	Level
O-Z	Tangent	-	-	5200	1580	+1/2*
Z-X	Tangent	-	-	1175	357	Level
X-Q	Tangent	-	-	6375	1938	+1/2
Q-E	Spiral/Curve	-	-	2000	608	Level
A-R	Spiral/Curve	-	-	2000	608	Level
R-Y	Tangent	-	-	3750	1140	Level
Y-X	Tangent	-	-	2625	798	Level
X-S	Tangent	1910	580	3000	912	Level
S-P	Tangent	-	-	3375	1026	Level
P-J	Spiral/Curve	-	-	2000	608	Level

*Undulating grades to suit site topography.

Table 4. 4

Track Section	Degree
S-T	3 ⁰
T-U	Tangent
U-Z	3 ⁰
Z-V	3 ⁰
V-W	Tangent
W-Y	3 ⁰
# 1	Tangent with #20 crossovers
# 2	Tangent with #10 crossovers

Mechanical Loop Geometry (Continued)

Curvature		Length		Grade
Ft.	Meters	Ft.	Meters	
1910	580	1125	342	Level
-	-	400	121	Level
1910	580	1475	448	Level
1910	580	1600	486	Level
-	-	400	121	Level
1910	580	1000	304	Level
-	-	12750	3876	Level
-	-	10125	3078	Level

adopted for each mileage series. Mechanical tests not requiring the functional capabilities available exclusively on the mechanical loop would be run on the main FAST loops.

4.7.1 Programmed Irregularities on Mechanical Loop

Programmed irregularities can be introduced on any of the sections when a deterministic test is planned. One example of such deterministic testing is an investigation of component life and wear in a "rock and roll" service environment. The programmed irregularities can be introduced in two ways. The selected length of section could be permitted to deteriorate to a maintenance level below the level to which it is normally maintained, or alternately, irregularities could be introduced by selective shimming of tie plates or similar means, consistent with the number and type of irregularities desired in the specification of the environment needed for the deterministic test.

Two extra tracks, bypasses around the main loop have been provided for the purpose of including specific programmed irregularities in the environment seen by cars by controlling the number of passes over the extra track.

4.7.2 Traffic Recommendations for Mechanical Loop

Mechanical tests will require normal size trains in order to simulate real life traffic. Consequently, a train consist with 85 cars, as is recommended for the main FAST loops, should be used. Each car acquired should serve as a test car also.

For normal use, it is recommended that four 3600 HP diesel electric units be acquired. These also should serve as test units.

The detailed specifications for the purchase of cars and locomotives should be based on specific initial use for the initial mechanical tests planned.

Some initial traffic will be necessary on the mechanical loop to achieve track consolidation and degradation to a level to which it will be maintained.

5.0 PROPOSED INITIAL TEST SERIES

The choice of test variables, whether track or mechanical, will invariably depend on the defined short and long term research needs, when loop construction is in the imminent future.

The proposed initial test series were developed as an aid for defining the rationale for selecting the initial loop configurations. In addition, the proposed initial test series constitute the framework within which a detailed near term test plan could be developed.

The railroads and the supply industry have been consulted in developing the proposed initial test series. The safety and economic benefits to be derived from each test series accounts for the major reason for selecting the tests proposed.

Each test series consists of several individual tests. The initial test series, it is expected, can be completed within two years. Approximately twelve traffic time periods may be used. The traffic parameters - cars, locomotives, speed, axle loads - will stay constant during each time period.

The total traffic requirements for tests will vary for each series. The tests within the settlement rate series, will on the average require a maximum of 150 MGT (135 Metric MGT) of traffic. Tests with substitute ties will require at least 300 MGT (270 Million Metric Tons). While estimates of this type are needed for purpose of planning, a certain amount of flexibility is desirable with respect to continuation of tests beyond the estimated traffic levels.

The test series described have been outlined so as to provide some idea as to the nature, type and number of tests. The specific details of each test, such as the exact design of the substitute tie are not pertinent. It is important, however, that substitute ties be tested and at least 300 MGT of traffic is expected to achieve reliable results.

5.1 Proposed Initial Track Test Series

A brief outline of each proposed test series is given below, including in summary form, the basic objectives, the areas of primary and in some cases the secondary benefits, and the parameters to be varied. General instrumentation requirements are listed in section 6.6 of the report.

A preliminary list of individual tests has also been developed. For each test the pertinent parameters have been selected. These are shown in Appendix I.

5.1.1 Settlement Rates Series

Objectives: To reduce periodic track maintenance costs.

Primary benefit areas:

Surfacing costs
Lining costs
Joint Maintenance costs

Secondary benefit areas:

Railwear - general
Tie Life
Ballast Degradation
Sub-grade Failure

Parameters to be varied:

a. Rail: 1) 132# CWR (60 kg), 2) 115# CWR (52 kg), 3) 132# (60 kg)

Jointed, 4) 115# (52 kg) Jointed

(4)

- b. Ballast Type, gradation and depth; twelve combinations (12)*
- c. Sub-grades: Natural and 2 selections (3)
- d. Ties: 7"x9"x9' (177 mm x 228 mm x 2.74 m), 7"x9"x 8 1/2' OAK
(177 mm x 228 mm x 2.58 m) (2)
- e. Speeds 1.75 mph (120.7 km/hr) (4)
2.60 mph (96.5 km/hr)
3.50 mph (80.5 km/hr)
4.40 mph (64.4 km/hr)
- f. Traffic: Random Mix, Unit Train - 70 ton cars, Unit Train (3)
100 ton cars
- g. Track Maintenance FRA - CLASS specified for speed -
- h. Gage - maintained -

5.1.2 Cant Optimization - Curves

Objectives: To determine optimum cant to minimize cost of rail
and track maintenance.

Primary benefit areas:

Railwear
Surfacing costs
Lining costs
Joint Maintenance costs

Secondary benefit areas:

Sub-grade Failure
Tie Life
Ballast Degradation

Parameters to be varied:

- a. Curvature 0^o, 1^o 30' (1161 m), 3^o (580 m), 5^o (348 m), 7^o (249 m),
and 10^o (174 m) (6)

* Numbers in parentheses indicate the number of variations for each parameter.

- b. Cant 1:14, 1:20, 1:30, 1:40 (4)
- c. Speed: Equilibrium, Equilibrium (E) + Unbalance (2)
- d. Gage @ AREA values -
- e. Ballast-One or two specified -
- f. Ties - 7" x 9" x 9' (177 mm x 228 mm x 2.74 m) OAK,
19-1/2" (495 mm) centers -
- g. Traffic: Random Mix -

5.1.3 Gage Optimization on Curves

Objectives: To determine optimum gage variation for each curvature to minimize costs for rail and track maintenance.

Primary benefit areas:

Maintenance of gage
Line
Surface
Joint Maintenance

Parameters to be varied:

- a. Curvature: 1°30' (1161 m), 3° (580 m), 5° (348 m), 7° (249 m),
and 10° (174 m) (5)
- b. Gage: Std, -1/4" (6.35 mm), +1/4", +1/2" (12.7 mm),
+3/4" (19.0 mm) (5)
- c. Anchoring Pattern - one to be specified -
- d. Ballast - one to be specified -
- e. Ties and spacing 7" x 9" x 9', OAK, 19-1/2" centers -
- f. Rail 132# (60 kg) CWR (2)
132# (60 kg) Jointed
- g. Traffic - Random Mix -

- h. Speed - equilibrium (E), $E_{\pm} V_u$ where V_u = Unbalance (3)

5.1.4 Tie Optimization and Development

- Objectives:
1. To optimize tie spacing, and tie design to reduce track maintenance costs.
 2. To develop alternative tie designs to increase tie availability, reduce tie first costs, and to improve total track maintenance economics.

Primary benefit areas:

Tie Life
Ballast Degradation

Secondary benefit areas:

Surfacing
Lining
Gage Maintenance

Parameters to be varied:

- a. Tie Material - Mixed hardwood, laminated wood, concrete (4)
soft woods (fir)
- b. Tie Size - 8', 9' (wood ties only) (2)
2 variations (laminated)
2 variations (concrete)
- c. Tie Spacing - 19-1/2", 21", 24", 27" (4)
- d. Ballast - to be selected -
- e. Rail 132# (60 kg) CWR -
- f. OTM - to be selected -

5.1.5 Maintenance Method Evaluation

To develop the relative economics of various maintenance methods as related to track structure performance under traffic.

For example, cycle times, lift thickness, consolidation, shoulder width, etc.

Primary benefit areas: Increased maintenance efficiency, lowered costs.

Parameters to be varied:

- a. Maintenance method: Cycle time for lift, tie, surface
Characteristics to be varied: Lift thickness (optimization of)
Rail grinding (deviation limit for)
Double insertion tamping
Consolidation - frequency
Shoulder size
Chord lengths for mechanized lining and surfacing
Tie renewals - effect of one pass, two pass
- b. Rails 132# (60 kg) CWR
132# (60 kg) Jointed
- c. Ties 7" x 9" x 9" OAK, (177 mm x 228 mm x 2.74 m)
- d. Other track material - to be selected
- e. Curvature 0°, 1°30' (1161 m), 3°00' (580 m)

5.1.6 Rail Chemistry

- Objectives:
- 1. To increase rail life, particularly for track with high degree of curvature and for lines with high density traffic.
 - 2. To define defect growth rates.

Primary benefit areas: Increased rail life.

Parameters to be varied:

- a. Rail chemistry - High Silicon
Induction Hardened Rail
Fully Heat-treated
Chrome - Moly
Vacuum Degassed Steel Heat-treated
Steel from Strand Cast Blooms Heat-treated
- b. Rail Size - 132# (60 kg) CWR, 132# (60 kg) Jointed

- c. Ballast - to be selected -
- d. Ties - 7" x 9" x 9' (177 mm x 228 mm x 2.74 m) Mixed hardwood -
- e. Other track material - to be selected -
- f. Traffic Parameters - two types to be selected (2)
- g. Curvature 0^o, 1^o30', 3^o, 5^o, 7^o, 10^o (6)

5.1.7 Loading Spectra

This test series will not require separate test sections. It will require the measurement of lateral loads and vertical loads for each of a number of vehicles, at various speeds and track conditions.

These will be useful in establishing track maintenance standards for safety and least maintenance costs.

Objectives: To define the loading environment for each vehicle type for each class of track geometry condition.

Primary benefit areas: Effective use of track maintenance funds with respect to safety and overall cost.

Parameters to be varied:

- a. Track Geometry Conditions (3 or 4 classes) (4)
- b. Vehicle Types - 12 car types, 4 locomotive types (16)
- c. Track Modulus - 4 levels (4)
- d. Before/after Track Maintenance -

5.1.8 Fastener Test Series

Objectives: To reduce rail rollover, rail creepage and to reduce gage maintenance costs.

Primary benefit areas:

Maintenance of Gage
Rail Creepage
Rail Rollover

Parameters to be varied:

- a. Fastening Systems - 4 types to be selected (8)
- b. Curvature - Tangent, 1°30' (1161 m), 3° (580 m), 5° (348 m) (4)
- c. Tie Material - Mixed Hardwood, Softwoods (fir) (2)
- d. Rail Size - 115# (52 kg) CWR, 132# (60 kg) CWR,
115# (52 kg) Jointed, 132# (60 kg) Jointed (4)
- e. Ballast - One to be selected -
- f. Subgrade - One to be selected -
- g. Speed - 75 mph (120 km/hr), 60 mph (96.5 km/hr), 50 mph
(80 km/hr), 30 mph (48 km/hr) (4)
- h. Traffic - Random Mix -

5.2 Proposed Initial Mechanical Test Series

There is an unlimited number of mechanical tests that can be conducted. A general outline is presented for each of the several mechanical series proposed. These are intended to delineate specific mechanical components for tests and the parameters that would be varied in each component area. A specific test plan is beyond the scope of this work.

5.2.1 Wheel Optimization Series

Objectives: To determine the effects of each of several parameters on wheel wear, with conventional trucks.

Primary benefit areas: Lower life cycle costs, improved safety.

Parameters to be varied:

1. Axle load
2. Wheel diameter
3. Profile
4. Center plate - Lubricated or dry
5. Center plate diameter
6. Brake Rigging Type: Truck mounted, Unit, Conventional
7. One-wear/Multiple-wear
8. Wheel Chemistry and heat treatment
9. Brake shoe materials
10. Speeds
11. Side bearing types
12. Car types
13. Adapters

5.2.2 Center plate Series

Objectives: To determine center plate wear characteristics, with conventional trucks.

Primary benefit areas: Lower life cycle costs.

Parameters to be varied:

1. Diameter of center plate.
2. Body Center plate material and hardness
3. Truck center plate hardness
4. Wear liner materials and hardness

5. Conical and spherical center plates
6. Side bearing types
7. Car types
8. Lubricant types

5.2.3 Truck Concept Series

Objectives: To evaluate alternative concepts for new basic types of truck design with parametric variations of each concept.

Primary benefit areas: Improved ride quality, lower rolling resistance, reduced wheel wear, reduced dynamic loads.

Truck concepts for evaluation:

1. Primary and secondary suspension trucks
2. Four point suspension trucks
3. Radial concepts trucks
4. Rigid H Frame types
5. Active suspensions
6. Single axle designs
7. Three axle designs

5.2.4 Securement Test Series

Objectives: To test alternative means of attachment of various car components.

Primary benefit areas: Lower first costs, lower bad order ratio.

Components to be considered:

1. Train lines

2. Doors, hatches, etc.
3. Reservoirs, valves, etc.

5.2.5 Car Design Series

Objectives: To test alternative structural details in car design for various car types with respect to fatigue damage.

Primary benefit areas: Reduced overdesign of cars, provide better understanding of the cumulative damage and its correlation with vertical and lateral ride quality, lower initial costs and reduced bad order ratio.

Design detail areas for test:

1. Center plate and attachment
2. Body bolster
3. Cushioned underframe body bolsters
4. Center plates - (Cushioned Underframes)
5. Crossbearers
6. Stub sill attachments - tank cars.
7. Center sills - flat cars

5.2.6 Surveillance Test Series

Objectives: To determine the reliability levels of surveillance type equipment for all parametric variations pertinent for each design, as for example, the readability of ACI labels.

Primary benefit areas: Surveillance system optimization, determination of reliability, improved safety.

Types of Systems to be tested:

1. Automatic car identification
2. Hot-box detection
3. Broken wheel detection
4. Dragging equipment detection
5. Derailment detection

5.2.7 Packaging Test Series

Objectives: To test alternative packaging methods for specific commodity types, particularly those aspects of packaging design that are dictated by ride quality.

Primary benefit areas: Reduced packaging costs and damage, isolation of damage causal factor costs.

Parameters to be varied:

1. Commodity type and characteristics
2. Package configuration, material type and thickness
3. Restraining and isolation arrangements

5.2.8 Fuel Consumption Series

Objectives: To compare diesel locomotive fuel consumption.

Primary benefit areas: Reduced fuel costs. Reduced atmospheric pollution.

Parameter to be varied:

1. Diesel locomotive types

6.0 FACILITY RECOMMENDATIONS

The recommendations made in this report are based on the assumption that no similar equipment owned by the Department of Transportation is available for use. A second assumption is that all major work will be procured by contract or sub-contract. Thirdly, that except as noted, the equipment is intended for long term use. Finally, it is assumed that manpower needs can not be met by available personnel or shared with other facilities at Pueblo, Colorado.

6.1 Motive Power Acquisition

It is recommended that four (4), 3600 HP Diesel Electric Locomotives of the types now used in general railroad road service full equipped with remote operation capabilities be acquired. This acquisition may be in the form of full purchase, net lease or full maintenance lease.

It is anticipated that three locomotives will be used with a low horsepower to trailing tonnage ratio of about 1.66 for the most economic operation. This will permit at any time, the fourth locomotive to be repaired and maintained without any lost test time. The industry-wide down-time ratio of diesel-electric locomotives is 15%. However, while not specifically known, this ratio is significantly lower with new locomotives. It is also suggested that the locomotives be equipped with SEARCH harnesses in order to reduce the down-time for maintenance diagnostics. For use with a heavier train, it is suggested that a short term lease be used to procure two additional locomotives for the duration of tests on the mini-loop.

The alternatives most frequently mentioned in connection with motive power have been considered in depth before making recommendations.

6.1.1 Four Axle and Six Axle Locomotives

The loading environment that a locomotive applies to the track structure is a significant element in the behavior of the track structure.

Much of the knowledge of this environment is restricted to coasting conditions, where the distribution of lateral forces to the track structure resulting from drawbar forces is not significant. Despite the absence of this definitive knowledge, six axle locomotives are preferable since they constitute the majority in heavy freight service. This underscores the need for tests with 4-axle locomotives with respect to the loading environment.

6.1.2 Electric Locomotives

The major argument for electrification is that the FAST would be a good place to evaluate the economics of electrification, along with mechanical and electrical tests. From an economic standpoint, no reliable estimate is available that indicates lower operating costs would accrue. Claims of longer economic life, shorter down-times and lower overall unit costs, while reasonable, cannot be substantiated with experience. Moreover, first costs will be substantially higher, approximately \$3 million higher.

The arguments against electrification besides the higher first cost include:

1. High horsepower electric locomotives with six-axles are not representative of current traffic.
2. Catenary adjustments may be necessary with changes in ballast depths.

3. Certain signalling system tests may be excluded.
4. Higher stand-by costs for locomotives because of the higher cost of each unit.

6.1.3 Manned, Semi-automatic or Remote Operation

Daily operating cost could be significantly lowered with remote operation. With a two-man crew the present worth of such savings at 15% for a 3 year test is around \$250,000. In addition, crew fatigue is further complicated by the monotony of a never changing landscape and the inability to view the track ahead. It is unlikely that a continuous 8 hour shift on board will be acceptable. This will reduce, on account of crew change stops, the traffic capabilities of the facility.

6.1.4 Fuel Capacity

Most locomotives commercially available have fuel capacities of around 3200 gallons (12100 liters). Consumption is estimated at 168 gallons (636 liters) per hour. With 20 hours operation, it is recommended that this capacity be increased to include the commercially available option of 4000 gallon (15160 liters) capacity.

6.1.5 Maintenance Considerations

A full scale maintenance facility constructed specifically for locomotives cannot be justified economically.

6.2 Freight Car Acquisition

The most general usage of cars will be in mixed random consists to constitute a 6500 ton (5895 metric tonnes) train consisting of 85 cars with the

industry average car capacity of 56 tons. Cars to be acquired should include a random mix of car types, car capacities and representative running gear with the exception of those components that are known not to have an impact on the track tests being conducted. Fifteen percent excess car capacity is recommended for minimizing loop down time and to schedule preventative maintenance.

In sampling to select a representative consist consideration must be given to the freight car population so that the probability of a car type being selected is in proportion to the population of that car type. (Table 6.1)

It is recommended that 100 freight cars be acquired so that a consist of 85 cars selected from it will be representative of actual traffic. It is recommended that these cars be new or relatively new in order to minimize train reliability problems. It is also recommended that cars be loaded with their representative commodities or simulations having the proper mass distribution of the load.

The running gear should be balanced with respect to wheel profile, truck component wear and centerplate wear. The foregoing pertains only to non-test cars, or at least 85% of the cars in the consist.

It is recommended that cars be obtained on short term leases or per diem (with supplemental costs) for use on the Mini-Loop or the main loop when conducting deterministic tests with consists either of the unit train type or predominantly with 100 ton (90 metric tonnes) capacity cars.

It is recommended that at least one car of each type be equipped to facilitate measurement of the loading spectra at any time during the test series

Table 6.1 Population of Freight Cars by Type

<u>Car Type</u>	<u>Percent of Total</u>
Box Cars - Plain	20%
Box Cars - Equipped	10%
Covered Hoppers	12%
Flat Cars	8%
Refrigerator Cars	6%
Gondola Cars	11%
Hopper Cars	21%
Tank Cars	10%
Other	2%

6.3 Preliminary Recommendations for Test Section Use

The proposed test series, after finalization, should be reviewed with respect to total work load. The scheduling problem should be examined and test section modification costs weighed for each of the scheduling alternatives. For example, it may be preferable to schedule adjacent sections with the same type of ballast but with different depths. The same sections with different ballast depths could have an alternate ballast material after the traffic requirements are met.

6.3.1 Test Duration

Each single test period should consist of 50 MGT (45 Metric MGT) traffic. Individual tests, such as Settlement Rate Series would last for one, two or three test periods for a total traffic of 50, 100, or 150 MGT, respectively. Total traffic proposed for the initial series is 600 MGT on the outer loops. Traffic on the Mini-Loop of the order of 200 MGT (180 Metric MGT) is proposed initially, in addition to the 600 MGT (540 Metric MGT).

6.3.2 Daily Operation Characteristics

Table 6.2 shows total traffic capabilities. Twenty hour operation is contemplated, with the other four hours allotted for track inspection, track geometry car measurements, switching out cars for test measurements, maintenance, fueling of locomotives and a limited amount of track maintenance.

The actual traffic applied will depend upon the precise environment exposure selected for the mechanical test cars with respect to the number of

Table 6.2 Daily Operating Characteristics - FAST

OUTER LOOP	Length of loop	= 10.0 miles (16.09 km)	
	Trip time @ 75 mph	= .13 hours (7.8 mins.)	
	Trips per day (20 hrs. operation)	= 153.8	
	Miles per day	= 1540 miles (2477 km)	
	Train size - total	= 6500 tons (5850 Metric Tonnes)	
	Traffic (6500 Total Train Tonnage)	= 1.0 MGT (.9 Metric MGT)	
	INNER LOOP	Length of loop	= 8.09 miles (13.02 km).
Trip time @ 60 mph		= .13 hrs. (7.8 mins.)	
Trip time @ 50 mph		= .16 hrs. (9.6 mins.)	
Trips per day (60 mph, 20 hrs.)		= 148.36	
Trips per day (50 mph 20 hrs.)		= 125.0	
Car miles per day (60 mph)		= 1200 miles (1931 km)	
Car miles per day (50 mph)		= 1000 miles (1609 km)	
Train size - total		= 6500 tons (5850 Metric Tonnes)	
Traffic (60 mph)		= 0.96 MGT (.86 Metric MGT)	
Traffic (50 mph)		= 0.80 MGT (.72 Metric MGT)	
MINI-LOOP		Length of loop	= 1.75 miles (2.8 km)
		Trip time @ 30 mph	= .06 hrs. (3.6 mins.)
		Trips per day (20 hrs.)	= 333
	Car miles per day	= 600 miles (965 km)	
	Train size - total	= 10,000 tons (9000 Metric Tonnes)	

trips over the undulating diagonal and the number and type of brake applications selected.

It is proposed that the test train consist operate on a cycle between 12 noon until 8 am the following day, allowing 4 daylight hours for track inspection and the other items mentioned above.

6.3.4 Test Interruptions for Measurement and Track Maintenance

Over the course of a 50 MGT ton (45 Metric MGT) test detailed measurements of track geometry will be required at defined intervals as, for example, after 2, 5, 10, 20, 30, 40, and 50 MGT traffic. It is proposed that mechanical measurements such as those for wheel profile and wear be co-ordinated with these intervals and time allowed by test interruption for a full day. If a target of 50 MGT traffic in two months is set, this will allow 10 days interruption, and traffic at 1 MGT/day for 50 days.

6.3.5 Section Modification Between Test Periods and Evaluation

In many instances, it may be decided that a test can be terminated before the full amount of projected traffic is applied, either due to the inability of a section to withstand another 50 MGT or if the results satisfy the test needs.

The required down-time between tests is available. It should be adequate for on-site modification of cars but not sufficient time for a car to be shipped elsewhere for modification.

6.3.6 Train Operation

Semi-automatic operation by radio control is suggested. This will limit the stops to those necessary for fueling. Safety interlocks to prevent entry from access trackage should be provided.

A single operator is recommended. He should be situated in a tower with full view of the facility. The ability to override the semi-automatic train control system should be provided. The operator should also monitor all safety and surveillance checks such as for hot box detection, broken rails, and dragging equipment.

6.3.7 Traffic Plan

A general traffic plan should be prepared for the duration of the initial test series. For example, the traffic plan, may call for Random Mix consists to operate at 75 mph (120 km/hr), on the outer loop, for three test periods of 50 MGT each at 60 mph (96.5 km/hr) on the inner loop. This may be followed by three test periods of 50 MGT on the Mini-Loop (at 3.5 MGT/day).

This traffic plan must be prepared as part of the test scheduling based on the test work load.

6.4 Track Maintenance Facilities

6.4.1 General Conditions

Although the proposed test track loop contains slightly more than 20 miles (32.1 km) of newly constructed, high quality track structure, the severe operating conditions and special test requirements necessitate provisions being made for a well equipped maintenance organization.

To maintain traffic at levels in excess of 1 million gross tons per day (0.9 million metric gross tons per day) and to avoid lengthy delays if maintenance is required, an inventory of machines must be available. The remoteness of the Pueblo site from major mainline railroad operations and the necessity of quickly restoring the loop to operating condition are factors arguing strongly for the purchase and ownership of machinery which will be used frequently. For large projects, which may be scheduled effectively, equipment rental or contract work is considered desirable.

The on-site maintenance force must have the capability of completing limited rail and tie changeouts, as well as lining and surfacing work during the assigned daily maintenance intervals. Larger tasks such as major rail relays, ballast cleaning or undercutting, rail surface grinding and similar work would be best handled as contract work.

6.4.2 Machine Characteristics

To maintain flexibility, machines purchased will be equipped with most available manufacturer's options. Although "overdesigned" for most of the work to be done, they will allow critical work to be performed quickly and reliably, enabling the loop to be rapidly returned to service.

Most roadway maintenance machines are to be equipped with road-rail options where appropriate. Most work would be done from the track to avoid excessive disturbance of the Pueblo soil cover.

Many of the machines will have excess capacity for use on the loop alone, and may be effectively worked in a pool to cover the entire Pueblo facility.

6.4.3 Machine Inventory by Class of Work

A. Rail Maintenance (CWR and Jointed) (10 rails/shift)

i-Road-rail truck with rail racks, jib crane,

hydraulic power source, rail saw, rail drill and bolter.

1-Welder, grinder and slotter combination for use with above

B. Tie Maintenance (80 ties/shift)

1-Small Tie Renewer with hydraulic spike puller/driver/drill

attachments-sufficient power to handle concrete ties.

C. Ballasting & Surfacing (1 mile/shift)

2-Ballast Cars

1-Ballast Regulator

1-Production Liner-Tamper

D. Materials Handling

1-2 or 3 cy. Front End Loader

1-4 ton hydraulic road-rail crane

6.4.4 Manpower Summary: (Machine support)

6 operators

4 laborers

1 mechanic

6.4.5 Maintenance and Inspection Crews:

Inspection Crew:

2 men with track motor car

Maintenance Crew:

Foreman plus 5 men with road-rail truck and basic track tools.

6.4.6 Total Manpower:

1 supervisor

2 inspectors

1 foreman

6 operators

9 laborers

1 mechanic

20

6.5 Mechanical Maintenance Facilities:

Present facilities at Pueblo must be reviewed for excess capacity before the recommendations given below are adopted.

The mechanical maintenance facilities required to support the FAST facility are primarily those necessary to perform running repairs and preventative maintenance on cars and locomotives.

Wheel profile maintenance is expected to be the major portion of the maintenance staff's efforts. Due to the high proportion of curved trackage negotiated, a 150,000 mile (241,000 km) interval between wheel turnings (approximately 300,000 miles on 2-W wheels) is considered optimistic. It would therefore be advantageous to schedule all other car maintenance work at the time of wheel changes. Complete inspection of running gear, draft gear and air brake systems could readily be worked into the wheel change-out schedule.

6.5.1 Maintenance Philosophy

A conservative approach to maintenance is recommended in order to insure full utilization of loop capabilities and to reduce accident risk.

Detailed mechanical inspections are to be carried out daily with all necessary minor repairs to be completed during the 4 hour maintenance period set aside.

Shop work is to be carried out on a scheduled basis with sufficient spares on hand to ensure a complete operating trainset is ready in advance of the next days scheduled test start time.

Most car maintenance (barring rebuilding or wreck repairs) is expected to be handled at the Pueblo site making extensive use of component changeouts. A small stock of rebuilt components may be used to reduce the requirements for spare cars. As an example, complete truck changeouts could be used to increase the number of cars processed during the maintenance period, with the worn wheels and other components changed out or rebuilt during the remainder of the day. This procedure will allow shop forces more time to work on the less routine work needed for the next day's testing.

6.5.2 Car Equipment Maintenance Facility

A small one-spot type of car repair facility is recommended. This facility would be designed for quick changeout of car trucks and wheelsets. It would have the ability to complete air brake maintenance and minor car body repairs. A large portion of the shop would be assigned to truck maintenance including dis-assembly, repair of components and replacement of wheelsets. A small machine shop, car jacks, jib cranes, hoists, welding equipment, a complement of tools and a car mover would complete the facility.

To the extent possible, component replacement maintenance would be used. Assembled wheel axle sets would be obtained from the suppliers. Wheelsets would be re-profiled on a contract basis.

6.5.3 Locomotive Maintenance Facility

On site locomotive maintenance would consist of detailed inspections, light running repairs, fueling, sanding and replenishment of engine fluids. A prefab metal building with platforms, pit and storage areas would be adequate.

Acquisition of one spare locomotive is proposed as the means to a program of preventative maintenance. Arrangements would be made with an industry owned heavy repair shop for scheduled heavy maintenance, wheel trueing and overhaul of locomotives. With one locomotive going through the maintenance phase at any given time, a reliable operating fleet would be on site at all times.

6.6 Required Instrumentation

The types of data collection equipment that are required may be considered to fall into two general categories. First, track geometry cars to measure the change in line and surface of candidate test sections, gages for measuring wheel and rail wear are required for evaluation of track and equipment. There also appears to be a need for more sophisticated instrumentation for monitoring the wheel loads to be sure that the mechanical test vehicles are not introducing unrepresentative loads.

The second general type of instrumentation is that which would be required for developing and validating mathematical models, developing

empirical relationships and developing loading environments that could be used in small scale laboratory tests. This instrumentation would be relatively sophisticated and of the kind that is employed on the Kansas Test Track or proposed for the AAR Moving Load Laboratory. The types of instrumentation would be those used for measuring such items as vertical and lateral motion of the rail, tie plate loads, track settlement, pressure distributions in the ballast and subgrade, strain gaging systems for measuring a variety of forces on many track components, and general types of instrumentation to be used in the equipment testing.

This instrumentation is relatively sophisticated. However, where one is attempting to validate mathematical models, developing loading environments or attempting to determine empirical relationships of loads; the instrumentation requirements must be dictated by the exact effort underway, whether it is model development or empirical loading. To make statements on the exact type of instrumentation, one would have to develop the types of models one is attempting to validate. This effort is obviously beyond the scope of this report.

7.0 ELECTRIFICATION OF FAST LOOPS

The electrification of FAST loops was considered for two main reasons.

A FAST loop would offer the capability for testing electric motive power and catenary structures. For example, the cost effectiveness of pantograph shoe pressures and materials on catenary and pantograph shoe life could be evaluated and optimized. The comparative evaluation of other design parameters with respect to electric motive power first costs and life cycle maintenance costs would be possible.

The second main reason for considering electrification is to reduce train operating expenses. No definitive estimates could be developed to indicate the daily operating expense reduction although there was general agreement that this would be the case. Major locomotive manufacturers also indicated that since diesel electric locomotives constituted the traffic in real life, it would only be proper to use diesel motive power on the loop, except for specific tests to be conducted.

In view of these considerations, no recommendation for electrification of loops is made for general operation of FAST loops. However, it is recommended that a separate test series be planned to conduct tests pertinent to advancing the state-of-the-art with respect to electrification and to gaining knowledge of life cycle costs of main line electrification.

8.0 MANAGEMENT RECOMMENDATIONS

It is suggested that an AAR - Industry - Government - RPI Task Force be set up to oversee the construction and operation of this facility through the initial test series.

In addition, each initial test series should be specifically designed and conducted under the direct supervision of a small industry group of technical specialists with expertise in the field of that particular test series. For example, if concrete ties are being tested, a group fully familiar with all of the relevant background should design and oversee the test. A facility manager with direct responsibility for all site operations directly responsible to the Task Force should be appointed concurrently with the initiation of facility construction planning. The facility manager would be responsible for all contractor performance during the planning and construction stage.

The management recommendations are made in order to:

1. Permit easy resolution of scheduling conflicts between mechanical, track and other tests as well as for assigning priorities to individual tests.
2. Provide for timely review of results and to re-assess the need for additional tests.
3. Ensure tests are meaningful.
4. Assure direct involvement of and prompt use of test results by railroad management.
5. Achieve proper co-ordination of FAST tests with those conducted by the suppliers, the railroads and the AAR in other facilities.

8.1 Facility Construction

It is recommended that an architect/engineer contractor be commissioned to design the facility details and to write engineering specifications for the acquisition of motive power, freight cars, track and mechanical maintenance equipment, track geometry car and other recommended equipment.

It is essential that due to the inherent nature of this test track loop facility, the detailed test plans for each of the proposed initial test series be developed concurrently in order to maximize the effectiveness of the capital expenditures. For example, the proper balance of ballast depth should be selected in order to minimize ballast change-over costs over the course of the initial track test series. Also, the specifications for purchase of freight cars should reflect full consideration to their use also as test specimens for individual components for the truck assemblies, and for the car itself.

In order to achieve maximum effectiveness of the capital expenditures it is suggested that the facility manager properly co-ordinate the input from each group developing detailed test plans to the A/E firm when making trade offs during the detail design of the FAST.

8.2 Facility Operation

There are two major areas of consideration in making recommendations for facility operation. These are discussed before making recommendations.

8.2.1 Limitations to Facility Use

The sponsorship of tests, it is expected, will come in large part from the Department of Transportation. Proprietary testing should not be precluded and user charges should reflect the "piggy back" nature of such testing.

8.2.2 Test Planning and Usefulness

A realistic view of the structure of the railroad industry must be taken with respect to new developments and potential improvements in safety and productivity. Mainly, emphasis should be placed on tests that will result in cost-effective solutions to equipment and track structure problems. The test facility is oriented towards researching solutions through a mix of analytical approaches and near-actual service testing in areas where complete understanding of systemic interactive effects does not exist.

It is often impossible to obtain by contract effective test plans without the direction participation of the industry organizations, who alone in many cases, possess the intimate understanding necessary.

8.2.3 Recommendations for Management of Operation

The facility manager should be responsible for all day to day operation.

The joint industry government task force should have overall responsibility for the FAST operation, including selection and planning of tests to be conducted. This task force should be created in advance of any contract award for facility construction. The task force should appoint the

technical specialists' committees for each test series. Informal groups of such technical specialists already exist in some areas and could serve in the capacity referred to.

9.0 ESTIMATES OF INITIAL CONSTRUCTION COST AND INITIAL TEST SERIES COSTS

The estimates provided here are presented with a view to placing the recommendations in economic perspective and to help further the facility planning process.

The estimates provided here are based on the preliminary recommendations for loop design and equipment made in previous sections of this report. A separate estimate is made for the mechanical loop. These estimates are generally conservative. Definitive estimates can only be made after the detailed Architectural - Engineering work is performed and the facility site selected and integrated with existing facilities. Also, some of the costs will be contingent upon the decisions made with regard to the management of the facility and the test series proposed.

A preliminary cost estimate for FAST is summarized in Table 9.1 with supporting detail shown in Tables 9.2 and 9.3. The estimate for the mechanical loop is shown in Table 9.4. The daily operating expenses shown in Table 9.3 can be used for mechanical loop operation also.

The costs to purchase hardware, such as those for new track fasteners or new truck types are specific test items and are not included in the estimates. The test expenses used in the estimates are the basic expenses required for facility operation and basic support elements.

Table 9.1 Summary of Estimated Total Expenses for Tests
to Be Performed Over Two Year Period

	<u>Millions</u>
A. Initial Capital Outlay*	\$15.407
B. Land Lease Costs - 2 yr. period	-
C. Operating Costs - \$11,300/day [#] , 50 day test for twelve test series on main loop and 60 day test on mini-loop	\$ 7.458
D. Section Changeover Costs	\$ 1.00
E. Instrumentation Costs	\$ 0.3
F. Data Reduction Costs	\$ 0.25
G. Incidentals	\$ 0.10
H. Contingency Fund	\$ 0.50
TOTAL	\$25.02
Less Salvage Value-Rail, Locomotives and Cars	\$ 3.00
TOTAL COST	\$22.02

*See Table 9.2 for details

#See Table 9.3 for daily operating costs

Table 9.2 Summary of Estimated Initial Capital Outlay

A. <u>Estimated Track Construction Costs</u>		
a.	Main loops - 18.95 miles (including diagonals) @ \$264,000/mile	\$5,002,800
b.	Mini-loop 1.75 miles	\$ 462,000
c.	Access and Extra track, 2.0 miles	\$ 528,000
d.	Grading cost allowance (contingent upon sit and test section subgrade selection)	\$ 600,000
e.	Power operated turnouts, Crossings	\$ 520,000
	Sub Totals	\$7,112,800
 B. <u>Estimated Motive Power Costs</u>		
1.	Purchase option	\$1,800,000
2.	Lease option	no estimate available
 C. <u>Estimated Building & Other Facility Costs</u>		
	Buildings (Office, Car and Locomotive shop)	\$ 500,000
	Office Equipment	\$ 10,000
	Utilities*	-
	Machinery & Equipment	\$ 500,000
	Totals	\$1,010,000
 D. <u>Instrumentation:# Estimate of non-expendable Items</u>		
1.	Dedicated Digital Computers, A/D Conversion	\$ 150,000
2.	Signal Conditioning Equipment	\$ 100,000
3.	Instrument Car	\$ 500,000
4.	Miscellaneous#	\$ 600,000

*Contingent upon site requirements

#Does not include specific instrumentation such as transducers, telemetry, etc.

Table 9.2 Summary of Estimated Initial Capital Outlay (Continued)

E.	Facility Design and other Expenses	\$ 600,000
F.	Signalling & Comm	Included in Item P below
G.	Hot Box Detector	\$ 55,000**
H.	Broken Wheel	\$ 100,000
I.	Dragging Equipment Detector	\$ 5,000** (add on)
J.	ACI System	\$ 25,000
K.	Weigh Scale	-
L.	Control Tower & Room	\$ 100,000
M.	Trackfax Car	\$ 250,000
N.	Sperry Rail Car - Lease	\$ 100,000
O.	Track Circuits for Broken Rail Detection	Included in Item P below
P.	Radio-Control Remote Operation - Equipment**	\$1,000,000
Q.	Estimate Freight Car Costs	
	1. Purchase option	\$2,000,000
	2. Net lease option	No estimate
	3. Full maintenance lease option	No estimate
R.	Track Maintenance Equipment	\$ 250,000

**Dollar value shown represents amount allowed in estimate. Actual estimate contingent upon system selected.

TOTAL (Items A-R) = \$15,407,800

Table 9.3 Estimated Daily FAST Loop Operating Expenses

A.	Car Leasing Costs [#]	
B.	Locomotive Leasing Costs [#]	
C.	Remote Operation with Automatic Train Control with One Controller Each Shift	\$ 384
D.	Fuel Costs **	\$8,000
E.	Track Maintenance Personnel (20 men single shift only) [@]	\$1,280
F.	Mechanical Maintenance Personnel (4 men, two shifts) [@]	\$ 512
G.	1) Maintenance ----- Diesel Locomotives	\$ 200
	2) Maintenance ----- Cars	\$ 600
H.	Technical and Administrative Staff	\$ 300
	Totals	\$11,276

** Based on three 3600 HP. , Locomotives
 168 gals/hr per Locomotive @ \$.39/gal. - \$11,300

[@] \$8/hr used for this estimate

[#] Short term lease will be required to procure additional cars or locomotives for certain tests.

Table 9.4 Additional Initial Capital Outlay - Mechanical Loop

A. <u>Estimated Track Construction Costs</u>		
a.	Loop Track - 21.42 miles @ \$264,000 per mile	\$5,654,880
b.	Access and Extra Track - 2 miles	\$ 528,000
c.	Earthwork Cost Allowance (dependent upon site considerations)	\$ 600,000
d.	Power Operated Turnouts, Crossings	\$ 520,000
	Sub Total	<u>\$7,302,880</u>
B. <u>Estimated Motive Power Costs</u>		
1.	Purchase option	\$1,800,000
2.	Lease option	-
C. <u>Freight Car Costs</u>		
1.	Purchase option	\$2,000,000
2.	Lease option	-
D.	<u>Other</u> - Includes Items F through P (shown in Table 9.3)	<u>\$1,610,000</u>
	Total	<u>\$12,712,880</u>

PART II

RATIONALE FOR FACILITY RECOMMENDATIONS

(Sections 10.0 through 14.0)

10.0 GENERAL APPROACH TO DETERMINING TEST FACILITY

The purpose of this task was to set forth the functional requirements for a track research laboratory test facility.

A comprehensive review of all existing facilities used for track research was conducted early in the course of the task. This included a preliminary review of all research facilities in Europe, Japan, the USSR and other countries. Facilities for highway tests and airport pavement testing were also examined.

An examination of the track research ongoing and planned revealed a need for three types of facilities. These were as follows:

- a. Rolling load facility
- b. Facility for track component testing and evaluation
- c. Test track loop facility

It was noted that a rolling load facility was being planned. Also, facilities of various types for component testing and evaluation did exist at different locations. It was concluded that a test track loop facility would be the most useful in meeting the industry needs.

A test track loop facility, it was determined, would not only permit track research tests but offer the opportunity to conduct tests on railroad mechanical and other equipment.

In particular, the test facility, could be used to assess track structure including related facilities such as bridges, signal circuits, warning devices, track maintenance equipment and track inspection equipment.

Locomotives, cars and their components; car maintenance procedures; defect detection equipment; car packaging; fastening systems, and other railroad related

equipment such as the testing and evaluation of ACI systems may also be tested under service environment conditions compatible with and complementary to the track structure test program in this facility.

Facilities for study and evaluation of railroad track and equipment can take many forms. They do, however, fall into two general categories and these are:

1. facilities for determining static and dynamic behavior of track and equipment, and
2. facilities for evaluating wear and fatigue characteristics of track and equipment.

In either of these general categories, there are essentially four types of research tools that may be employed.

These are as follows:

- a. Small scale laboratory testing equipment for determining dynamic behavior of the component such as those for snubber characteristics, center-plate friction, or stiffness coefficients for a variety of components. Tie wear test machines, and rolling load machines would be in this category also.
- b. Full scale laboratory testing equipment such as the moving load track structures research facility the AAR is building, or the Rail Dynamic Laboratory the DOT is building at Pueblo.
- c. Full scale outdoor test facilities such as the Track-Train Dynamics Loop at Pueblo.
- d. Actual in-service test facilities such as the Kansas Test Track or the number of service tests the ARA has employed for investigating rail wear.

It should be noted that all of these types of test facilities are required and that each has its own inherent benefits.

However, the one major type of facility that is currently missing is one which can be used to perform accelerated wear and fatigue tests on full scale vehicles and track structures. This test track loop will be such a facility. The environment to which both the track and the equipment should be subjected must be representative of the real world railroad operating environment.

It should be noted that this facility's prime purpose is to develop information on a controlled basis much faster than would be possible with the alternatives that exist today; that is, actual service testing. The major cost justification for this facility is that it can provide answers sooner than any facility currently in existence.

For example, if one wished to develop an improved track structure, one alternative would be to actually fabricate full scale track structures and place them in the actual revenue service environment. This is essentially what was done on the Kansas Test Track. Assume for the moment that it would take 150 million gross tons (136 million metric tonnes) to start to develop an indication of whether or not an improved track structure would work. If the annual revenue tonnage is 50 million gross tons (45 million metric tonnes) it would take approximately 3 years to obtain the results.

Let us also assume, and these figures will be substantiated later on, that out of the annual \$12,000 per mile (\$7500 per km) average used for track maintenance that: improving the track structure could yield a mere \$50 per mile of track in savings. Now suppose that one had a facility which could develop the information within 6 months as in FAST. This, in essence, means that you would have the results

2 years sooner. A saving of \$50 per track mile (\$35 per km) for 150,000 track miles (240,000 kilometres) means that the facility could give information in a more timely fashion which would save 7.5 million dollars a year. Thus, such a facility as compared to a revenue service test, would yield a total of 15 million dollars in savings.

Consider also that one chose not to build FAST but attempted to develop an improved track structure by running service tests of 150 million gross tons and evaluating the results. Let us also assume that the first series of tests after 3 years did not allow any improvement in the track structure and a new series of tests was then initiated that would lead to an improvement in the track structure. Again, assuming 50 million gross tons (45 million metric tonnes) per year, by the time one had sufficient information, a total of 6 years would have elapsed since one started the investigation. After this point, assume that the results were implemented and a savings of \$50 per track mile (\$31 per kilometre) were then realized. Having FAST, one would have set up the first series of tests. The test would have taken approximately 6 months to accumulate 150 million gross tons (135 million metric tonnes). One would have then realized that no economic benefits could be achieved by the initial configurations and set up a new test series. Six months later the results would be available. Within approximately one year, economic benefits from the tests would start to accrue.

In this particular example, the facility has given information 5 years sooner than a service test. While an economic analysis should include present worth factors and inflation, a conservative estimate of savings would show figures of approximately 40 million dollars (7.5 million dollars times 5 years) resulting from the use of the facility.

In the arguments above, we have not discussed the economic benefits that could be achieved with equipment testing.

A major point is that FAST, as its name implies, does give results faster, and more reliably than actual revenue service testing and does indicate that a substantial investment in the facility could be justified.

10.1 Defining the Scope of the Facility

In developing the functional specifications for the track test loop, it is necessary to consider some limitations of the purpose of the facility.

These limitations are as follows:

1. The facility is not intended for use in investigations of dynamic vehicle behavior not related to accelerated fatigue testing. In other words, investigations on issues such as long car-short car problems, truck hunting tests, development of coupler forces in emergency brake applications, or investigations of roll behavior of high center of gravity cars are not an intended prime purpose of this facility. There are other facilities such as the Rail Dynamics Lab and the Track Train Dynamics Loop which are intended for these purposes and would be more effective in dynamic vehicle behavior investigations.
2. The facility is not intended for use in developing the service environment in railroad classification yards.
3. The facility is not intended for excessively high speeds such as those in the 100-150 mph (160-240 km/hr) range. The testing at these speeds can be performed on the High Speed Loop at Pueblo.

4. While it is desirable to have a total simulation of the railroad environment, one must realize that the loop cannot completely cover the spectrum of actual railroad environmental conditions.

The reasons for this tend to be economic rather than technical.

However, within the above constraints, the facility should be as versatile as possible and be capable of simulating the railroad environment as closely as possible. For several reasons, the loop design cannot represent all conditions found on any representative railroad system.

These reasons are as follows:

- a. The loop, being located at a fixed location, will be subjected to the climatic conditions at the location. In this study the prime candidate location was Pueblo, Colorado. Obviously, conditions of severe frost or extreme temperature variation are not achieved naturally at Pueblo. It is possible, however, to use cooling and heating coils to simulate such conditions. However, this is of doubtful economic feasibility.
- b. Actual railroad track has many combinations of grades and curvatures and may be subjected to a variety of train consists and train operation modes. Similarly, freight vehicles are subjected to a wide range of track conditions at varied speeds. Obviously, a limitation in the design of the loop is going to be specifying the number of curve and grades that are used and the type of operation.
- c. There are other issues that will limit the scope of the facility. These are based upon engineering considerations that will be

developed in later sections. For example, it will be demonstrated that certain types of operations such as drag braking are not possible, since no extended grades can be incorporated in the facility.

The list of the functional capabilities needed for the FAST facility has been shown in Part I of this report.

10.2 Elements to be Considered in the Design of a Test Loop

There are a number of questions to be considered in the design of a test facility. These are as follows:

Test Area

- a. What is the loop size and geometric configuration: grades, curvatures, shape, and connections with adjacent tracks?
- b. What are the test support facilities: size and geometric relationship to the loop?
- c. Will more than one loop be required?

Test Train

- a. How much traffic is required over test sections?
- b. What will be the required running speed for the train?
- c. What will be the train consists: lengths, tonnages, mix of loads and empties, car types?
- d. What horsepower is required?
- e. How is horsepower to be distributed?
- f. Will more than one train be required?
- g. Will remote units be used?

- h. Will units be diesel, diesel-electric or electric?

The Test Sections

- a. What are the lengths of the test section(s)?
- b. What is the general purpose of the section, or what are the test objectives?
- c. What types of instrumentation and measurement are required?
- d. What are the types of maintenance to be performed on a test section?

The Test Vehicles

- a. What kind of test vehicles should be used: (what are their sizes, are they loaded or empty, what are the wheel contours?)
- b. What are the types of instrumentation required?
- c. What are the inspection and maintenance requirements and schedules for the vehicle?

Operations

- a. What is the staff size and responsibility assignment?
- b. What are the support facilities required: maintenance, fueling, inspection?
- c. What types of general maintenance equipment for track and what facilities for vehicle equipment are required?
- d. What is the type of train control to be used: manual, semi-automatic, or fully automated?
- e. What types of test instrumentation and data collection systems are required?
- f. What are the necessary safety control considerations?
- g. How is scheduling of the testing to be performed on the test sections decided?
- h. When and what type of maintenance will be required on test sections?

- i. How is maintenance of track and train equipment to be scheduled?
- j. Which maintenance is done by facility personnel; which by outside contract?

There are other considerations such as: should one very long train be used with remote units or should several short trains be used? What are the conflicts between mechanical equipment testing and track testing and how can they be resolved?

11.0 APPROACH TO FACILITY DESIGN

From a practical standpoint, one cannot develop the facility functional requirements if every element is allowed to have complete freedom, that is, each element is considered to have complete independence from all other elements. One of the more obvious reasons for this is that one must determine what types of tests are to be considered and their priority order for performance. If, for example, it turned out that the highest priority tests to be performed were 100 mph (160 km/hr) operation with 100 car trains having each car weighing 315,000 lb (143,000 kg); the loop design would be considerably different than the loop design for investigating rail metallurgy. Similarly, if the greatest benefit would come from testing supplemental snubbing devices for cars; the optimum loop configuration would be to have a test train operating over one half staggered jointed track, within a speed range of 15 to 25 mph (24 to 40 km/hr).

To resolve these conflicts the rational approach would be to determine the economic benefits from each of the various types of proposed tests and to determine the costs for these types. The loop configuration would then be based on this economic analysis.

In detail the approach would be to determine the test facility configuration as follows:

- a. Establish in general terms the types of tests desired at the facility. This would include determining which types of tests should be performed, the test objective, the costs associated with each test, and the time to complete the tests.

- b. Establish the economic benefits that would be achieved from the test. This would include every test that could be incorporated into the facility.
- c. Attempt to develop the optimum test facility, (i. e. the train length, the test section length and number, tonnage required, and similar parameters) so that each test would be justifiable on a cost-benefit analysis.

12.0 DETERMINING AN OPTIMUM TEST FACILITY

Assume one desires to minimize the cost per test whether it is a track or equipment test, and then attempts to develop an optimum layout, train consist, number of test sections, weight of vehicle, and other factors. The conclusion reached is that there will be a number of fixed costs which includes such items as crew cost, a number of the support facilities, administrative cost, and other items that are independent of numbers or type of tests. It can then be demonstrated that the optimum solution is to increase the number of test sections to the greatest possible number, make the test train of infinite length, a vehicle weight of infinity, a speed of infinity, and test sections of zero length. It is obvious that this conclusion will certainly maximize the train miles, car miles, and tonnage over a section; and, therefore, result in a minimum cost per test. While it may seem irrelevant to present this argument, there are two points to consider.

First, this basic relationship between attempting to minimize the operating overhead cost per test will always have an influence on decisions. For example, two test trains may be more cost effective than one.

Second, suitable constraints on the design will have to be chosen. The problem of designing the loop was constrained in two directions, 1) technical feasibility and 2) engineering judgment. The analysis is developed in the next section.

13.0 CONSTRAINING THE DESIGN

There are two general ways in which the problem of design of the test facility can be constrained. These are: a) technical feasibility and b) on the basis of engineering and practical judgment. Each of these is discussed in the following sections.

13.1 Constraining by Technical Feasibility

One prime purpose of the facility is to generate rapid accumulation of wear and fatigue for evaluation of track and equipment design; to do so, a high accumulation of tonnage to evaluate track and a high accumulation of car miles for equipment testing is desirable. In this regard, it is technically feasible to build cars weighing 400,000 lb (181,600 kg) each and operate them in 200 car trains at 100 mph (160 km/hr). Such an approach would yield a great number of miles on the vehicle as well as great tonnage on the track. One must question how rational an approach this would be. To do so, we must look at two issues. First, the nature of an accelerated fatigue test, and second, considerations of the usage of the results from such a test.

13.2 Accelerated Fatigue Problems

One of the problems encountered in accelerated fatigue testing is shown in Figure 13.1. This is a fatigue curve of stress level versus number of cycles to failure for two materials. The figure shows that if we desire to evaluate two materials that will be used at a low stress level, material (A) is better than material, (B). However, these curves cross and if the test were at the low stress level (the level at which the materials are to be used), material B is better than A. Thus, this one curve demonstrates

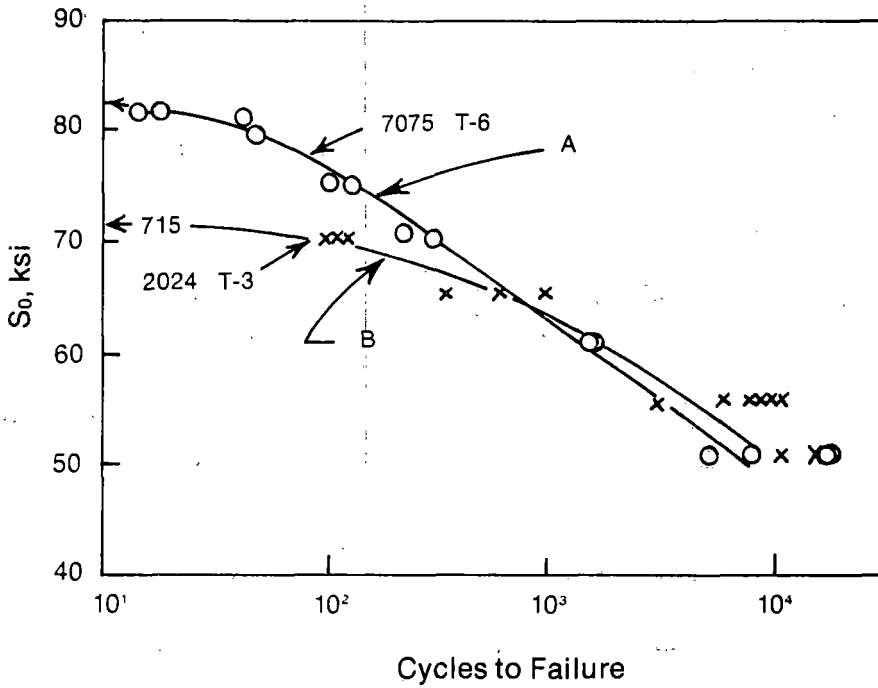
one of the problems of accelerated fatigue testing and that is: by raising the stress level substantially from operating stress levels, and then attempting to make a comparison on the basis of these results, the conclusions drawn may be erroneous. This fact indicates that one would be well advised to develop a track-vehicle loading environment in a test facility that is as representative of actual conditions as possible.

The second problem of accelerated fatigue testing is demonstrated in Figure 13.2. This particular curve is for soil materials at various stress levels under a repeated tri-axial load test. Essentially this curve shows that a threshold stress limit exists. If this stress level is exceeded, increments of plastic deformation with every load cycle occur. This phenomena should not be overlooked because one of the purposes of the facility would be to attempt to determine optimum track configurations. For example, if the track structure is overloaded with the hypothetical 400,000 lb (181,600 kg) vehicle, and a number of track configurations are tested, it is likely that those found to be optimum would be overdesigned for actual service conditions.

From a railroad's standpoint, they would like to know what is the most economical track configuration. If overloaded vehicles with their non-representative loading environments are used, definite risks exist in that the most economical track structure configurations would not be found by tests.

One might argue that the 400,000 lb vehicle (181,600 kg) 200 car train running at 100 mph (160 km/hr) might be designed so that its dynamic

LOW CYCLE FATIGUE

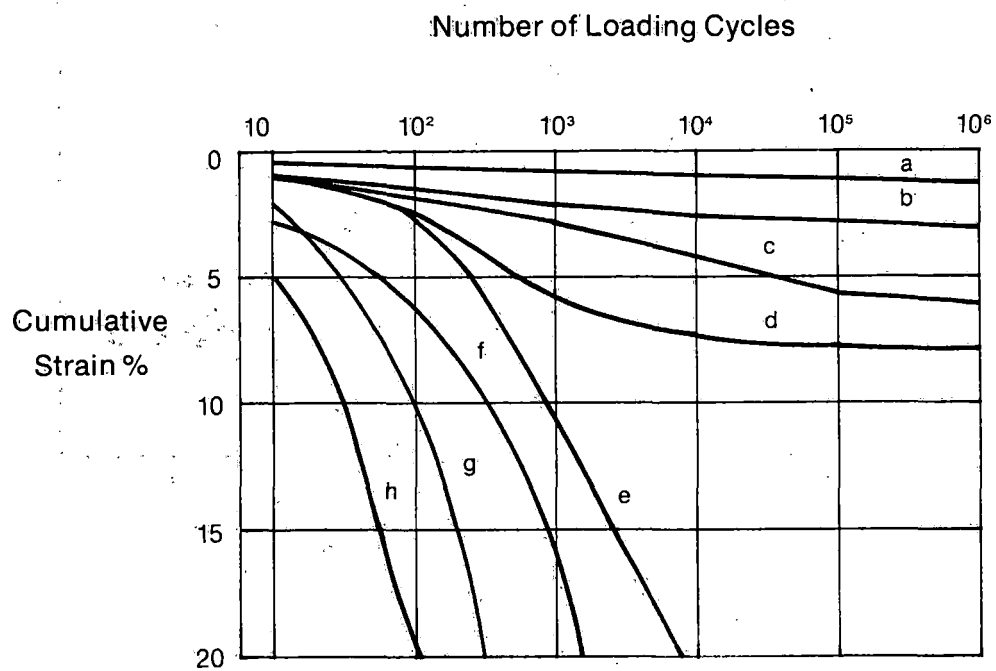
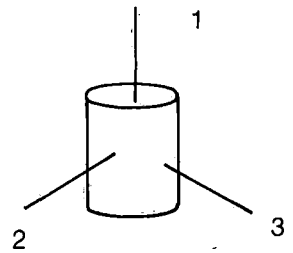


Source: Fatigue of aircraft structures,
Naval Air Systems Command

Figure 13.1 Problems with Accelerated Fatigue Testing

Curves a → h, ($\sigma_1 - \sigma_3$) increases in value.

Curve d = Threshold value.



Source: Proc. Instn. Civ. Engrs., 1972

Figure 13.2 Problems with Accelerated Testing with Subgrade Materials

properties and thus input into the track structure would be representative of present train consists. For example, an increase in the number of wheels, to give representative wheel loads per inch of diameter and changing the dynamic characteristics of the vehicle such that force inputs would be the same, are possible design variations. Placing remote power distributed throughout the train so that the longitudinal force inputs would be representative of the normal train environment is also feasible. In essence, could we not build a test train at the edge of technical feasibility that would give the most number of car miles and tonnage over the test section?

A simple answer is that if the current state of knowledge were sufficiently exact that one could build a vehicle with dynamic characteristics and train dynamics which were representative of the real world, then there would be little use in performing any tests, as we would already have many of the answers. In essence, the very things the facility is designed to find out are the types of information that would be required to design this technically feasible train of test vehicles.

13.3 Constraining the Design by Engineering Judgment

The design of the loop cannot be developed only on the basis of technical feasibility. Thus the approach was to develop a loop design on the basis of engineering judgments. A starting point for this was to develop information from the railroad industry by posing questions on a variety of the loop design elements (eg. climate, subgrade conditions, speed, and curvature). The questions were aimed at establishing the values of the design elements that would be required to perform research of value to

them. The information was carefully evaluated and a number of design considerations developed which led to the interim loop design. The design considerations were as follows:

1. Intended speed
2. Effects of climate
3. Train lengths
4. Tonnage
5. Time length of the test
6. Space requirements
7. Length of test section
8. Problems of test loops
9. Period required for maintenance
10. Inspection of track and equipment
11. Test section
12. Change out times
13. Interfacing mechanical and track testing
14. Operation (automatic or manual)

13.3.1 Intended Speed

There are essentially four operating speed ranges that are of most interest. These are as follows:

- a. 70-80 mph (112-128 km/hr)
- b. 50-60 mph (80- 96 km/hr)
- c. 40 mph (64 km/hr)
- d. 15-25 mph (24- 40 km/hr)

These can be explained with the following judgments. Considering that 79 mph (126 km/hr) is currently the maximum permissible speed without ATS equipment, 80 mph (128 km/hr) appears to be a logical upper limit for speed. If it is to be argued that the speed should be in excess of this, one should realize that there are no present indications that freight operations will move towards 90 and 100 mph (144 and 160 km/hr). Also, as explained before, attempting to operate trains at 90 mph (144 km/hr) and draw conclusions in a lower range may be dangerous. This is largely because of the attendant increase in track and vehicle loading with speed. Another speed range that is of interest is the 50-60 mph (80-96 km/hr) range primarily because of the onset of the bounce modes of present vehicles. The speed of 40 mph (64 km/hr) is of interest because many responses from railroads indicated they operate at this speed. This would also appear to be a speed of interest because of test results that indicate that truck hunting initiates around 40-50 mph (64-80 km/hr). Thus, 40 mph (64 km/hr) would be of an interest to a number of railroads and also would generate data points for speed below the lowest truck hunting speed (truck hunting will increase the loadings on the track structure). Another speed range of interest would be 15-25 mph (24-40 km/hr). The type of testing that would be performed in this speed range deals primarily with the evaluation of supplemental snubbing design and the force inputs into the vehicle. This speed range is well documented and causes the onset of severe car rocking problems when a certain rail vehicle negotiates one half staggered joint conditions. As will be shown, to run the loop at 20 mph (32 km/hr) drastically decreases

its utilization. There is not much value in terms of track testing at this speed and these tests would be solely for equipment testing. Thus, it would appear that it is necessary to seriously consider performing this type of testing on a separate facility. In summation, the speed ranges of interest and approximately 80 mph (128 km/hr) because it is representative of an upward limit in operation today; 50-60 mph (80-96 km/hr) because of the onset of the bounce mode; 40 mph (64 km/hr) because it is under the accepted threshold of the onset of truck hunting; and 20 mph (32 km/hr) because it is in the range of 15-25 mph (24-40 km/hr) for the onset of vehicle harmonic roll action.

13.3.2 Effects of Climate

For purposes of discussion, the climate at Pueblo is shown in Table 13.1. Information was taken at the Pueblo airport weather station about 14 miles from the test center. There are several things to be noted from carefully observing this meteorological data. First of all, temperatures below freezing may exist in the period between mid-October and mid-April. From the track standpoint, this would mean that the materials in test will be subjected to frost action and it in turn follows that freeze-thaw cycles are likely to occur. During the summer period from April to October, this is not the case. Thus, if a material that were frost susceptible is under test, there is a good chance that running the test during the summer period would not yield the same results as running it during the fall period. Thus, any given period (even a test period starting in January through June) may not yield the same results as one running through July to

Table 13.1 Meteorological Data, Pueblo, Colorado

NORMALS, MEANS, AND EXTREMES

Month	TEMPERATURE					PRECIPITATION					SNOW, ICE PELLETS									
	NORMAL		EXTREMES			NORMAL		EXTREMES			NORMAL		EXTREMES							
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	Normal heating degree days (Base 65°)	Normal Total	Maximum Monthly	Year	Minimum Monthly	Year	Maximum in 24 hrs.	Year	Mean Total	Maximum Monthly	Year	Maximum in 24 hrs.	Year
J	45.3	14.7	30.0	78	1971	-17	1971	1085	0.31	1.45	1948	0.02	1950	0.59	1945	5.7	20.0	1948	7.3	1956
F	48.5	19.2	33.9	77	1970	-12	1965	871	0.48	0.79	1947	T	1970*	0.46	1947	4.7	14.4	1965	5.9	1965
M	54.9	25.3	40.1	84	1966	-10	1964	772	0.52	1.82	1948	0.05	1966	0.69	1941	7.5	22.4	1948	9.0	1964
A	65.8	35.5	50.7	88	1965	15	1971	429	1.18	6.17	1942	T	1963	2.49	1957	3.3	21.2	1957	16.8	1957
M	75.3	45.8	60.6	97	1970	30	1966	174	1.80	5.43	1957	0.03	1965	2.53	1957	0.5	4.8	1946	5.6	1954
J	86.9	55.2	71.1	104	1971*	39	1970	15	1.22	4.26	1961	0.07	1952	1.88	1961	0.0	0.0		0.0	
J	92.1	60.8	76.5	105	1971	51	1968*	0	1.82	4.41	1968	0.25	1963	1.87	1968	0.0	0.0		0.0	
A	89.7	59.5	74.6	104	1969	40	1968	0	1.85	5.85	1955	0.08	1960	2.95	1955	0.0	0.0		0.0	
S	82.5	50.6	66.6	99	1971	29	1971	54	0.84	2.49	1959	T	1956	1.44	1942	0.7	14.0	1959	9.5	1959
O	70.8	38.7	54.8	92	1964	18	1971*	326	0.99	4.91	1937	T	1952	3.77	1957	0.9	6.7	1959	4.2	1970
N	75.7	24.3	40.0	83	1971	7	1967	750	0.53	2.43	1937	T	1966*	0.82	1957*	4.0	29.3	1946	16.3	1946
D	48.7	17.6	33.2	77	1970*	-8	1967	986	0.30	0.93	1967	T	1970*	0.49	1966*	4.5	15.3	1967	8.7	1961
YR	68.0	37.3	52.7	105	JUL. 1971	-17	JAN. 1971	546.2	11.84	6.17	APR. 1942	T	DEC. 1970*	3.77	OCT. 1957	31.8	29.3	NOV. 1946	16.8	APR. 1957

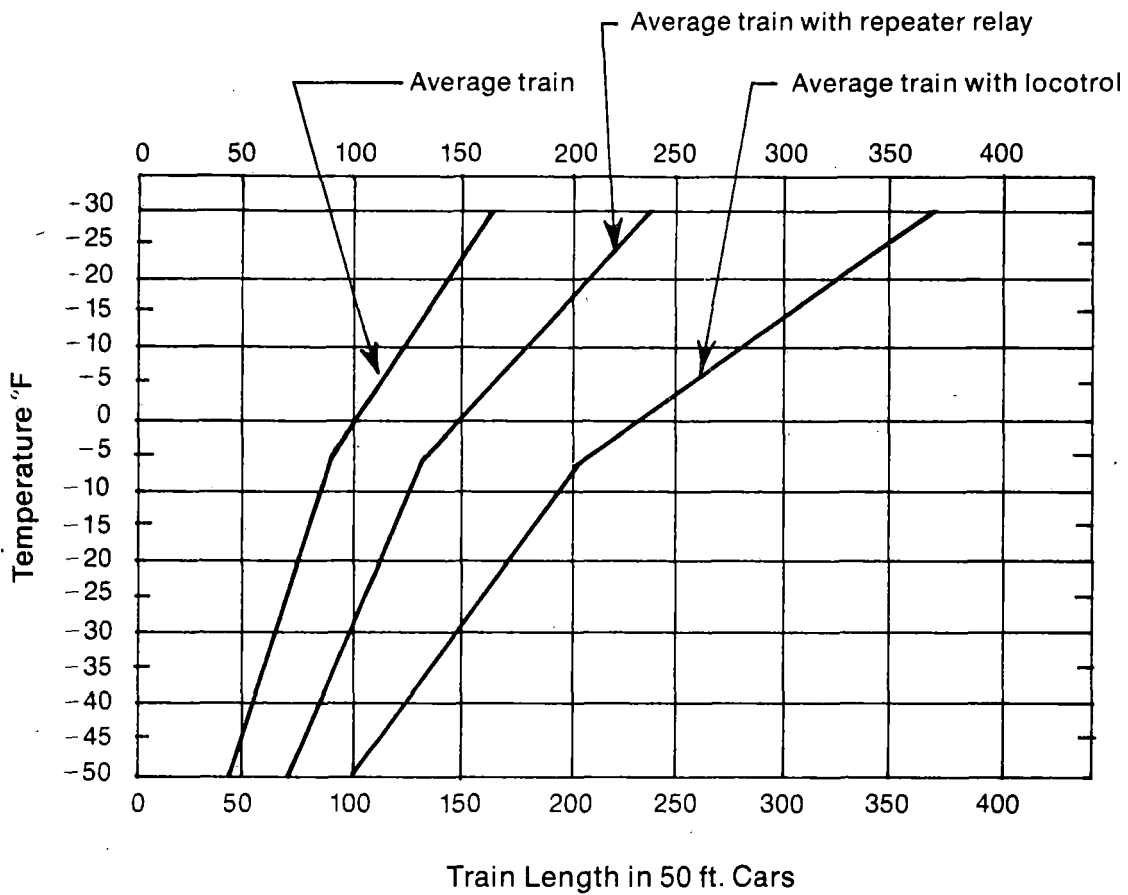
the end of the year, mainly because of the difference in the direction of the temperature cycles. In some respects, the location of Pueblo would enable one to investigate conditions without any frost action and in turn be able to investigate conditions in which there was some frost action, if the tests were divided between summer and winter series. Thus, we have another constraint which is that when test series that may be influenced by temperature action are planned, they have to be completed during a six month period comprising either a summer or a winter period.

The other consideration that temperature will have is its effect on the ability of the train to brake. This is shown in Figure 13.3. This figure demonstrates that the average train should be limited to approximately 150 cars at 20°F (-7°C) and if one wished to use a design temperature of 0°F (-18°C), the train lengths would be limited to approximately 100 cars.

13.3.3 Train Length and Number of Trains

There are few technical considerations that would limit the maximum train length other than the temperature, stopping distance, acceleration time, and drawbar strength of conventional equipment.

There are no considerations which would limit the number of trains that may be used. That, in essence, means as long as one could provide sufficient headway between the trains; it would be advantageous for accumulation of traffic both for the track and equipment investigations to run many trainsets of the heaviest train consist. This again refer to the comments in previous sections about the fixed cost of the operating the facility, making it advantageous to run the heaviest, longest and fastest



Source: CN Technical Research Centre Report 12-72

Figure 13.3 Approximate Maximum Train Length for Various Ambient Temperatures

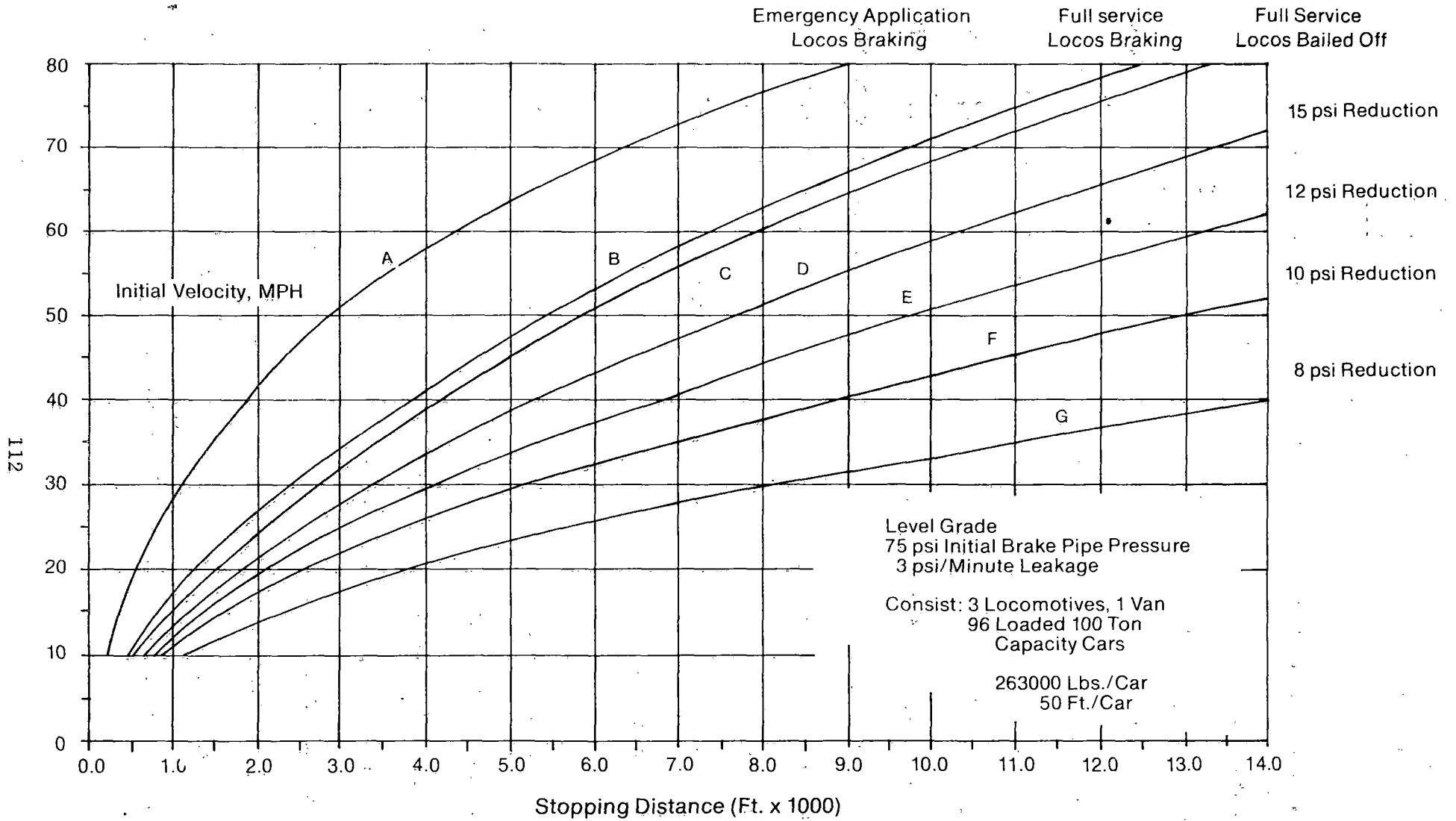
trains. However, let us review some concepts that may begin to determine train length and tonnage. First, if we design a loop for a maximum 500 car train or many shorter trains, there is a definite level of uncertainty on the types of forces that would be put into the track structure. In other words, the 500 car train with remote units could put unrepresentative forces into the track structure and make conclusions difficult to draw. This is primarily because most trains currently in operation simply do not have remote units. For the moment let us assume that no trains should have remote units, at least for design concepts, as we can always add them back in later and thereby increase the daily tonnage. Several constraining relationships become: the strength of the drawbar, stopping distances, and acceleration times. However, calculations based upon a drawbar strength of 200,000 lb (90,800 kg) (actual strength is 300,000 lb (136,200 kg) limit, this leaves a safety margin) for a train of 100 ton (90 metric tonnes) cars loaded to capacity (263,000 lb gross) indicate that 147 cars would be possible. The total tonnage is 19,000 tons (17,100 metric tonnes). Horsepower requirements for this train would be 15 to 16 SD-45 locomotives. It could also be shown that such a train, while it may have some difficult problems in starting, could achieve a speed of 80 mph (128 km/hr) on tangent level track. Temperature considerations indicate that this train could operate a good part of the year. On some days when 24-hour operation is considered, train speed would have to be reduced, and train length would have to be decreased to approximately 100 cars. Thus, limits on train length even for head-end powered trains, yield

a very heavy train. However, it seems reasonably logical that the test loop should be designed, as a minimum, for an average train and that a reasonable track tonnage accumulation would be possible with this train. Longer, heavier train would provide higher tonnage accumulations.

13.3.4 Tonnage of Trains

There are many types of test that could be performed in an attempt to determine optimum track configurations and for this reason, it would seem logical to operate trains which were near the average type. In this regard, the Advanced Coupling Program at the AAR has determined that an average load per car is 56.8 tons (51.1 metric tonnes). Considering the car weight and use of 3,300 HP locomotives yields a total train tonnage of around 6500 tons (5850 metric tonnes). This train can be considered an average train. It should be considered as a basis for design. Also on the basis of typical railroad practice, the type of consist should be a random mix, and this tonnage train should be used for a number of tests.

Again, in regard to how many trains, running two of these trains would be better than running one. It would be more economical. The only constraint that appears in terms of its interaction with the loop design is the requirement for adequate headway to be provided so that, under a full service stop, there is sufficient stopping headway between the trains. Thus, for this particular train, Figure 13.4 shows that a stopping distance on the order of 2 miles (3.2 km) is required. The train length is approximately 1 mile (1.6 km). The first constraint becomes that the train must be spaced on the order of 4 miles (6.4 km) (an additional 1 mile (1.6 km) is given for safety



Source: CN Technical Research
Centre Report 12-72

Composition Shoes, Brake Ratio: 8.62 Loaded
Truck Mounted Rigging, Efficiency: 80%

Figure 13.4 Train Stopping Distances

and for testing of 200 car trains). This is to say that if a loop were 4 miles (6.4 km) in length, and the last car derailed; the train should be able to stop short of the point of derailment. If two trains are used the headway should be sufficient so that if the last car of the first train were derailed; the second train would be able to stop safely. Thus, 8 miles (12.8 km) of loop would be required for two trains and by the same logic, 12 miles (19.3 km) if 3 trains were used.

13.3.5 Time Length of Test

Consideration of the time length of test may be made using one of two approaches. The first is to consider how long it will take to run the test of track or equipment to destruction. For example, if one is interested in rail wear, one could run the test until the rail was worn out. The second way to evaluate how long a test should run is on the basis of the trend that is developing. When one is confident of this trend, the test is terminated and the results are extrapolated. Taking again the rail wear tests, one could measure rail profile at successive tonnage to determine the amount of material that was being worn away and then extrapolate to find a figure for rail life. Once a reliable trend was established the test would be terminated. The same is true of settlement rates. One could continue to plot on a log scale the settlement rate against the number of tons. When a straight line relationship develops, one can again terminate the test and extrapolate the results. Thus, the length of the test may be developed on the basis of either a test to destruction or a test which gathers sufficient information to evaluate the trend that is developing. While the time duration of tests will

be developed further in succeeding sections of this report, one of the constraining relationships is the time to complete the tests on track settlement rates. On the basis of current knowledge, approximately 150 million gross tons of traffic will have to be accumulated in each settlement test series.

Considering the climatic conditions, a test series should be completed within 6 months. Thus, it appears that traffic accumulations of 1 million gross tons (0.9 metric tonnes) daily are not only desirable but necessary. One could also argue that results in written report form should be available in 6 months. Approval and distribution of the report within the next 6 months could yield a continuous input to the railroad industry, coinciding with their planning schedules for the following year.

13.3.6 Space Requirements

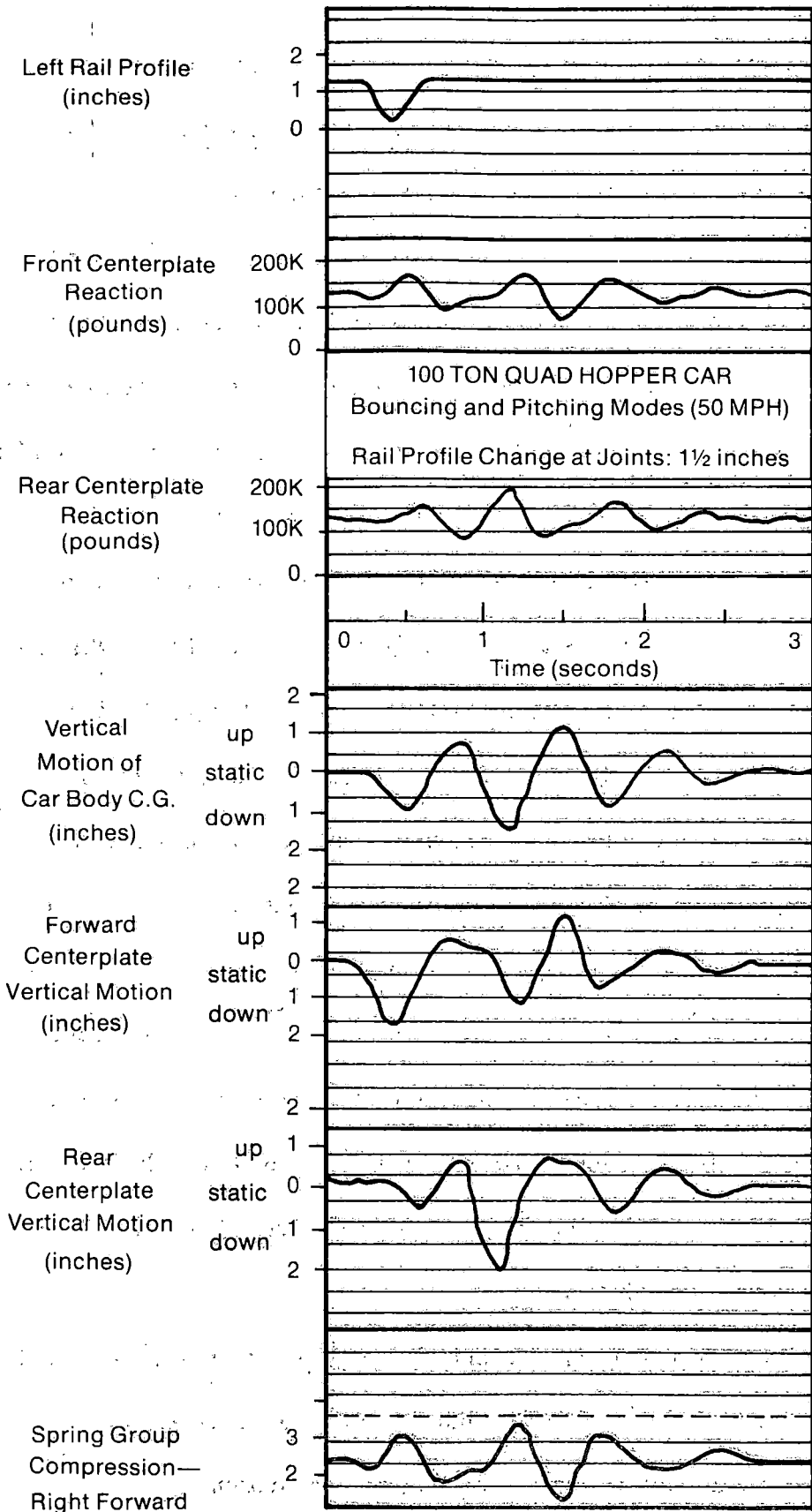
The only limitation that has been placed on space requirements is to consider that the loop should be built at the Pueblo facility. The loop and its related facilities should be accommodated within the areas apparently available there. Several trials on the design were made and the space available is adequate since the design is constrained by other considerations.

13.3.7 Length of Test Sections

There are two considerations in the design of a test section length. The first is that whatever happens on an adjacent section should not have a major influence on the test section in question. The second consideration is that information derived from a test section should be statistically representative of the real world. In other words, the test section has to be long enough so that statistical variations may be determined.

Considerations of the first type can be developed from vehicle dynamics. Let us suppose that we consider that a track irregularity has developed, just prior to entering a test section. Figure 13.5 shows an example of a car running at 60 mph (96 km/hr) traversing a 1" (25.4 mm) low joint. Assume that this low joint is immediately ahead of the test section. As shown, the natural frequency of the system indicates that this disturbance will last approximately 2 seconds into the test section. At 80 mph (128 km/hr) this effect will be carried approximately 250' (76 m) into the test section. While it has not yet been stated, any test train will have to be turned and operated in each direction across the test section. This would mean that the test section has to be a minimum of 500' (152 m) long at 80 mph (128 km/hr). At 60 mph (96 km/hr) it would have to be a minimum of 350 feet (106 m). But the problem is more complicated than this. One can argue that if the 1" (25.4 m) low joint existed just off the test section that this would create a dynamic impact on the test section, create an excessive amount of settlement at that point, and the next time around that second point itself would cause a settlement farther on down the test section. This effect could propagate down the test section and the results would be completely distorted by the 1" (25.4 m) low joint that had been off the test section. There is, however, a way to circumvent this effect.

Transition sections of approximately 100' (30.4 m) are built at each end of the test section. These will be adjacent to the test section, with the end sections as dynamically equivalent to neighboring section, as possible. Finally, maintain the transition sections so that a smooth transition between



Source: Computer Simulation of the response of a 100 Ton Quad Hopper Car, A. Stucki Company

Figure 13.5 Typical Car Response to Track Irregularity

the adjacent test section occurs. This maintenance would be performed daily. One still should consider that approximately 150' (45 m) on each end of the test section may give some results that are questionable.

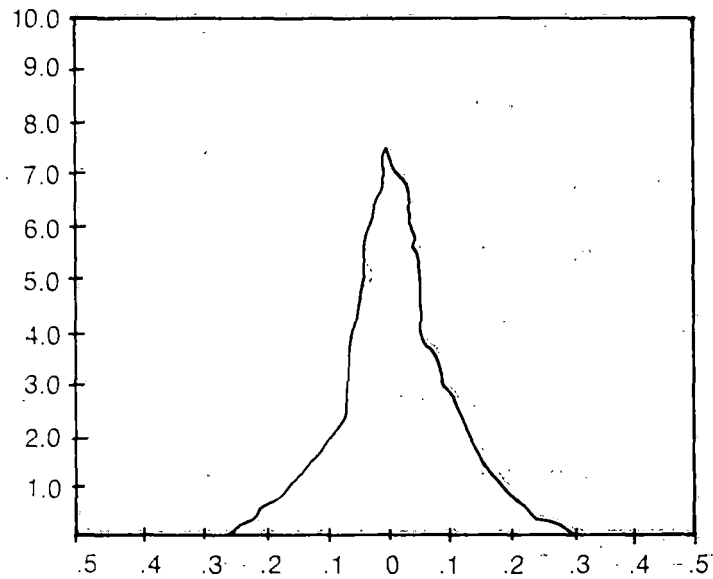
The other consideration that one can enforce is of ensuring that the test section is of sufficient length to obtain statistical information that is representative of the real world. On the basis of limited information such as shown in Figure 13.6, a test section of approximately 600' (182 m) would be required. More information is required to determine this length, but it does indicate that a test section on the order of 1000' (600' + 300') is required. It should be noted that test section length is train speed dependent. However, for discussion purposes, we will assume a 1000' test section with 100' (30.4 m) transition sections on either side is required.

13.3.8 Problems of Test Loops

There are a number of problems that are inherent with having a train operating over a loop. One of these has already been mentioned; the loop should be of sufficient length so that, should failure such as train separation occur, the train can stop before it reaches the point at which the failure occurred.

The second is the problem of irregular wear. Let us take for example on oval configuration with train traffic. It can be readily seen that the wheels on the outside would tend to wear much more rapidly than the wheels on the inside due to flanging on the high rail. Again, since the train would be used for mechanical types of tests, the drawbars near the front end would always be subjected to higher levels of coupler force than those near

	<u>Run 1</u>	<u>Run 2</u>
Mean	-.0022	.0079
Var	.0037	.0126
S.D.	.0608	.1124
SL/M	48	484



L. PROFILE HISTOGRAM

Source: DOT/FRA ORD & D 75-27

Figure 13.6 Typical Track Geometry Parameter
Field Measurement Distribution

the rear end. Thus, it becomes essential to not only turn the train periodically so that the wheels do see equal amounts of wear but also to move the locomotives from one end of the train to the other.

The third problem of test loops involves speed changes. Other sections will show this in more detail, however, the maximum speed possible at any limiting point in the loop, whether it is caused by a turnout or by a curve, will govern test train speeds. This is because loops on the order of 10 miles (16 km) in length do not allow for significant speed changes around the loop itself.

The fourth problem with loops is that they may not generate a representative environment for train operation. As an example, a loop introduces far higher ratio of curved to tangent track than most vehicles ever experience. This may be either good or bad. Also, if one is programming vertical irregularities, the train could see far more run-ins and run-outs than a train ever encounters in actual service. If you do not program for vertical irregularities, the train would experience far fewer than in the service environment. This indicates that some programmed types of irregularities (grades, changes in track line and surface, or reverse curves) may be necessary in order to simulate the environment in a realistic manner. Also, for tests of brake equipment and of the effect of braking forces on the track structure, some levels of program braking will be necessary to introduce longitudinal forces.

There is a final problem encountered on test loops. This involves levels of contaminants, particularly those used in curve wear areas.

Generally, one might say that up to 3° (580 m) in curvature, curve lubricators are not used. Beyond this curvature, lubricants will be used. Thus, in rail wear tests of a 1° (1740 m) curve, one would not want the rail lubricated. But for those of 7 to 8° (249 to 217 m) one certainly would. Now suppose that one designed a loop where there was a 1° (1740 m) on one end and a 5° (348 m) curve on the other end. In addition to the problem of the 5° (348 m) curve would eventually be tracked down to the 1° (1740 m) curve and beyond. The rail wear results obtained from the 1° (1740 m) curve would, therefore, be of little use. Thus, it is necessary to separate loops that are to be used for tests under heavy curvature with lubrication from those that are to be used for tests having light curvature with no lubrication.

13.3.9 Period Required for Maintenance

As previously mentioned, the track transition sections will have to be maintained. In addition, the entire test loop will need to be inspected for rail defects. Measurements are made for a variety of reasons on track and equipment. The equipment will have to be inspected to verify that it is in good working order, and to investigate what levels of wear have occurred. It seems apparent that a 4 hour period each day will be required for a variety of purposes.

13.3.10 Inspection of Track and Equipment

This 4 hour period meets the requirement for general routine inspection and maintenance of the test sections and equipment but may be less than required for change-out of a test section. This period of approximately

4 hours should suffice for performing all routine maintenance on track and equipment as well as many section change-outs.

13.3.11 Test Section Failure

If the test sections are of a conventional track structure design it is conceivable that sufficient time would be available to observe the section daily to measure the deterioration occurring, and to then determine when the section would be expected to fail. The maintenance period should be adequate for change-out of conventional track sections. One question that does arise is the testing of unconventional track structures. If unconventional track structures such as those used at the Kansas Test Track were to be tested, then it is doubtful whether sufficient time for repairing or change-out of the test section is available within the daily maintenance period. Thus, one should consider the viability of the concept of providing by-pass tracks for some of the test sections.

13.3.12 Change Out Times

The problem is essentially one of the economics and also of the test loop design. To provide by-passes for each test section will require turnouts. The turnouts will be relatively expensive. A second problem is that for 80 mph (128 km/hr) operation, it is extremely difficult to negotiate anything but a custom designed turnout at such a high speed. Alternatively, one could cut out the unconventional section and resurface and reline the track to provide a smooth transition, including superelevation; so that the high speed could be obtained. It is sufficient to say that if unconventional track structures are to be placed in service, by-passes will have to be considered and these high

risk, high probability of failure sections should be isolated from sections of conventional track. Either very high speed turnouts will have to be considered or the method of relining and surfacing the track to pass around the failed unconventional sections will have to be employed.

13.3.13 Interfacing Mechanical and Track Testing

There are several incompatibilities between mechanical and track testing. A number of these have been mentioned in previous sections. For example, from the track testing standpoint one would desire to operate representative freight trains over the track section and make a variety of measurements such as rate of settlement and rail wear.

However, from the mechanical equipment testing standpoint, one would desire to have a representative track test section with programmed vertical and lateral irregularities as well as grades and curvature. From the mechanical standpoint, the track should be representative track that equipment actually traverses.

Now consider that one desires to change the metallurgical properties of wheels or wheel contour in an investigation to achieve a longer wheel life.

If one ran a train with a proposed new wheel hardness or with a proposed new wheel contour over track sections that were also being tested, it is easy to see that the results for items such as rail wear may not be representative of the results that were achieved in the actual service environment.

Also, a candidate test for equipment testing would be to change the dynamic properties of the vehicle. Again, this may subject the track structure to unrepresentative loadings.

The question then arises as to what may be done to arrive at some compromise between proposed equipment testing and proposed track testing. One solution of course, is to develop two loops; one dedicated for track testing, in which the trains are representative and one for mechanical testing, discussed earlier as an option, in which the track structure is representative and the equipment is changes. A second approach if one decided that two loops were not advantageous to build would be to:

- a. Permit as much as arbitrarily 10% of the train consist to be varied for equipment testing of any type and
- b. Monitor force levels in the track structure as these equipment test vehicles passed over the structure.

If the force levels were substantially changed from the representative average train consist, one would then have to either stop the equipment test or, by using engineering judgment, attempt to assess how much error was being introduced by these vehicles.

In any event, if only 10% were changed, it seems logical to assume that the loadings at the track structure would be fairly representative of revenue freight trains.

13.3.14 Type of Operation

One consideration is whether one should use diesel or electric locomotives. Since the current fleet of diesel-electric locomotives far

exceeds the number of electric locomotives, it is reasonable to expect that they would apply a more representative loading. Also, a considerable amount of diesel locomotive testing should be incorporated. Electric locomotive tests will also be required, but the initial recommendation is to defer electrification of the loop and to employ conventional diesel-electric motive power.

A final consideration is that of adequacy of manual operation of the locomotives. Manual operation appears to be cheaper; however, there are two items that weight heavily in favor of automating the railroad in the manner of the Black Mesa and Lake Powell. These are as follows:

For safety reasons, anyone operating a train in the monotonous environment of running around the loop could become easily fatigued and even fall asleep. The AASHO road tests, in which manned vehicles were employed, indeed demonstrated a number of accidents can occur on a small operating loop because of fatigue.

A second consideration, more in favor of an automatic operation, is that as the loop is envisioned; there is a need to perform programmed braking applications. To obtain the degree of control necessary, and to limit the amount of variability in the control between tests, automatic operation becomes essential.

These then are a number of basic considerations for loop design that must be evaluated on the basis of engineering judgment. These considerations and others have been used in preparing the specific recommendations for FAST described in the first part of the report.

13.4 Summary of Design Elements

The purpose of this section is to summarize the content of the previous sections on elements to be considered in the design of the test loop.

The summary is as follows:

1. The speed range for operation of the test train will be between 40 mph (64 km/hr) and 80 mph (128 km/hr). These speed ranges are established on the basis of knowledge of vehicle track behavior and current operating practices in the United States.
2. Test trains that are representative of real world trains do not have extremely good acceleration characteristics for incorporating into the loop. This is to say that large speed variations on the order of 10-15 mph (16-24 km/hr) cannot be accommodated in the loop design.
3. More than one loop will be required. This results from a number of considerations as follows:
 - a. The minimum operating speed at any point in a loop is generally the operating speed at other parts of the loop. This is because of the acceleration characteristics of a test train. The operating speed for the curves tend to limit maximum test train speed.
 - b. In order to operate at 80 mph (128 km/hr) the curvature must be relatively shallow. The maximum curvature for 80 mph (128 km/hr) speed with 3" (75 mm) unbalance with 6" (150 mm) superelevation is about 2.1° (830 m).

c. However, there is a need to test varying degrees of curvature, particularly, for rail wear. Thus, higher degrees of curvature are required.

The curve lubrication would contaminate the entire loop unless a separate loop is constructed for the curve wear tests.

d. There are incompatibilities between the desire to test track and equipment. This is to say that for equipment tests, it is desired to have reversing curvature and programmed irregularities; while on the other hand, the track test should have representative test train without programmed irregularities in the structure.

4. The loop should be designed for an average train. This would be an 85 car train with cars weighing approximately 73 tons (65 metric tonnes).

5. The daily test train tonnage must be such that a test of a 150 million gross tons (135 million metric tonnes) for track settlement can be completed within 6 months. The 6 months figure results from the climatic considerations at Pueblo with the potential effects of frost action.

6. The test section should be approximately 1,000' (304 m) long although the exact length will be speed dependent. The test section should have a 100' (30.4 m) transition section on either end that is maintained daily.

7. An inherent problem of a loop will be that the percentage of curvature to which a vehicle is subjected during traverses around the loop is much greater than that to which revenue equipment is subjected. This will give excessive levels of wheel wear.
8. The test train should have capabilities of program braking and should be automatically controlled.
9. Instrumentation requirements can be presented in general terms, but detailed array design will be dictated by the test series specifications.

14.0 POTENTIAL BENEFITS FROM FAST

Initial test series have been described in earlier sections. The initial track loop configurations, in large measure were selected on the basis of anticipated benefits. The benefits from these initial tests constitute an integral part of the rationale for the recommendations made for FAST.

In this section benefits from each type of test will be discussed. While system optimization may also be realized as a result of the proposed tests, the benefits will not necessarily be derived in the near future. For example, if the tests points out that costs for track maintenance and freight car maintenance are minimized with 70 ton (63 metric tonnes) cars and after considering other aspects of transportation logistics and economics, a 70 ton (63 metric tonnes) car is a usable maximum weight car, significant savings from system optimization will not accrue until 100 ton (90 metric tonnes) cars are phased out. System optimization savings, therefore, are only discussed in a general way. The benefits are discussed for track research, mechanical equipment research and other areas.

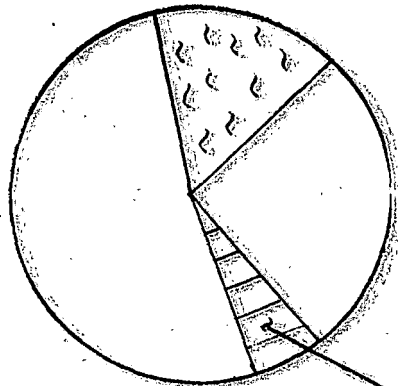
14.1 Estimate of Benefits from Track Tests

FAST will be useful to the railroad industry in improving productivity of equipment and labor through an increase in the life obtained from track structures. By obtaining a more complete understanding of track structure deterioration the industry will be better able to program maintenance, optimize maintenance cycles and use improved materials that result in lower total life cycle costs. Table 14.1 shows 1973 expenditures for Maintenance of Way and Structures. It is expected that tests conducted

Table 14.1 Maintenance of Way Expenditures

DISTRIBUTION OF MAINTENANCE OF WAY EXPENSES - 1973

ICC A/C NO.	Total M of Way (Frt. Service Only)	% Total M of Way
201*	188,407	10%
202c	92,337	5%
212c	109,441	6%
214c	83,571	4%
216c	89,939	5%
218c	32,929	2%
220c	424,929	22%
	Total of 201, 202c, 212c, 214c, 216c, 218, & 220c	54%



M of Way
14%
(1,964,292,000)

NET RAILWAY OPERATING INCOME

7%

(1,037,122,000)

DISTRIBUTION OF RAILWAY OPERATING REVENUES (1973)

*No breakdown available between running tracks and other (yard and switches)

in the FAST will have an impact to some degree on 54% of the total amounts expended for maintenance of way.

Material costs represent 17% of the total Maintenance of Way and Structures budget. Expenditures consist of rail replacement (approximately 6000 miles (9654 km) projected for 1975) tie replacement (20 million projected for 1975) track surfacing (47,000 miles in 1975) and other track materials.

Table 14.2 shows estimates of annual maintenance costs per track mile. A 1% increase in productivity of the dollar expended on maintenance of way would result in annual savings of \$24 million.

Elements of total life cycle costs for main line track are shown in Tables 14.3, 14.4, 14.5, 14.6, 14.7, and 14.8. Many potentially beneficial concepts for track structures which have a higher first cost are often rejected or put aside since there is no assurance of increased life or reduced cyclic maintenance costs. FAST will afford the opportunity to ascertain within a relatively short time whether a concept is, in fact, cost effective. It will also afford the opportunity to concurrently test the cost-effectiveness of more than one design or assembly alternative and to demonstrate this in a meaningful way.

The following is a sampling of some of the benefits from FAST track research tests:

1. Reduction in track inspection costs
2. Reduction in slow order periods following maintenance
3. Lowered material costs for track components

Table 14.2 Estimates of Maintenance of Way Costs Per Track Mile

ESTIMATED \$12,000

RAIL SERVICE IN THE MIDWEST AND NORTHEAST REGION
 pg 11, Vol I, DOT, 2/1/74: COST ESTIMATE FROM
 FRA/OFFICE OF ECONOMICS, OR&D, AND OFFICE OF
 SAFETY

TOTAL
 MAINTENANCE
 COSTS PER TRACK MILE = \$ 9,292

MAINTENANCE OF WAY PER EQUATED TRACK MILE
 (Corrected to 1974 Prices - 5%/Yr.)

(HVY. DENSITY)
 CLASS 4-5 PER YEAR \$16,720

RAILROAD "A" ESTIMATE (\$.50 per 1000 GIM
 @ 30 MGT DENSITY)

1 mile = 1.609 km
 1 Gross Ton Mile (GTM) = 1.46 Metric Ton - km

Table 14.3 Elements of Life Cycle Costs for Main Line Track

FIRST COST*

- I. GRADING & EARTHWORK, DRAINAGE
- II. BALLAST - MATERIALS
LABOR
EQUIPMENT
- III. A TIE
MATERIALS
- B OTM LABOR PANEL
EQUIPMENT CONSTRUCTION
- C RAIL
- D ASSEMBLY LABOR FIELD
CONSTRUCTION
- IV. TRACK SURFACING & ALIGNMENT
- V. BREAK-IN COSTS
- VI. DOWN TIME

* or Present Replacement Value for Present Trackage

Table 14.4 Elements of Life Cycle Costs for Main Line Track (Continued)

INSPECTION FUNCTIONS

- VII. TRACK GEOMETRY INSPECTION
- VIII. RAIL FLAW DETECTION
- IX. A) DRAINAGE INSPECTION
B) BALLAST CONDITION INSPECTION
- X. TIE INSPECTION
- XI. RAIL SURFACE
- XII. A) RAIL JOINT INSPECTION
B) INSULATED JOINT INSPECTION
- XIII. DOWN TIME FOR INSPECTION

Table 14.5 Elements of Life Cycle Costs for Main Line Track (Continued)

MAINTENANCE/RENEWAL
WORK ELEMENTS

- XIV. SPOT TAMPING
- XV. SKIN LIFT
- XVI. RAIL END WELDING & GRINDING
- XVII. JOINT TIGHTENING
- XVIII. ODD TIE RENEWAL
- XIX. SURFACING & LINING
- XX. TIE RENEWAL
- XXI. BALLAST CLEANING AND/OR RENEWAL
- XXII. ODD RAIL RENEWAL
- XXIII. RAIL RENEWAL
- XXIV. SURFACING & LINING FOLLOWING RAIL/TIE RENEWAL

Table 14.6 Elements of Life Cycle Costs for Main Line Track (Continued)

DOWN TIME AND BREAK-IN
COSTS ASSOCIATED WITH
MAINTENANCE AND/OR RENEWAL

- XXV. DOWNTIME FOR SPOT TAMPING.
- XXVI. DOWNTIME FOR RAIL END WELD & GRIND
- XXVII. DOWNTIME FOR JOINT TIGHTENING
- XXVIII. DOWNTIME FOR ODD TIE RENEWAL.
- XXIX. DOWNTIME FOR SURFACING & LINING.
- XXX. DOWNTIME FOR TIE RENEWAL.
- XXXI. DOWNTIME FOR BALLAST CLEANING AND/OR RENEWAL.
- XXXII. DOWNTIME FOR ODD RAIL RENEWAL.
- XXXIII. DOWNTIME FOR RAIL RENEWAL.
- XXXIV. DOWNTIME FOR SURFACING & LINING FOLLOWING RAIL/
TIE RENEWAL.

Table 14.7 Elements of Life Cycle Costs for Main Line Track (Continued)

MISCELLANEOUS ELEMENTS OF WORK

- XXXV. SLOW ORDER (WORK ONLY)
- XXXVI. WEED CONTROL
- XXXVII. STABILIZATION OF SOILS
- XXXVIII. DRAINAGE MAINTENANCE

MISCELLANEOUS DOWNTIME ELEMENTS

- XXXIX. DOWNTIME FOR WEED CONTROL
- XL. DOWNTIME FOR SOIL STABILIZATION

Table 14.8 Elements of Life Cycle Costs for Main Line Track (Continued)

MATERIALS COST IN MAINTENANCE

XL I.	WELD METAL
XL II.	BALLAST
XL III.	TIES
XL IV.	TIE PLATES, OTM
XL V.	RAIL
XL VI.	JOINT BARS, INSULATED JOINTS ETC.
XL VII.	WEED CHEMICALS
XL VIII.	STABILIZATION MATERIALS
XL IX.	DRAINAGE MATERIALS

4. Lowered track maintenance costs
5. Increased life of track components
6. Reduction in new component introduction time
7. Improved programming of track maintenance
8. Improved safety standards
9. Overall reduction in track related safety costs.

A new concept may, for example, require in-service testing for 10 years or 300 million gross tons of traffic before the industry is convinced that the life expectancy and maintenance costs associated with it are going to prove cost-effective. With tests on FAST, this service test period is accelerated to 1 year. In addition, many more design options can be concurrently tested resulting in design optimization as well as an improved probability of success. An estimate of the potential benefits from the proposed initial track tests has been made. These are presented in summary form in Table 14.9. The numbers shown can be described as intelligent estimates. The benefits from one track test series can overlap those from another track test series. It is important, however, to convey that total benefits derived will be significant regardless of which test series they derive from. In developing each of the estimates presented in Table 14.9, no savings are shown for at least two years and practical constraints, such as maximum rate of track improvements due to budgetary limitations are imposed in estimating benefits. The present worth shown in Table 14.9 represent amounts any commercial banker would risk given the promise of return on investment at 15% in the form of benefits to be obtained in ensuing years.

Table 14.9 Summary of Benefits From Initial Track Research Tests

TEST SERIES DESCRIPTION	ESTIMATED PRESENT WORTH OF BENEFITS (MILLION DOLLARS)
I SETTLEMENT RATE SERIES	165.0
II CANT OPTIMIZATION SERIES	75.0
III GAGE OPTIMIZATION SERIES	
IV TIE OPTIMIZATION SERIES	50.0
V TRACK MAINTENANCE METHOD SERIES	60.0
VI RAIL CHEMISTRY SERIES	32.0
VII LOADING SPECTRA SERIES	No Estimate
VIII FASTENER DEVELOPMENT SERIES	No Estimate

The benefits and the methods of estimating these are illustrated by two examples given below. These are for the Settlement Rate Series and the Rail Chemistry Series.

Example 1

Benefits from Settlement Rate Series

This test series is designed to produce definitive information for developing life cycle costs (particularly the portion which varies with tonnage) of roadway maintenance costs for each track structure tested.

A rough estimate of the variable portion of road maintenance costs is around 53%. This test series will produce mean settlements and the standard deviation of settlement (a measure of differential settlement) and measurements of line, cross-level, gage and twist. Initial measurement intervals will be smaller than subsequent intervals. Experience with the first test series will guide the selection of intervals for subsequent series. Examples of settlement rate curves obtained in Europe are shown in Figures 14.1 and 14.2.

The pertinent elements of life cycle costs for main line track were shown earlier in Table 14.5. The cost of material and the cost of construction are well known. The production costs associated with right-of-way maintenance and the "life" expectancy are known only in a general way.

Specific comparisons of "life" expectancy of a maintenance operation for different track component characteristics will result in track structure optimization. Only actual testing can tell the exact benefits to be derived. An estimate of these benefits is attempted based on an expected

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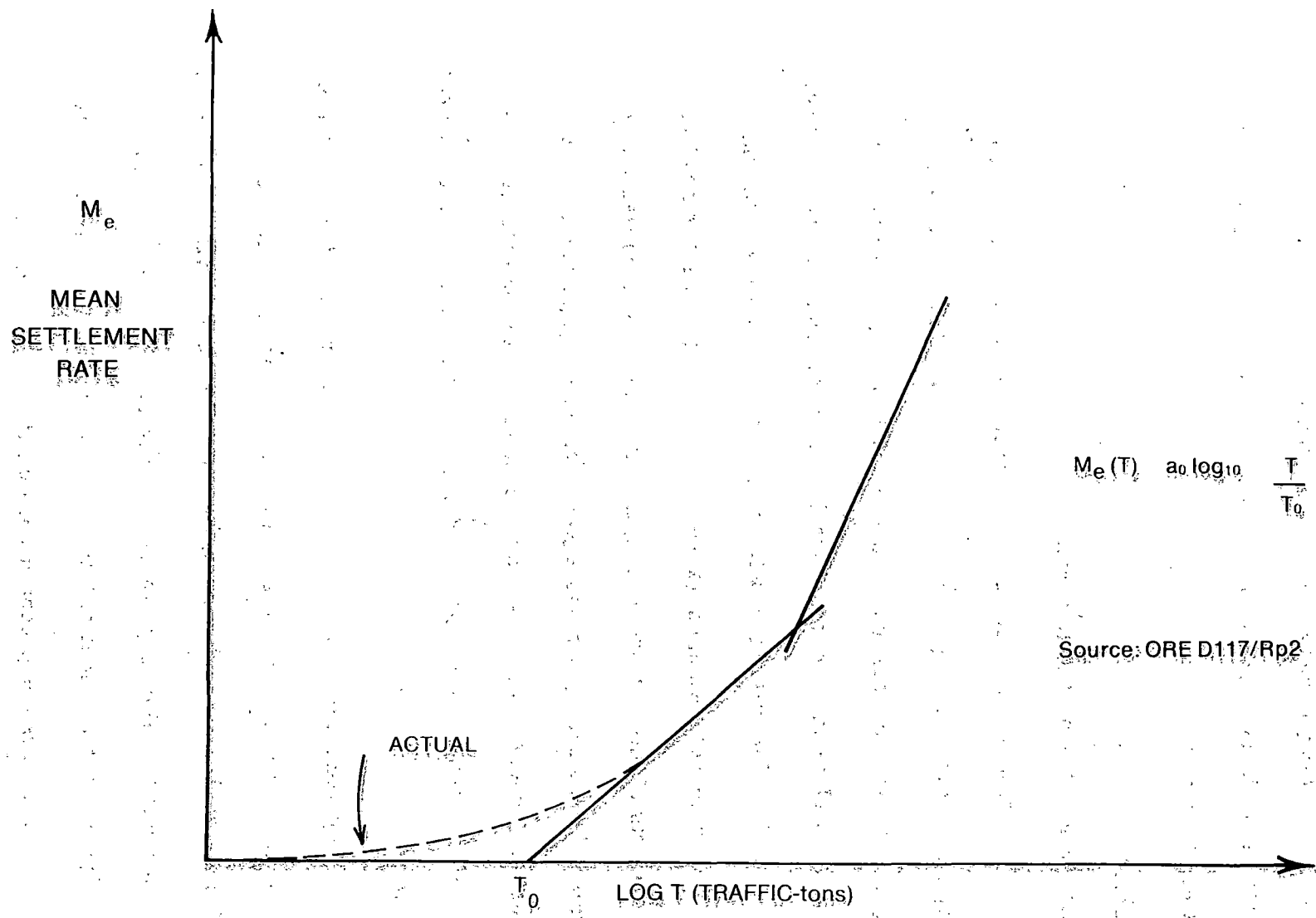


Figure 14.1 Example of Mean Settlement Rate Curve— Vertical Profile

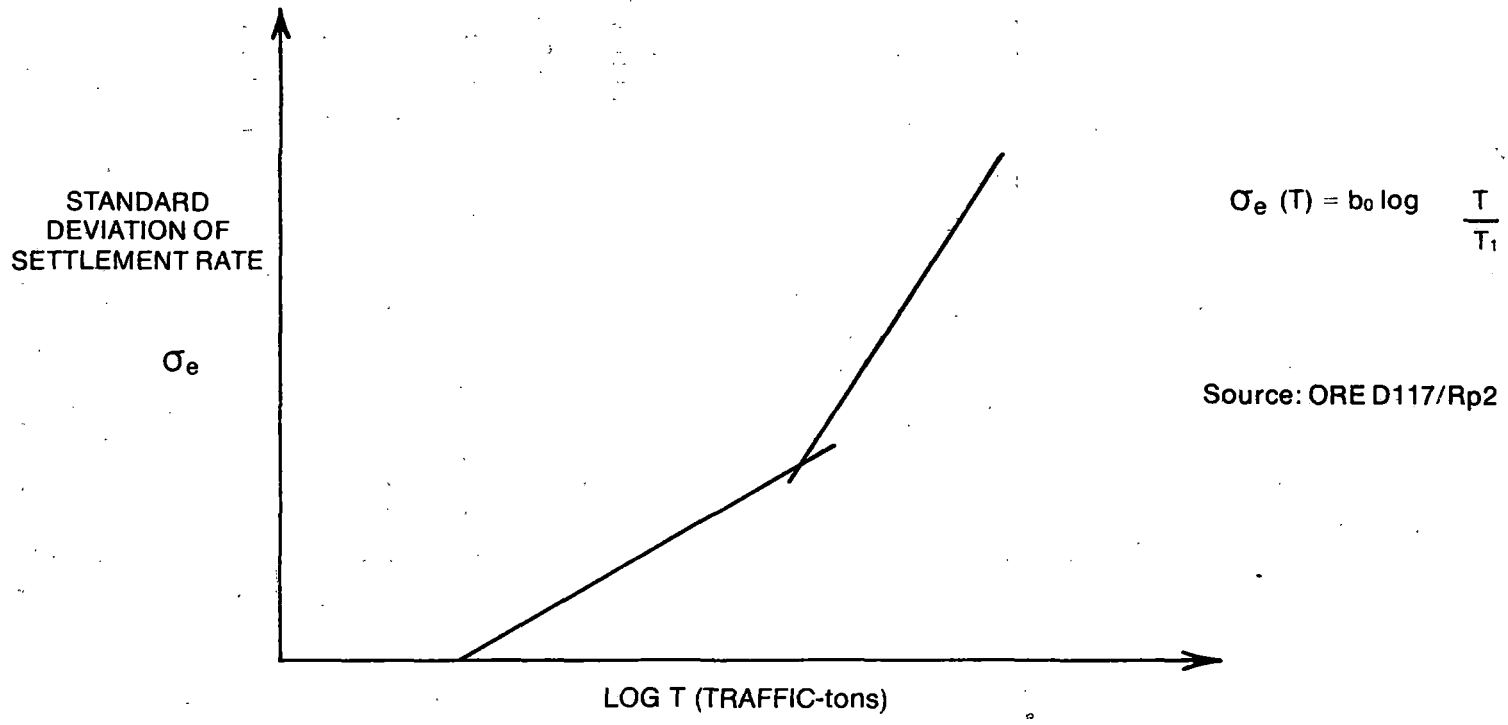


Figure 14.2 Example of Standard Deviation Curve—Vertical Profile Deviation

increased life expectancy or an increased maintenance interval. Table 14.10 shows how the present worth of increased track maintenance cycle is derived. An explanation follows. Annual expenses for surfacing and lining with present equipment, present structure and present cycle are shown at \$40.0 million in column 2, for each period (0 to 1, 1 to 2 etc.). The cash flow is projected in column 3 for each period for 13 years. No savings are shown until the period 5 to 6 (the sixth year). No change is anticipated for two years; thereafter surfacing and lining would use test results in the annual maintenance program for surfacing and lining, as shown in Table 14.10. Benefits from the Settlement Rate Series will also come from a reduction in track geometry related accidents, rail joint maintenance costs and other items. The example given, therefore, represents only a portion of the total benefits from this series.

Example 2

Benefits from Rail Chemistry Test Series

Table 14.11 gives the second example of benefits from the proposed initial track test series. The amount of new rail laid annually is about 3,000 miles. Of this, it is estimated that 10% is in the form of low calendar life, that requires replacement every 10 years. This exists mainly in curve territory. This problem is also extending into high speed main lines where plastic flow and shelling occur, particularly on lines with traffic rates on the order of 50 MGT per year.

The other way of examining investment is by considering what savings must result for a proposed investment.

Table 14.10 Example of Benefits, Settlement Rate Series

Year	Cash Outflow Present	Cash Flow Projected	Net Savings	PWF @15%	PW
0-1	40.0	40.0	0		-
1-2	40.0	40.0	0		-
2-3	40.0	40.0	-	.7057	-
3-4	40.0	40.0	-	.6136	-
4-5	40.0	40.0	-	.5336	-
5-6	40.0	-	40.0	.4640	18.56
6-7	40.0	-	40.0	.4035	16.14
7-8	40.0	24.0	16.0	.3508	5.61
8-9	40.0	24.0	16.0	.3051	4.88
9-10	40.0	24.0	16.0	.2653	4.24
10-11	40.0	24.0	16.0	.2307	3.69
11-12	40.0	24.0	16.0	.2006	3.21
12-13	40.0	24.0	16.0	.1744	2.79

\$59.12 million

Present cycle between successive surfacing and lining operations = 3 years (75 MGT)

Projected cycle between successive surfacing and lining operations = 5 years (125 MGT)

Cost of surfacing and lining = \$800/mile (\$497/km)

150,000 = 50,000 miles/year (80,000 km/yr.)
Annual mileage surfaced and lined = 3 year cycle

Projected Maintenance cycle = 5 years or 30000 miles/year

Present total cost-annual = \$40.0 million

Projected annual cost-annual = \$24.0 million based on 5 year cycle

Table 14.11 Example of Benefits, Rail Chemistry Series

Year	Cash Outflow For Rail Replacement- Present (Million)	Cash Outflow For Rail Replacement Projected (Million)	Net Savings	PWF \$15%	PW Million\$
0-1	32.4 #	32.4	-	.9333	-
1-2	32.4	32.4	-	.8441	-
2-3	32.4	32.4 *	-	.7057	-
3-4	32.4	32.4	-	.6136	-
4-5	32.4	32.4	-	.5336	-
5-6	32.4	32.4	-	.4640	-
6-7	32.4	32.4	-	.4035	-
7-8	32.4	32.4	-	.3508	-
8-9	32.4	32.4	-	.3051	-
9-10	32.4	32.4	-	.2653	-
10-11	32.4	32.4	-	.2307	-
11-12	32.4	32.4	-	.2006	-
12-13	32.4	- @	32.4	.1744	5.65
13-14	32.4	-	32.4	.1517	4.91
14-15	32.4	-	32.4	.1319	4.27
15-16	32.4	-	32.4	.1147	3.71
16-17	32.4	-	32.4	.0997	3.23
17-18	32.4	-	32.4	.0867	2.83
18-19	32.4	-	32.4	.0754	2.44
19-20	32.4	-	32.4	.0656	2.12
20-21	32.4	-	32.4	.0570	1.84
21-22	32.4	-	32.4	.0496	1.60
22-23	32.4	32.4	0	-	-
				Total =	32.6

* Replacement scheduled at same annual rate with higher life rail

300 track miles/year - (10% of new rail installed)

@ No replacement due to doubling of life

Table 14.12 Present Worth Calculation for Future Benefits - FAST Tests

YEAR	TIME PERIOD	CASH/TRACK* FLOW/MILE/YR (Dollars)	CASH FLOW TOTAL (Million \$)	PRESENT WORTH FACTOR TOTAL 30%	PRESENT WORTH (Million \$)	CUMULATIVE PW IF BENEFITS TERMINATE GIVEN YEAR
1975	0	N/A	-4.2		-4.2	-4.2
1976	0 to 1	N/A	-2.9		-2.9	-7.1
1977	1 to 2	N/A	-2.9		-2.9	-10.0
1978	2 to 3	+\$50	+7.5	.5205	3.9	3.9
1979	3 to 4			.4004	3.0	6.9
1980	4 to 5			.4080	2.31	9.21
1981	5 to 6			.2369	1.78	10.99
1982	6 to 7			.1822	1.37	12.36
1983	7 to 8			.1402	1.05	13.41
1984	8 to 9			.1078	0.81	14.22
1985	9 to 10			.0829	0.62	14.84
1986	10 to 11			.0638	0.48	15.32
1987	11 to 12			.0491	0.37	15.69
1988	12 to 13	+\$50	+7.5	.0378	0.28	15.97

*Values in column represent potential reduction in M of Way for all improvements

#For rail network rationalized at 150,000 miles

Table 14.13 Present Worth Calculation for Future Benefits - FAST Tests

<u>YEAR</u>	<u>TIME PERIOD</u>	<u>CASH/TRACK* FLOW/MILE/YR (Dollars)</u>	<u>CASH FLOW TOTAL (Million\$)</u>	<u>PRESENT WORTH FACTOR TOTAL 15%</u>	<u>PRESENT WORTH (Million\$)</u>	<u>CUMULATIVE PW IF BENEFITS ARE LIMITED TO GIVEN YEAR</u>
1975	0	N/A	-4.2		-4.2	-4.2
1976	0 to 1	N/A	-2.9		-2.0	-7.1
1977	1 to 2	N/A	-2.9		-2.9	-10.0
1978	2 to 3	\$50	7.5	.7057	5.29	5.29
1979	3 to 4			.6136	4.60	9.89
1980	4 to 5			.5336	4.00	13.89
1981	5 to 6			.4640	3.48	17.37
1982	6 to 7			.4035	3.03	20.40
1983	7 to 8			.3508	2.63	23.03
1984	8 to 9			.3051	2.29	25.32
1985	9 to 10			.2653	1.99	27.31
1986	10 to 11			.2307	1.73	29.04
1987	11 to 12			.2006	1.50	30.54
1988	12 to 13	\$50	7.5	.1744	1.31	31.85

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#For rail network rationalized at 150,000 HI-Grade track mile.

All estimates at 1974 prices.

*Values in column represent potential reduction in M of Way costs for all improvements

Tables 14.12 and 14.13 show the present worth using a discounted cash flow analysis using rates of 15 and 30% respectively, if a potential saving of \$50 per year per track mile for each mile of a rationalized 150,000 mile rail network is attained. The analysis shows that a \$31.85 million investment can be justified (at a 15% rate). If the higher 30% rate is used, a \$16 million investment can be justified.

The anticipated benefits are far in excess of the \$50 value used in Tables 14.12 and 14.13. The benefits from the Settlement Rate Series "spill over" to other aspects - for example rail end batter and bolt hole failures would also be reduced to provide additional benefits that are not readily associated with track geometry.

14.2 Estimate of Benefits from Mechanical Tests

Annual expenses on maintenance of equipment for Class I railroads is around \$2.4 billion. Of this amount \$776 million is expended directly in the repair and maintenance of freight cars and \$556 million in the repair and maintenance of diesel locomotives. Specific estimates for some series have been made, however, these are based on the limited amount of data that was available and should only be considered as offered to indicate that the potential benefits are in fact very significant.

Wheel Optimization Series: The annual replacement of freight car wheels is estimated to be 0.6 million. Annual wheel expenses on this basis are around \$180 million. Estimated wheel life ranges from 150,000 miles to 300,000 miles. The present worth of a 20% increase in wheel life would be at least \$36 million. A 20% increase in wheel life could conceivably be

achieved by use of heat-treated wheels alone. Each of the parametric variations listed as part of this series, such as profile, adapter configuration, brake shoe materials, offer the potential for increased life.

Additional benefits from this series will come from increased life of roller bearings and axles. Estimates of annual expenditures on roller bearings and axles range up to \$50 million each.

Center Plate Series: Based on a limited amount of data, an average annual body center plate replacement rate of 2 to 5 percent has been estimated. Using a 3.5% value, and 1.7 million car fleet size the total annual replacement is around 119,000 body center plates. The average material costs are estimated to be \$66 for non-cushioned underframe center plates and \$400 for cushioned underframe center plates. Approximately, half of the replacements are cushioned underframe center plates. Material costs alone amount to \$27 million annually. Total costs, including labor can be estimated at \$40 million. This does not include minor repairs, such as bolt tightening, repair welding, etc.

Assuming that annual center plate expenditures can be reduced to \$20 million (one-half the present amount) the present worth of these savings is \$63 million over a 20 year period.

Truck Concept Series: The opportunity to reduce life cycle costs for truck suspension concepts has been recognized and many new truck concepts have been tested. FAST will afford the opportunity to test promising concepts under near actual service conditions to demonstrate in a short time that total life cycle costs are in fact lower than presently available trucks.

The costs referred to are costs associated with component wear and fatigue and do not include wheel wear, for which separate estimates have been discussed. Also, benefits could come from opportunities for additional revenue due to improved ride quality provided by the new truck concept. The present worth of benefits from this series could well exceed \$25 million.

The benefits from the test series discussed are in fact very significant. Benefits from tests on other components will add further to the justification.

14.3 Summary

In estimating potential benefits from a test series three elements of information are required. These are as follows:

- a. Present performance with respect to life (and therefore cost)
- b. Potential performance with respect to life (and cost)
- c. Feasible implementation schedule in order to estimate present worth of proposed change

In most cases, even the present performance is not known definitively. Potential performance can at best only be estimated. A feasible implementation schedule is a function of many industry variables. It simply has to be assumed within the context of this report that given the economic justification a reasonable implementation schedule will be arrived at.

Many of the estimates provided here can be criticized. The types of data that will be developed in an accelerated test facility is also the same data required to make a more definitive estimate of potential benefits, absent

a meaningful data base. These comments are included in summary to place in proper perspective the estimates provided, the present worth of which totals nearly reached \$0.5 billion.

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APPENDIX I

LIST OF TRACK TEST SERIES

List of Tests

A description of the initial test series and the objectives of the test series were outlined in section 5 of the report. A list of specific track tests was made in order to assess the number of track test sections that would be required concurrently. This list, shown in Tables A1.1 through A1.8, details the number parametric variations considered for each series. This list was developed, in consultation with industry representatives.

The list includes 157 separate tests. The available sections would be used in a manner so as to minimize the changeover costs for sections. Each of the tests will require different amounts of cumulative traffic. It is expected that 150 MGT traffic will be required for most of the tests. A considerable amount of flexibility will be required in scheduling the tests and it is expected that some tests may need to be extended if results are not conclusive. In other cases, tests may be terminated prior to achieving the planned amount of traffic. Traffic periods of 50 MGT, attained in approximately 50 consecutive days of daily traffic can be contemplated. Decisions to extend or terminate individual tests can be made and section changeout completed prior to the start of the next traffic period.

TABLE A1.1 SETTLEMENT RATE TEST SERIES - LIST OF TESTS

Test No.	Parameters Selected						Test No.	Parameters Selected					
1.	a ₁	b ₁	c ₁	d ₁	e ₁	f ₁	16.	a ₁	b ₁	c ₂	d ₁	e ₁	f ₁
2.	a ₂	b ₁	c ₁	d ₁	e ₁	f ₁	17.	a ₁	b ₁	c ₃	d ₁	e ₁	f ₁
3.	a ₃	b ₁	c ₁	d ₁	e ₁	f ₁	18.	a ₁	b ₁	c ₁	d ₂	e ₁	f ₁
4.	a ₄	b ₁	c ₁	d ₁	e ₁	f ₁	19.	a ₁	b ₁	c ₁	d ₁	e ₂	f ₁
5.	a ₁	b ₂	c ₁	d ₁	e ₁	f ₁	20.	a ₁	b ₁	c ₁	d ₁	e ₃	f ₁
6.	a ₁	b ₃	c ₁	d ₁	e ₁	f ₁	21.	a ₁	b ₁	c ₁	d ₁	e ₄	f ₁
7.	a ₁	b ₄	c ₁	d ₁	e ₁	f ₁	22.	a ₁	b ₁	c ₁	d ₁	e ₁	f ₂
8.	a ₁	b ₅	c ₁	d ₁	e ₁	f ₁	23.	a ₁	b ₁	c ₁	d ₁	e ₁	f ₃
9.	a ₁	b ₆	c ₁	d ₁	e ₁	f ₁	24.	a ₁	b ₁	c ₁	d ₁	e ₂	f ₁
10.	a ₁	b ₇	c ₁	d ₁	e ₁	f ₁	25.	a ₁	b ₄	c ₁	d ₁	e ₂	f ₁
11.	a ₁	b ₈	c ₁	d ₁	e ₁	f ₁	26.	a ₁	b ₆	c ₁	d ₁	e ₂	f ₁
12.	a ₁	b ₉	c ₁	d ₁	e ₁	f ₁	27.	a ₁	b ₇	c ₁	d ₁	e ₂	f ₁
13.	a ₁	b ₁₀	c ₁	d ₁	e ₁	f ₁	28.	a ₁	b ₈	c ₁	d ₁	e ₂	f ₁
14.	a ₁	b ₁₁	c ₁	d ₁	e ₁	f ₁	29.	a ₁	b ₇	c ₁	d ₁	e ₂	f ₁
15.	a ₁	b ₁₂	c ₁	d ₁	e ₁	f ₁	30.	a ₁	b ₁	c ₂	d ₁	e ₂	f ₁
							31.	a ₁	b ₁	c ₃	d ₁	e ₂	f ₁

Rail
a₁ = 132# CWR
a₂ = 115# CWR
a₃ = 132# J
a₄ = 115# J

Ballast
b₁ = Trap Rock
9" Ballast
6" Sub-ballast
See Table A1.3 for
b₂ - b₁₂

Speed
e₁ = 75, e₃ = 50
e₂ = 60, e₄ = 40

Subgrade
c₁ = Natural
c₂ = Clay
c₃ = Loam

See Table A1.2

Ties
d₁ = 9'
d₂ = 8 1/2'
7" x 9"

OAK

Traffic
RM - Random Mix = f₁
Unit 70 = f₂
Unit 100 = f₃

**TABLE A1.2 SUB-GRADE MATERIAL TYPES TO BE
USED FOR SETTLEMENT RATE TEST SERIES**

1. Natural Subgrade - (Sandy)
2. Clay (medium & highly plastic)
3. Loam (Clay loam, Sandy loam)

**TABLE A1.3 BALLAST MATERIALS PROPOSED FOR
SETTLEMENT RATE TEST SERIES**

<u>Code</u>	<u>Ballast Material</u>	<u>Ballast Depth</u>	<u>Sub-Ballast Material</u>	<u>Sub-Ballast Depth</u>
b ₁	Trap rock	9"	Crushed rock	6"
b ₂	Trap rock	12"	"	"
b ₃	Trap rock	6"	"	"
b ₄	Granite	9"	"	"
b ₅	Granite	12"	"	"
b ₆	Steel Slag (Blast Furnace & OH)	9"	"	"
b ₇	Phosphate Slag	9"	"	"
b ₈	Basalt	9"	"	"
b ₉	Granite	15"	"	"
b ₁₀	Basalt	12"	"	"
b ₁₁	Limestone	12"	"	"
b ₁₂	To be selected	-	-	-

TABLE A1.4 CANT OPTIMIZATION - CURVES - LIST OF TESTS

1.	a_1	b_1	c_1	10.	a_2	b_1	c_2
2.	a_1	b_2	c_1	11.	a_2	b_2	c_2
3.	a_1	b_3	c_1	12.	a_2	b_3	c_2
4.	a_2	b_1	c_1	13.	a_3	b_1	c_3
5.	a_2	b_2	c_1	14.	a_3	b_2	c_3
6.	a_2	b_3	c_1	15.	a_3	b_3	c_3
7.	a_3	b_1	c_1	16.	a_2	b_1	c_3
8.	a_3	b_2	c_1	17.	a_2	b_2	c_3
9.	a_3	b_3	c_1	18.	a_2	b_3	c_3
19.	a_3	b_1	c_2	28.	a_4	b_1	c_4
20.	a_3	b_2	c_2	29.	a_4	b_2	c_4
21.	a_3	b_3	c_2	30.	a_4	b_3	c_4
22.				31.	a_5	b_1	c_4
23.				32.	a_5	b_2	c_4
24.				33.	a_5	b_3	c_4
25.				34.	a_6	b_1	c_4
26.				35.	a_6	b_2	c_4
27.				36.	a_6	b_3	c_4

Legend

Curvature
 a_1 = Tangent (0%)
 a_2 = 1%30'
 a_3 = 3% 00'
 a_4 = 5% 00'
 a_5 = 7% 00'
 a_6 = 10% 00'

Cant
 b_1 = 1:14
 b_2 = 1:20
 b_3 = 1:40

Speed
 c_1 = Equilibrium (E)
 c_2 = E - V unbalance
 c_3 = E + V unbalance

TABLE A1.5 GAGE OPTIMIZATION - CURVES - LIST OF TESTS

1.	a_1	b_1	c_1	11.	a_1	b_1	c_2
2.	a_1	b_2	c_1	12.	a_1	b_2	c_2
3.	a_1	b_3	c_1	13.	a_1	b_3	c_2
4.	a_1	b_4	c_1	14.	a_1	b_4	c_2
5.	a_1	b_5	c_1	15.	a_1	b_5	c_2
6.	a_2	b_1	c_1	16.	a_2	b_1	c_3
7.	a_2	b_2	c_1	17.	a_2	b_2	c_3
8.	a_2	b_3	c_1	18.	a_2	b_3	c_3
9.	a_2	b_4	c_1	19.	a_2	b_4	c_3
10.	a_2	b_5	c_1	20.	a_2	b_5	c_3
21.	a_1	b_1	c_3	28.	a_2	b_3	c_2
22.	a_1	b_2	c_3	29.	a_2	b_4	c_2
23.	a_1	b_3	c_3	30.	a_2	b_5	c_2
24.	a_1	b_4	c_3	31.	a_3	b_3	c_4
25.	a_1	b_5	c_3	32.	a_3	b_4	c_4
26.	a_2	b_1	c_2	33.	a_4	b_3	c_4
27.	a_2	b_2	c_2	34.	a_4	b_4	c_4
				35.	a_5	b_4	c_4

Legend

Curvature

$a_1 = 1^{\circ} 30'$
 $a_2 = 3^{\circ} 00'$
 $a_3 = 5^{\circ} 00'$
 $a_4 = 7^{\circ} 00'$
 $a_5 = 10^{\circ} 00'$

Gage

$a_1 = \text{Standard}$
 $a_2 = -1/4''$
 $a_3 = +1/4''$
 $a_4 = +1/2''$
 $a_5 = +3/4''$

Speed

$h_1 = \text{Equilibrium (E)}$
 $h_2 = \text{E - V unbalance}$
 $h_3 = \text{E + V unbalance}$
 $h_4 = 30 \text{ MPH}$

TABLE A1.6 TIE OPTIMIZATION TEST SERIES - LIST OF TEST

1.	a ₁	b ₁	c ₁	Rail: 132# CWR
2.	a ₁	b ₂	c ₁	OTM: As appropriate
3.	a ₁	b ₃	c ₁	IV. 1-6 Trap Rock
4.	a ₁	b ₂	c ₂	BALLAST:
5.	a ₁	b ₂	c ₃	IV. 7-10 Trap Rock
6.	a ₁	b ₂	c ₃	IV. 11-14 Trap Rock
7.	a ₂	b ₃	c ₁	
8.	a ₂	b ₃	c ₂	
9.	a ₂	b ₄	c ₁	
10.	a ₂	b ₄	c ₂	
11.	a ₃	b ₅	c ₃	
12.	a ₃	b ₅	c ₄	
13.	a ₃	b ₆	c ₃	
14.	a ₃	b ₆	c ₄	
15.	a ₄	b ₁	c ₁	
16.	a ₄	b ₂	c ₁	

Legend

Material
a₁ = Mixed Hardwood
a₂ = Laminated Wood
a₃ = Concrete
a₄ = Softwoods (Fir)

Design
b₁ = 8' Wood
b₂ = 9' Wood
b₃ = Design 1 Lamin.
b₄ = Design 2 Lamin.
b₅ = Design 1 Concrete
b₆ = Design 2 Concrete

Tie Spacing
c₁ = 19 1/2"
c₂ = 21"
c₃ = 24"
c₄ = 27"

TABLE A1.7 MAINTENANCE METHOD EVALUATION SERIES - LIST OF TESTS

			<u>Legend</u>	<u>Curvature</u>
1.	a_1	e_1	$a_1 = \text{Method 1@}$	$e_1 = 0^0$
2.	a_2	e_1	$a_2 = \text{Method 2}$	$e_2 = 1^0 30'$
3.	a_3	e_1	$a_3 = \text{Method 3}$	$e_3 = 3^0 00'$
4.	a_4	e_1	$a_4 = \text{Method 4}$	
5.	a_5	e_1	$a_5 = \text{Method 5}$	
6.	a_6	e_1	$a_6 = \text{Method 6}$	
7.	a_7	e_1	$a_7 = \text{Method 7}$	
8.	a_8	e_1	$a_8 = \text{Method 8}$	
9.	a_9	e_1	$a_9 = \text{Method 9}$	
10.	a_1	e_2		19. $a_1 e_3$
11.	a_2	e_2		20. $a_2 e_3$
12.	a_3	e_2		21. $a_3 e_3$
13.	a_4	e_2		22. $a_4 e_3$
14.	a_5	e_2		23. $a_5 e_3$
15.	a_6	e_2		24. $a_6 e_3$
16.	a_7	e_2		25. $a_7 e_3$
17.	a_8	e_2		26. $a_8 e_3$
18.	a_9	e_2		27. $a_9 e_3$

132# Jointed

@ Maintenance Methods to be selected

TABLE A1.8 RAIL CHEMISTRY TEST SERIES - LIST OF TESTS

1.	a_1	f_1	g_{456}	7.	a_1	f_2	g_{456}
2.	a_2	f_1	g_{456}	8.	a_2	f_2	g_{456}
3.	a_3	f_1	g_{456}	9.	a_3	f_2	g_{456}
4.	a_4	f_1	g_{123}	10.	a_4	f_3	g_{123}
5.	a_5	f_1	g_{123}	11.	a_5	f_3	g_{123}
6.	a_6	f_1	g_{123}	12.	a_6	f_3	g_{123}

Legend

a_1 = Hi Silicon

a_2 = Curvemaster Heat Treated

a_3 = Bethlehem Fully Heat Treated

a_4 = Chrome-Moly

a_5 = Vaccum Degassed Steel - Heat Treated

a_6 = Steel from Strand Cast Blooms - Heat Treated

f_1 = UNIT 100 Ton

f_2 = RM

f_3 = UNIT - 125 Ton (tentative)

g_1 = 0° (Tangent)

g_2 = $1^\circ 30'$

g_3 = 3°

g_4 = 5°

g_5 = 7°

g_6 = 10°

APPENDIX II

Questionnaires and Summaries

SUMMARY OF QUESTIONNAIRE RESPONSES

Two questionnaires were developed and sent to appropriate industry organizations in order to receive their input to the concept of a track test loop facility. The questionnaires were only one form in which industry input was received, personal contact and meetings with AAR committees were also used to obtain input. Industry responses were detailed and comprehensive and covered the full spectrum of industry suppliers and railroads. The response from industry to the concept of a test track loop facility for accelerated service tests was universally enthusiastic. The limitations of any potential facility were pointed out in describing the concept and the range of possible scope of the facility. The two questionnaires can be categorized as a track questionnaire and a mechanical questionnaire. Copies of the questionnaires are included in this appendix. A summary of the responses is given below. It is important to bear in mind the basic premise of the questionnaires that the facility is intended for joint use, for track research and mechanical equipment research.

1.0 Summary of Mechanical Questionnaire Responses Shape of Loop

Of fourteen responses, from the choices offered, the dumbbell shape was mentioned most often. No response accepted the dumbbell configuration without modification. An unsymmetrical oval or modified race track was mentioned in the remaining responses. Reversing diagonals were added to all modified race track configurations. The consensus appeared to be that a range of curvatures and a reverse running capability was needed. A modified race track with two curvatures and diagonals for reverse running would appear to meet the criteria of all respondents.

Minimum Curvature for Real Life Wear

To achieve real life simulation of wear the minimum curvature requirements varied from 6° to 17° , although most of responses mentioned 10° . Qualification added to the curvatures mentioned emphasized the need for a range of curvatures to be introduced.

Minimum and Maximum Curvature Range

Most responses agreed upon a range with a minimum of 2° and a maximum of 10° .

Vertical Curves

Of fourteen responses, four indicated no need for vertical curves, indicating that a loop would not properly simulate slack action and/or wear of draft system components. The remaining responses indicated the desirability of some vertical curvature, with some suggestions to include vertical curves on the diagonals of a loop. The desirability of the introduction of dynamic braking in the loop environment was also pointed out in two responses.

Features Overlooked

The absence of vertical curves and a reverse curve were identified as missing elements on the shapes identified in the questionnaire. Reverse curves with and without intervening tangent were mentioned with reference to train stability. Mention of turnouts, railroad and road crossings was also made.

Track Maintenance Level

All of the responses indicated that track maintenance should be at a realistic level. Some responses indicated that the facility should be used to determine the level

of track maintenance necessary. A mix of track maintenance levels was recommended by most respondents.

Non-Conventional Track

The majority of respondents to the mechanical questionnaire indicated their feeling that non-conventional track structures such as those with greater ballast depths and concrete ties would detract from mechanical tests unless such non-conventional trackage is limited to a small portion of the loop, such as 5% of the total track loop length.

Running Gear Tests

Despite the limitations outlined with respect to the environment on a closed loop the responses indicated that the facility would be extremely useful for running gear tests. Most of the tests suggested were of a comparative type. Wheel life was the area most mentioned. Tests to establish critical flaw size and thermal capacity under drag braking for all wheel designs. The basic objective of most tests proposed was Wheel Optimization with present truck configurations to decrease life cycle costs for wheels. Some of the tests suggested included validation of presently recommended condemning limits for running gear components and acceptance requirements for reconditioned running gear components. The speed requirements for some of the tests suggested were as high as 79 mph. The test loop facility was deemed suitable for development of new truck concepts by most respondents.

Wheel defect detection equipment validation was suggested by many responses.

Side bearing tests were suggested by many, particularly the constant contact type.

Draft Component Tests

An overwhelming majority of responses indicated that the facility was not, in general, particularly useful for tests with draft components. Wear of components due to car dynamics, particularly on high mileage cars, was considered feasible and desirable to test. Coupler carrier system wear, coupler butt wear and cross key wear were among components deemed possible test candidates.

A few responses indicated that a comparative test of in-train car handling characteristics for sliding sill cars and end-of car cushioning equipped cars would be beneficial. Automatic couplers were also mentioned as test candidates.

General Car Design and Centerplate Tests

Use of the test loop facility for tests with centerplates for wear and fatigue evaluation was recommended by most respondents. Some responses suggested use of the facility to establish correlation between the alternate forms of laboratory testing, loop track testing and in-service life. Also, the need to establish correlation between car structural fatigue and centerplate wear with track and truck maintenance levels was pointed out by some responses and the test track loop facility deemed suitable for same.

Some responses indicated that considerable benefit would accrue from a packaging test series. In the area of structural attachment of components to the car body tests on train line and angle cock attachment were suggested.

Simulation of Braking Environment

The air braking environment was estimated from values provided in about half the responses. A summary of this estimate of the air braking environment in general service is shown in Table A2.1.

A majority of responses indicated that they would consider it feasible to run braking system tests, but that the nature of the facility did not make it particularly suitable for programmed braking.

Suggestions for braking system tests were of a "one-shot" type and those requiring programmed brake applications. Basically, braking tests of the "one-shot" type could be conducted anywhere, although a controlled environment full scale facility would be particularly conducive to running the tests suggested.

Motive Power Recommendations

All responses indicated that diesel electric locomotives should be used. One response indicated desirability for a dual capability.

Diesel Electric Tests

A number of performance related tests were suggested along with fuel economy tests. In addition, tractive effort tests, wheel wear, and noise tests were suggested.

Electrification Tests

A majority of responses indicated that they considered the facility suitable for electrification tests. The effect of pantograph shoe material and pressures on catenary and shoe life was mentioned most often as a candidate test series.

TABLE A2.1 ESTIMATE OF AIR BRAKE ENVIRONMENT
FOR FREIGHT CARS IN GENERAL SERVICE BASED ON RESPONSES

	<u>Average*</u>	<u>Range*</u>
I. Number of service applications for each thousand miles travelled	119	60 to 250
II. Number of full service for each thousand miles	53	6 to 200
III. Number of emergency applications per thousand miles travelled		
- Total	4	
- From 60 MPH <u>or</u> more	.67	
- From 40 MPH <u>or</u> more	2.67	
- From 20 MPH <u>or</u> more	3.33	
- Under 20 MPH	.67	
IV. Miles run with service application for each thousand miles travelled	150	8 to 500
Miles run with full service application for each thousand miles travelled	84	1 to 400
Miles run with emergency application for each thousand miles travelled	-	0 to 3
Miles run with hand brake applied for each thousand miles travelled	-	0 to 3

*Average value and range derived from responses received

2.0 Summary of Track Questionnaire Responses

Seventeen responses were received to this questionnaire. The responses indicated general agreement with the general test objectives of track loop in the areas of track structures and vehicle design investigation listed.

The optimization of track components as an assembled structure was mentioned in most responses.

Tests to obtain track deterioration and loading with poor maintenance and/or extreme conditions were frequently mentioned. Specific areas of track structure and vehicle design suggested for investigation included the following:

- a. Track surfacing and lining equipment evaluation.
- b. Joint and anchor behavior and requirements.
- c. Evaluation of new track structure concepts.
- d. Adhesion and rail wear with and without lubricators.
- e. Rail wear with and without sanding.
- f. Verification of Talbot formula for rail stresses.
- g. Determination of optimum cant and superelevation for all conditions.
- h. Determination of optimum gage for curves - stress on rail, wear, gage widening.
- i. Evaluation of FRA track standards.
- j. Evaluation of tamping equipment.
- k. Effects of rail joint maintenance.
- l. Determination of contact stress variation with wheel diameter.
- m. Compare lateral thrust on curves for 4-wheel and 6-wheel trucks.

- n. Comparison of rail wear and track geometry deterioration between track structures with clean ballast and fouled ballast.
- o. Evaluation of track deterioration at locations of changing support conditions.
- p. Evaluation of anchoring and spiking patterns, particularly on grades.
- q. Evaluation of alternative concrete tie designs.
- r. Rail shelling and corrugation.

Traffic Requirements

In general, mixed consists with heavy cars were recommended. Unit trains with 100 ton cars were also recommended for certain tests.

Maximum capability for wheel loads suggested was 42,000 lb.

The minimum traffic required for tests was generally estimated at 100 MGT. Estimates for traffic required for certain tests ranged up to 1000 MGT.

The desired daily rate of traffic accumulation was 1 MGT. Most responses indicated that a reverse running capability was needed.

The acceptable speed capability for the loop ranged from 55 mph to 100 mph. Most of the responses indicated 65 mph or less was the maximum speed required. A number of responses also indicated that 80 mph was the minimum acceptable speed capability for traffic operating continuously.

The recommendations for traffic to be applied to the loop were primarily mixed consists with a bias toward high capacity heavily loaded cars. Unit trains with 100 tons hoppers were also suggested.

The general recommendations for motive power were to use the most popular diesel electric locomotives for use on the loop.

Comments on the test train consists all indicated an emphasis on a need to reproduce actual train operation as well as the most severe effects encountered in real life. Also, an emphasis was apparent on retaining the capability to change consists by changing car types, train lengths and car locations within a train consist.

Track Design

Exclusive of test sections, 132# - 136# rail, both CWR and jointed was recommended. Wood ties, 8 ft. and 9 ft. long at 19 1/2" spacing with 14" and 18" tie plates were suggested. It was suggested that FRA standards be used for track maintenance levels, consistent with speed.

Test Sections

The maximum suggested test section length ranged from 900 ft. to 1320 ft. Ten to twenty sections were suggested as being needed to effectively utilize the potential of the test loop. Three different sub-grade types were suggested for use as available test sections with at least 4' depth over the full width of the embankment.

It was also suggested by some responses that a poor drainage simulation capability be provided.

Granite, slag and lime stone were the ballast types suggested with 9" to 12" depth along with 6" sub-ballast.

115#, 132# and 136# rail was recommended for initial use on test sections. Use of 90 lb. rail on some sections was suggested in view of such sections still being in use on many rail systems.

Geometry of Test Track Loop

A number of specific loop design configurations were proposed in lieu of selecting from among the shapes shown on the questionnaire. Responses not proposing

specific loop configurations opted in general for the dumbbell configuration with some modifications. Comments indicated that a reverse running capability as the basic criteria for selecting the dumbbell configuration. Proposed loop configurations included a range of curve capabilities, reverse running capability and a high speed and low speed loop section. All of the proposed loop configurations can be characterized as ovals or tapered ovals (or race track and modified race track).

All responses indicated a range of curvature was needed. Minimum curvatures of 1° to 2° was suggested with a maximum curvature of 10° .

Most responses indicated that bypasses to test sections would be desirable on some test sections. Vertical curves were not deemed necessary. Crossovers were also recommended for inclusion. 3° + 4° reverse curvature was suggested, although the reasons for including reverse curves were based on need for tests on train stability.

A minimum tangent track length exceeding train length was also mentioned.

Environmental Effects

The equivalent of 1" rain per hour or 6" per day was considered an adequate maximum for test with poor drainage conditions. Temperature control of sub-grade was not recommended for consideration. A majority of responses indicated that the ability to provide controlled track modulus variations was important. A range of 1000 to 5000 in/in was suggested. It was recommended that possible inclusion of track deficiencies, up to 50% greater than FRA limits should be within the capabilities.

Surfacing equipment, ballast compactors and lining equipment were among those suggested for evaluation at the facility.

Of the test proposed, some can generally be grouped as those whose primary goal is optimization of present track structures with respect to track settlement, component wear and life between maintenance cycles. The other type proposed can generally be characterized as train stability or track-train dynamics type tests, those not requiring a large amount of traffic.

The tests proposed in the area of track structure optimization can be sub-grouped as follows:

1. Track Settlement group
2. Cant and gage optimization group
3. Rail chemistry and heat treatment evaluation group
4. Maintenance of way equipment and practice evaluation group
5. New materials and component designs group including concrete ties, fasteners and insulated joints

In the second type of tests proposed, namely the train stability group of tests, the basic objective common to them is the determination of the load spectrum over the full range of operating conditions, car and motive power types and track maintenance levels.

FACILITY FOR ACCELERATED SERVICE
TESTING (FAST*)

Parts I thru IV: General description, background and scope

Parts V thru VII: Questionnaire

*The Track Test Loop facility is referred to as the FAST facility since it simply and accurately conveys the intent of the facility.

FACILITY FOR ACCELERATED SERVICE TESTING (FAST)

I. Purpose of Questionnaire

The purpose of this questionnaire is two fold: 1) to solicit input from the Mechanical Officers of each railroad to assist the AAR Research and Test Department in defining the functional requirements of a test track loop facility on which accelerated tests with rapid accumulation of car miles and gross tons of traffic will be possible, and 2) to compile a list of tests for which the FAST facility should be used in the near future.

The FAST facility is to be used for Track Research and Rolling Stock Research.

II. Background

The construction of a FAST facility has been contemplated at the research level of the FRA and by the Association of American Railroads' Research and Test Department. It is intended that the subject facility be constructed with government funding. Approval at the budgeting levels of government is still necessary and will be sought by the FRA.

Such facilities have existed for some time in the USSR, Czechoslovakia and Japan and are contemplated in West Germany and Romania.

The concept of a FAST facility originated with the prime purpose of track structures research, with a view to rapid accumulation of gross tons of traffic. Such traffic would in the main be random mixed consists. Test track loop curvature design configuration would limit the maximum operating speeds. It was quickly recognized that cars running as part of a random mixed consist offer an ideal opportunity to test mechanical components for accelerated fatigue and wear

in a controlled environment. Consequently, the intent of the facility has been expanded to include research on mechanical equipment.

It is important to keep in mind that trade-offs are necessary in the design of the loop configuration to satisfy contradictory requirements for Track Research and Mechanical Equipment Research. There are contradictory requirements even within the mechanical areas, for example, body center plate wear testing may suggest the need for higher operating speed as compared with an endurance test of rock and roll control devices. It is essential, therefore, for us to accurately assess each of these with a view to expected potential economic benefits to the industry as a whole.

III: Scope of FAST Facility

The emphasis will be on accelerated wear and fatigue tests on track components and mechanical components. Tests on signalling system components, surveillance components, A CI type components are also specifically included.

This facility is not expected to be suitable for examination of longitudinal slack action problems or heavy impact problems. Such Track-Train Dynamics problems do not require rapid accumulation of traffic and are not within the scope of this facility.

It is recognized that the operating environment for mechanical equipment includes longitudinal train action, and frequent brake applications.

A FAST loop facility designed also for track research to great extent precludes the simulation of this aspect of the mechanical operating environment and therefore limits its anticipated usefulness for testing mechanical equipment. On the plus side, a disproportional amount of car miles of curve travel which

permit rapid accumulation of this particular aspect of the mechanical operating environment are possible.

You are invited to comment on the need for an entirely separate FAST loop facility for testing mechanical equipment and to make an economic case for building one if you feel that a facility used jointly for track research and mechanical equipment research will severely limit the usefulness for mechanical equipment research purposes.

IV. Tests on FAST Loop vs In-Service Tests

In-service operation of mechanical equipment is characterized by operation at various speeds, track curvature, empty or loaded, various temperatures, track quality and terrain. For example, the following estimate was made for a hopper car:

Speed Range Data

<u>Speed mph</u>	<u>% Miles Run</u>
0- 9	3
10-19	10
20-29	16
30-39	24
40-49	26.5
50-60	20.5

The empty car miles may be up to 50% of the total miles. Other characteristics to consider include the number of service brake applications per mile run, the number of 1^o, 3^o, 5^o, and 10^o curves negotiated per mile run, the percentage of miles run in rainy weather or at lower temperatures.

The cumulative wear and fatigue damage to a freight car or locomotive is not accrued in the same proportion as the percentage of miles run at a given speed range. It is anticipated that the full range of speeds will be used so that a close simulation of speed ranges will be possible on the FAST loop.

The major inadequacies of the FAST loop with respect to simulation of in-service operation are expected to be as follows:

- a. Significantly lower number of brake applications per car mile run unless programmed brake application and release is provided for at a sacrifice in the number of car miles run per test period.
- b. Absence of major terrain-induced train action.
- c. No yard impacts.

A car operating on the FAST loop will, depending on the loop configuration, negotiate more curves per mile run than it would under in-service operation. Consequently, if a test is primarily concerned with wheel wear on curves, the significant portions of in-service operation may be applied with far fewer actual car miles run. Such considerations are pertinent to other car components also.

The loaded car miles run will require that the commodity in question be "going nowhere" and therefore make it hard to procure.

The track condition, at all times, will be fairly well defined. Track maintenance, in general, will be consistent with normal or proposed practice. Certain specific track structure tests, may in certain cases, make it advisable to include only random mixed consist cars (those not being monitored for specific mechanical tests).

The FAST loop will make it possible to run up to 1200 miles per day. Many of the tests can only be run on a dedicated track because of safety. For example, it would not be appropriate to monitor crack propagation on a wheel with well defined flaws in revenue trains. Cars can not be easily located for inspection if running in regular revenue service. Tests on cars operating on a FAST loop will not completely obviate in-service testing, but will complement it by rapid accumulation of mileage under controlled conditions.

QUESTIONNAIRE

The questionnaire is divided into several sub-parts. You may wish to have other individuals respond to individual sub-parts separately. Please return all of the ensuing pages after completion. You are invited to make specific suggestions on any of the questions. Any suggestions on estimating potential economic benefits of a FAST facility will be more than welcome.

The questions are of two types:

1. Questions about tests you would like to see conducted on mechanical and other equipment.
2. Questions about equipment and maintenance facilities that you would recommend for "non-test" cars - those that will constitute the bulk of the traffic applied to the test track structures.

In listing proposed tests, please outline minimum acceptable criteria for a meaningful test.

Please use additional sheets as necessary for your comments.

V. Geometry of Test Track Loop

The exact shape of the test track loop will be determined by many factors operating expenses, available site, etc. The purpose of this sub-part of the questionnaire is two fold:

1. To solicit your opinion regarding the functional characteristics such as number and degrees of curvature, etc. that are needed for the range of tests suggested in subsequent sub-parts.
2. To solicit your opinion regarding the relative merits of different configurations with respect to first costs and operating expenses per million gross tons of traffic applied.

Va. The attached Table A2.1 indicates the characteristics of several simple test track loop designs. Please evaluate and indicate your preferences considering the types of tests you would expect the loop to address.

Vb. Do you feel any essential features for track loop geometry have been overlooked? If so, what would you add?

Vc. Considering that increased curvature will increase lateral loads and accelerate wear, but reduce maximum speed and the rate of mileage accumulation; what is the maximum curvature that you feel is necessary to achieve rapid wear and real world effects?

Vd. Do you feel a range of curvature is needed? If so, what would you recommend?

Minimum

Maximum

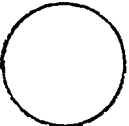
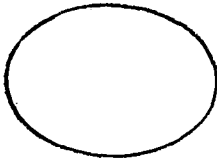


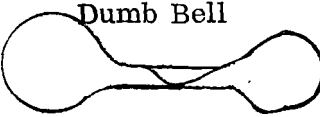
Ve. Do you feel that vertical curves are needed, considering the type of tests you would expect the loop to address.

Vf. Do you feel that track maintenance level should reflect present levels in order to achieve real world simulation? What track standards would you recommend?

Vg. Considering that the FAST facility is also intended to serve Track Research needs, do you feel that non-conventional track (greater ballast depth, concrete ties, etc.) over certain test sections will detract from the test results obtained?

TEST TRACK LOOP CONFIGURATIONS

TABLE A2.1

<u>Name</u>	<u>Includes</u>	<u>Excludes</u>	<u>Characteristics</u>
Circle, Ring 	One Radius	Tangent Spiral Varying Radii Turnouts Frogs Reverse Running	Rapid Traffic Accumulation
Elipse 	Two Radii	Tangent Turnouts Frogs Reverse Running	
Race Track 	Two or More Radii	Reverse Cvs. Reverse Running	
or 			
Dumb Bell 	Variety of Curves Tangent Spiral Reverse Cv. Frogs		Max. Flexibility Lowest rate of Traffic Accumulation

VI. Sub-Part A: Running Gear-Frieght Cars

Freight car running gear accounts for a significant portion of the total costs of maintenance of equipment and operating expenses in general. Such costs include initial purchase, acceptance testing, regular inspection, periodic maintenance, renewal or replacement, and cost of operation.

Traditionally, the development of new and improved components has occurred with supplier in-house tests, AAR qualification tests, and the greatest emphasis has been on actual in-service tests. Apart from the slow accumulation of in-service experience, the results are often lost in ambiguity since no precise definition of the operating environment exists.

The FAST facility offers the potential to answer many of the aforementioned criticisms. With this in mind, please list specific tests that you would like to see conducted on Wheels, Axles, Roller Bearings, Journal Bearings, Adapters, Truck Bolsters, Side Frames, Springs, Truck Assemblies, alternative suspension systems, brake rigging, etc.

A1 Wheels and Axles

Please list tests that you would like to see conducted at a FAST facility on wheels and axles (present or proposed designs).

d. Other comments

A3 Wheel Defect Detection and Surveillance

Please list any developmental, procedural, quality or other acceptance test procedure that you feel can be validated in the FAST facility. Please include estimate of potential economic benefits.

A4 Roller Bearings (including Adapters)

What tests would you like to see conducted on present, improved designs or potential designs? Please indicate:

- a. Purpose of test
- b. Duration of test for fatigue or wear
- c. Test measurements and frequency
- d. Estimate of potential savings
- e. Truck Assembly
- f. Operating speeds for test

A5 Roller Bearing Defect Detection and Surveillance

Please indicate any developmental, inspection, acceptance or surveillance procedure that you feel can be validated in the FAST facility. Please include estimate of potential economic benefits.

wear plates of different metallurgical characteristics can be compared for wear characteristics. Please indicate the types of truck assembly tests that you would like to see conducted. Include operating speeds, test measurement criteria and frequency, minimum duration of tests. Please include any estimate of potential economic benefits.

A8 New Truck Designs

Please indicate below if you consider a proposed FAST facility as being suitable for the development and optimization of new truck design concepts. Please keep in mind the major differences between train operation on a loop facility and actual in-service operation.

A9 Side Bearings (including constant contact types)

Please list all side bearing tests that you feel can be run on a FAST facility. Include all pertinent information - truck assembly, car type, test measurement, frequency of inspection and measurement, duration of test, specific objectives of test and potential economic benefits.

VI. Sub-Part B: Draft Rigging Including Couplers

B1 Coupler Design

Considering the nature of the FAST facility, please list tests that you would like to see conducted. Please list all pertinent details and potential economic benefits.

B2 Yokes, Keys, Draft Lugs and Gears

Do you consider the FAST facility to be useful for tests on these components? Please list all tests that you feel should be run.

B3 Cushioning including Sliding Sill Units

Please list below all tests on cushioning units that you feel can be run on a loop facility.

B4 Other Alternative Systems

Do you consider the FAST facility suitable for development and validation of other draft systems, for example, semi-permanently coupled joints on articulated cars? Please list all tests that you can anticipate a potential for.

VI. Sub-Part C: Car Body Design including Center Plates

The fatigue and/or wear failure of car body components is often at locations where details of a design have been overlooked or where residual stress or assembly stresses are not known. These occur most frequently either on new designs or where assembly procedures particularly relating to welded or other attachments have been changed. The potential use of a FAST facility for rapid "design shakedown" appears to offer significant economic benefit.

C1 General Car Design

Please list tests that you feel could be run on a FAST facility. Include minimum criteria for an acceptable test. Your comments on economic benefits from tests listed would be appreciated.

C2 Center Plates, Center Fillers and Attachments

- a. In the area of center plates, please list all specific tests you feel would be useful. Include minimum criteria for acceptable test.

- b. Include all comments on the relative merits of FAST facility as opposed to other forms of accelerated fatigue testing of center plates (static rock and roll, fatigue cycling with MTS equipment, etc.)

C3 Center Plates - Cushioned Under Frames

Please list all tests that you feel can be run on a FAST facility in the area of cushioned under frame center plates and attachments.

C4 Body Bolsters (Cushioned UF and Regular UF)

Please list all body bolster tests that you would recommend. Include all pertinent information - car type, type and frequency of inspection and measurements, duration of test, minimum acceptable operation parameters, etc.

C5 Doors, Inlet/Outlets, Hitches, etc.

Considering that the longitudinal train environment and loading/unloading environment simulation limitations, what tests do you feel can be conducted on the FAST facility in the subject areas?

VI. Sub-Part D: Brake Systems

D1 Braking Environment

Please indicate what you consider to be representative of a freight car braking environment by filling out the table below:

		Service Type		
		General	Unit Train	Other
Number of Service Applications per 1000 miles	5 lb. reduction (a)			
	10 lb. (b)			
	15 lb. (c)			
Number of Emergency Applications per 1000 miles run	From 60 mph			
	From 40 mph			
	From 20 mph			
	Less than 20 mph			
Actual car miles run per 1000 total car miles with specified reduction indicated	5 lb.			
	10 lb.			
	15 lb.			
	Retainers applied			
	Emergency Application			
	Hand brake applied			

D2 Possible Simulation of Braking Environment in FAST Loop Facility

What portion of the braking environment do you consider feasible for simulation on a FAST facility? Please elaborate.

D3 Braking System Component Tests

- a. If the FAST facility provided for Continuous Train Operation without planned or programmed brake application would you consider the facility useful for brake system tests. Please list any tests that you feel can be run.

- b. In view of your recommendations shown in parts VI D1 and VI D2 above
please list tests that you feel can be run on Brake Systems and Components.

D4 Recommendations

For "non-test" cars used to apply traffic to the Track Structure with
random mixed consists, what brake system components would you recommend
for minimum maintenance.

D5 General Comments

Please include any comments you have pertinent to accelerated fatigue
and wear testing of braking systems and components.

VI E Sub-Part E: Motive Power Systems & Components

To apply traffic at a rate of one million gross tons/day to a FAST loop facility will require, for example, three locomotives with an estimated 10,000 HP operating 20 hrs. per day and an estimated 1200 miles. Motive power costs represent the biggest single item of daily operating expenses.

E1 Motive Power Recommendations

What motive power recommendations would you make to keep operating expenses and maintenance expenses at a minimum level? Would you recommend remote operation?

E2 Electrification of FAST Loop

Would you consider electrification of the FAST loop to lower operating and maintenance expenses? If so, how much lower would you estimate the costs to be?

E3 Tests for Electrification

Would you consider the FAST loop facility suitable for testing electric motive power, catenary systems, etc? If so, can you suggest specific tests that may be useful to the railroad industry?

E4 Tests on Diesel Electric Locomotives

For present or proposed designs of locomotives including all individual components and systems, please list tests that you would consider appropriate for a FAST loop facility. Use additional sheets if needed and append. Estimates of potential economic benefits will be appreciated also.

E5 Diesel-Electric Locomotive Performance Tests

Please list any diesel-electric locomotive performance tests, such as a comparative fuel-economy tests, that you would consider appropriate in the controlled environment of a FAST loop facility.

E6 General Comments

Please list any general comments or tests that you would like to be considered with regard to motive power on the FAST facility.

VI F Sub-Part F: Signalling and Communications

The FAST facility with more or less continuous traffic operation in a controlled environment will afford the opportunity to run tests on equipment that may be considered too hazardous to conduct in-service. Tests for reliability also appear to be meaningful in view of the rapid accumulation of traffic.

F1 Signalling and Communications equipment

Please list all tests in the area of signalling and communications equipment that you would consider appropriate to conduct in the FAST loop environment. Include estimates of potential economic benefits.

VI G Sub-Part G: Surveillance Equipment, ACI, etc.

G1 Surveillance equipment, etc.

Please list any tests you consider the FAST loop facility suitable for in the development and testing of surveillance equipment such as hot box detectors, presence detection, automatic car identification equipment.

G2 Recommendations

Would you recommend the installation of any presently available surveillance equipment or ACI on the FAST facility in the interest of safety or efficient operation of the facility. Please include all pertinent details.

Subject: Design considerations for Test Track Loop

The Research and Test Department, Association of American Railroads, as part of ongoing track research work has given consideration to the design and construction of a Track Research Laboratory and the potential benefits to be gained from such a facility. A test track loop would be the biggest single item in such a facility. The Research and Test Department will prepare a preliminary description for such a facility after seeking advice from responsible railroad engineering, mechanical and transportation officers on the design and operation involved.

Test on Test Track Loop vs. On-Line Service Tests

1. It has been estimated that up to one million gross tons of traffic can be applied in one day on a loop. In six-weeks the equivalent of one year on-line traffic can be applied under controlled conditions.
2. It is also estimated that locomotives, rolling stock and their components can be subjected to up to 1200 miles of accumulated service per day on a test track loop.
3. Many types of tests should only be run on a dedicated track because of safety. For example, it would not be appropriate to attempt to monitor the crack propagation rate for rails with well defined flaws in track subjected to revenue trains.
4. Main lines can not conveniently be taken out of service for any length of time. However, for research work it is frequently necessary to stop or divert traffic to install instrumentation and install or modify test sections. A test track loop does not obviate in-service testing but complements it

through rapid traffic and mileage accumulation under controlled conditions with minimal hazard to revenue traffic.

Objectives of Test Track Loop

There are many test for which a test track loop will be useful. A test track loop may include a number of test sections, both tangent and curves. Bypass sections could be provided around test sections.

The list given below is suggestive of the types of tests that can be conducted.

You are invited to make additional suggestions.

A. Track Structure Investigation

1. Actual measurements of rates of track deterioration (loss of surface, line, gage, and cross level), as a function of type of track construction or track maintenance procedures.
2. Fatigue tests of new track materials, such as insulated or plain joints, rail, ties and similar components.
3. Comparative wear tests on different types of rail. (Various sections, chemistries, heat treatments).
4. Wear tests on switch points and other special trackwork.
5. Evaluation of rates of track deterioration as a function of types and amounts of traffic, such high-speed passenger traffic and low-speed mineral freight.
6. Systematic evaluation of present and any proposed track standards with respect to their impact on safety and economics of maintenance.
7. Measurement of stresses and strains on track components, including

ballast and subgrade for all vehicle types, all track structures,
at a range of speeds.

Test Track Loop Questionnaire

A. General Test Objectives:

After reviewing the test objectives previously stated, what additional areas of investigation do you feel significant benefits could be achieved:

1. Track Structure Investigation: (Please list in order of preference)

2. Vehicle Design Investigation: (Please list in order of preference)

B. Traffic Requirements:

Keeping in mind the general test objectives, what would you recommend for the following traffic parameters in the case of (1) track structure tests; and (2) vehicle tests:

For Track Tests

For Vehicle Tests

- (a) Type of consist
- (b) General car design
- (c) Wheel loads
 - minimum
 - maximum
- (d) Min. tonnage per test
- (e) Optimum tonnage per test
- (f) Desired daily rate of tonnage accumulation
- (g) Direction - reverse running capability needed?
- (h) Operating speed range
 - minimum acceptable
 - optimum

C. Vehicle Design:

1. For accumulation of traffic on the test track loop, please state your general recommendations for car design, such as overall length, truck centers, capacity, loaded e. g. , type of running gear and similar parameters:

2. Exclusive of specific cars selected for vehicle testing, which car designs are suitable for the train consist for traffic accumulation on the test track?

3. Exclusive of designs selected for specific tests, what general recommendation would you have for motive power for the test loop train?

4. Do you have any other comments, suggestions or restrictions on the test train consist?

D. Track Design

1. Exclusive of selected test sections, what general recommendations do you have for construction standards for test track loop?
 - a. rail section(s):
 - b. tie (material, dimensions, spacing):
 - c. OTM:
 - d. ballast (type, depth under tie, etc.):
 - e. track geometry standards:

2. For the instrumented sections of track (test sections), you are invited to comment on the following questions:
 - a. What minimum length of test section(s) would you recommend and why?
 - b. What is the minimum number of test sections you feel should be included in the test loop in order to effectively utilize its potential?
 - c. How many different subgrade materials and type would you like to see in test sections?

- d. What depth and width of replaced subgrade material would you consider adequate to ensure useful results?
- e. Would you prefer any specific condition(s) of subgrade to be simulated or maintained?
- f. Which ballast materials would you like to see used?
Please list in order of preference.
- g. What ballast depths (beneath tie) would you use for each of the above ballast types?
- h. What recommendations would you have for ties, including type, and spacing for the test sections?
- i. What rail sections would you prefer to be used initially on test sections designed to measure settlement rates?
- j. Other comments or suggestions on the design of track test sections:

E. Geometry of Test Track Loop:

- a. The attached table indicates the characteristics of several simple test track loop designs. Please evaluate and indicate your preferences considering the types of tests you would expect the loop to address.

- b. Do you feel any essential features for track loop geometry have been overlooked? If so, what would you add?

- c. Considering that increased curvature will increase lateral loads and accelerate wear, but reduce maximum speed and the rate of tonnage accumulation; what is the maximum curvature that you feel is necessary to achieve rapid wear and real world effects?

- d. Do you feel a range of curvatures is needed? If so, what would you recommend?

Minimum:

Maximum:

e. Please indicate your thoughts on the need for the following

features in a test track loop:

-by passes around track test sections

-cross over(s)

-reverse curvature, degree

-vertical curves, shape

f. After reviewing the requirements for level of traffic, test section design and loop geometry; and evaluating the design tradeoffs, give a brief description of the essential features which you consider must be included in the design.

F. Test Section Modifications:

1. Considering that the test track loop may be built at Pueblo, do you feel a section(s) with artificial rain is necessary? If so, what amount?

Would subgrade moisture control be sufficient?
2. What are your feelings on the need for temperature control? What temperature range do you recommend?
3. Are there other environmental effects you would consider important to control?
4. Do you consider the ability to provide controlled track modulus variations important? If so, what levels of track modulus values and rate of change do you recommend?
5. What track deficiencies (in material or in geometry) would you recommend that the track test sections be capable of simulating?
6. What geometric deficiencies in track would you like to place in the test track loop in order to evaluate equipment response?

7. What other capabilities for special effects would you like to have at this facility?
8. Do you have a list of priorities for the comparative evaluation of selected track maintenance procedures on the test sections of the loop facility?
9. Which types of maintenance of way equipment would you suggest for evaluation at the facility?

G. Facility Operation and Maintenance:

Considering the operating conditions outlined, please indicate your recommendations for vehicle and track maintenance as outlined below:

VEHICLES:

- required inspection interval
- required preventative maintenance interval
- recommended maintenance (mechanical) staff
- recommended on-site maintenance equipment

-other comments

TRACK:

-recommended maintenance standards

-required inspection interval

-recommended inspection method (track geometry car ?)

-required preventative maintenance interval

-recommended maintenance manpower

-recommended maintenance machinery inventory

-recommended spare parts inventory

Do you have any suggestions for the number and qualifications of operating personnel? Train control method? Necessary or desirable safety features? Support facilities? Please be free in commenting on any additional items you feel are important.

H. Proposed Test Series:

Considering the flexibility and the realistic traffic simulation capabilities of the test track loop facility, please outline several test investigations from which you would like to have results? Indicate the nature of the tests, what you would like to measure, how many and the location of measurement points, and the test conditions required.

Name:

Title:

RR:

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Functional Requirements for A Facility for
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25-Goverment Policy, Planning & Regulations

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