OFFICE OF STANDARDS AND PROCEDURES

OFFICE OF SAFETY

A REVIEW OF ATIP

OVERVIEW

THE FEDERAL RAILROAD ADMINISTRATION

AUTOMATED TRACK INSPECTION PROGRAM

(ATIP)

September 1981

EXECUTIVE SUMMARY

The unacceptable rail accident rate in the early 1970's prompted the FRA to establish Federal Safety requirements for track and to implement an enforcement program. This program consists of inspections by Federal or state field personnel and is supplemented by rail operated vehicles capable of measuring and recording certain track or rail conditions and perturbations.

The operation of these vehicles is the Automated Track Inspection Program (ATIP). Presently this program consists of operating on selected rail lines, three high-speed, heavy-axle-load equipment sets and one low-speed, hi-rail vehicle. The heavy axle load permits track geometry data to be collected under loaded conditions not possible by the individual inspector. Combined, this equipment is operated over more than 70,000 miles of track annually.

During operation of the ATIP vehicles, both Federal and state inspectors together with responsible railroad personnel are located in a position in the vehicles which permits the general observation of track condition in conjuction with real-time produced oscillographs. These data detail specific defects and indicate a loss of track integrity reflecting possible subgrade failures, inadequate drainage, ineffective cross ties, etc.

The monitoring action of ATIP of selected lines each year (less than 1 percent of the annual inspections by the railroads) results in greater industry awareness of actual track geometry conditions permitting appropriate remedial action to insure safe train operation. Some railroads object to this type of track inspection because identified defects require immediate corrective action regardless of the railroad's programmed maintenance activity.

ATIP inspections performed in 1978 and 1979 have shown that there is a direct correlation between track-caused accidents and track geometry condition (approximately 40% of all railroad accidents are caused by track problems and over 45% of these are caused by geometry defects). More significantly, less than 56% of the track miles surveyed in 1978 and 1979 met the railroads' posted track class.

ATIP has been primarily directed at locating geometry defects to prevent track-related accidents. However, the data collected by the ATIP vehicles is also used to:

- Schedule track inspections to cover track with poor maintenance records.
- Aid in maintenance-of-way planning so that MOW funds are spent more effectively.
- Predict the degradation of track so that future maintenance-of-way monies can be efficiently allocated.

The unacceptable track-related accident rate and the railroad industry's lack of compliance due to corporate pressure to make a profit indicate the continuing need for Government-sponsored track inspections with emphasis on the railroads with the most severe accidents and highest accident rate. The need for Federal track inspection may be reduced in the future as the rail industry demonstrates its ability to reduce accidents and maintain track at safe levels.

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1.0 INTRODUCTION

1.1 SCOPE OF THE PROBLEM

The FRA, under the authority of the Federal Railroad Safety Act of 1970, has the responsibility of assuring the safety of the nation's railroads. To meet this objective, the FRA is attempting to reduce accidents through enforcement of the Federal Track Safety Standards (FTSS) (49CFR213). This work is being implemented by Regional Safety Offices and supported by the Automated Track Inspection Program (ATIP).

In addition, Title V of the 4R Act includes provisions for the inspection of the railroads' properties to verify accomplishment of the objectives for which federal financial assistance is provided. The Office of Federal Assistance administers this program and requires considerable support in automated track inspection for both initial track rehabilitation and for monitoring the continued railroad obligation under long-term Federal Assistance agreements.

FRA has identified the leading causes of accidents and attempts to concentrate resources on those causes. Track related accidents account for about 40% of all accidents.† Property damage to the railroads exceeds 100 million dollars per year.* (Accidents slow commerce and reduce productivity as well as directly destroying property.) The accident data also indicate a rise in these accident causes over the past fifteen years and a sharp rise in the mid 1970's. Data gathered on track geometry by FRA track geometry cars and on rail flaws from railroads and the Sperry Rail Service indicate that at any one time there are on the average over ten potentially dangerous defects per mile of track. These data vary from railroad to railroad, but even the best have at least one defect per mile of track.

*Includes only property damage to the railroads.

†Over 45% of the track-related accidents are caused by track geometry defects.

It is the railroads' responsibility to inspect their own track and post appropriate speed limits and/or repair defective track. The basic philosophy of the FRA is to monitor the railroads' inspection effort. The railroads perform routine visual inspection of most track twice a week. They also inspect the higher classes of track for rail flaws once/twice per year and some of the railroads inspect their higher classes of track with automated track geometry cars on a periodic basis. This may be adequate inspection if performed properly and recommendations are heeded. Unfortunately, in recent years this has not been the case. Deferred maintenance has become more common and so, apparently, have improperly posted speed limits. The railroads require an incentive to comply with FRA standards. At a minimum this incentive should come in the form of spot inspections and fines for non-compliance. This has been done by FRA Track Safety Inspectors since 1973. To be effective, the program requires both manpower and effective tools.

Studies indicate that automated track geometry and rail flaw detection equipment provide an economical way to obtain large, accurate and uniform samples of the track parameters that cause most severe accidents. While FRA track inspectors -- through experience, knowledge of the territory and examination of records -- have good reason to believe that certain sections of track are defective, the automated vehicle provides detailed data which reflects the condition of track under load. The inspector uses such automated data to select problem areas on a priority basis for further detailed visual inspections and uses the data to issue immediate slow orders if necessary. The inspector, the Office of Safety and the railroad use the data following the survey to review the overall condition of the track.

The Federal Railroad Administration developed a set of instruments capable of geometry measurements that are accurate and reliable. Additionally, FRA employs rail flaw detection equipment capable of operation at 10 to 12 mph. The ultimate goal is 50 mph and will require additional research, potentially by FRA. The FRA vehicles have displayed capabilities in track geometry measurements which were not previously available. The industry looks toward the FRA for leadership in the area of automated track geometry.

The Chessie System, Southern, Burlington Northern, Chicago and Northwestern Transportation Company and Santa Fe, each have a heavy track geometry vehicle. The Union Pacific, Southern Pacific, Norfolk and Western and Long Island have one medium size geometry vehicle each. Prior to 1960 only Chessie had a heavy vehicle and there were no medium size vehicles. The FRA interest in automatic track measurement can only be assumed to have been instrumental in stimulating industry interest.

1.2 ACCIDENT RATE

For 15 years prior to 1965, annually less than 1 accident per million train miles was caused by track defects and track caused accidents were less tha 13% of the total train accidents. The overall railroad accident rate has risen approximately 70% from 1967 to 1979 (Table 1-1) while the accident rate of track-related accidents has risen approximately 160% during the same period. In 1979, track-related accidents accounted for over 40% of all railroad accidents. These figures indicate the growing need for a cost-effective system for examining track to detect areas in need of repairs and to monitor compliance with the FTSS.

There were thirty-six Class 1 railroads operating in calendar years 1978 and 1979. These railroads operated 304,316 miles of track* including multiple main tracks, yard tracks and sidings. Tables 1-2 and 1-3 show the ranking of these railroads based on their track caused accident rate per million train miles.**

As shown, the average for 1978 was 6.6 track caused accidents per million train miles and 5.5 accidents in 1979. Grouping the railroads into the above and below average track caused accidents per million train miles shows that in 1978 and 1979 the accident rate of the above average railroads remained approximately the same, 3.2 in 1978 compared to 3.1 in 1979, while the accident rate of the lower half improved from 10.9 in 1978 to 8.9 in 1979. While improvements have been shown in the last two years, the overall track related accident rate remains critical.

1.3 PURPOSE OF ATIP

The purpose of the Automated Track Inspection Program (ATIP) is to provide the means for the FRA Office of Safety to cost-effectively examine as many miles of high-speed and heavy tonage track as possible to measure conformity with the Federal Track Safety Standards (FTSS) and to cause a minimum of interference to railroad traffic while examining this track. The automated vehicles can survey track in areas where manual inspections and the use of hi-rail vehicles would be dangerous and would interfere with rail traffic.

*"Analysis of Class 1 Railroads, Year 1979", Association of American Railroads, February 1979.

**"Accident/Incident Bulletins No. 147 and No. 148", U.S. Department of Transportation.

TABLE 1-1

ACCIDENT RATE *

YEAR	TOTAL OF ALL TRAIN ACCIDENTS (PER MILLION TRAIN MILES)	TRACK RELATED ACCIDENTS PER MILLION TRAIN MILES	TRACK RELATED PERCENT OF TOTAL ACCIDENTS
1967	8.15	2.06	25.3
1968	9.16	2.43	26.5
1969	9.89	2.87	29.0
1970	9.65	2.95	30.6
1971	9.36	2.90	31.0
1972	9.64	3.23	33.5
1973	11.67	4.28	36.7
1974	12.83	5.12	39.9
1975	10.65	4.21	39.5
1976	13.23	5.50	41.6
1977	13.82	5.78	41.8
1978	15.00	6.59	43.9
1979	12.76	5.50	43.1

*All accident rates and statistics data were extracted from Accident/Incident Bulletins Nos. 145, 146, 147 and 148. U.S. Department of Transportation, Federal Railroad Administration, Office of Safety.

TABLE 1-2

1978

ACCIDENT RATES FOR CLASS I RAILROADS RANKED BY

TRACK CAUSED ACCIDENT RATE PER MILLION TRAIN MILES

Top Half Railroads	Number of Track Caused Accidents	Number of Train Miles Million*	Track Caused Accident Rate Per Train Miles Million
Long Island Railroad	1	8.269	0.1
Denver & Rio Grande Western Railroad	5	6.664	0.7
Florida East Coast Railway	14	3.087	1.3
Atchison Topeka & Santa Fe Railway	88	57.042	1.5
Union Pacific Railroad	73	42.115	1.7
Western Pacific Railroad	8	4.509	1.8
Grand Trunk Western Railroad	11	5.723	1.9
Missouri Pacific Railroad	71	36.388	1.9
St. Louis - Southwestern Railway	19	6.530	2.9
Norfolk & Western Railway	65	22.699	2.9
Bessemer & Lake Erie Railroad	3	1.003	3.0
Elgin, Joliet & Eastern Railway	12	3.062	3.9
Southern Railway	104	25.013	4.2
Duluth, Missabe & Iron Range Railway	5	1.086	4.6
Southern Pacific Transportation Co.	224	46.091	4.9
Burlington Northern	334	68.456	4.9
Chesapeake & Ohio Railway	109	19.878	5.5
Boston & Maine Corporation	26	4.192	6.2
Subtotal	1172	361.807	3.2
Bottom Half Railroads			
St. Louis - San Francisco Railway	89	13.371	6.7
Seaboard Coast Line Railroad	216	28.419	7.6
Detroit, Toledo & Ironton Railroad	14	1.696	8.3
Baltimore & Ohio Railroad	186	21.832	8.5
Consolidated Rail Corporation	824	97.274	8.5
Clinchfield Railroad	12	1.344	8.9
Western Maryland Railway	14	1.572	8.9
Delaware & Hudson Railway	24	2.391	10.0
Soo Line Railroad	73	6.962	10.5
Louisville & Nashville Railroad	333	29.147	11.4
Missouri - Kansas - Texas Railroad	51	4.350	11.7
Kansas City Southern Railway	40	3.400	11.8
Ft. Worth & Denver Railway	24	2.007	12.0
Colorado & Southern Railway	21	1.641	12.8
Illinois Central Gulf Railroad	368	25.887	14.2
Chicago, Milwaukee, St. Paul & Pacific Railroad	307	16.211	18.9
Chicago & Northwestern Transportation	437	21.811	20.0
Pittsburgh & Lake Erie Railroad	32	1.355	23.6
Subtotal	3065	281.670	10.9
Total	4237	643.477	6.6

*Totals do not equal all Class I Railroads as the figures exclude Amtrak and Chicago, Rock Island and Pacific Railroads.

TABLE 1-3

1979

ACCIDENT RATES FOR CLASS I RAILROADS RANKED BY TRACK CAUSED ACCIDENT RATE PER MILLION TRAIN MILES

Top Half Railroads	Number of Track Caused Accidents	Number of Train Miles Million*	Track Caused Accident Rate Per Train Miles Million
Long Island Railroad	2	8.354	0.2
Denver & Rio Grande Western Railroad	5	7.101	0.7
Bessemer & Lake Erie Railroad	1	1.111	0.9
Florida East Coast Railway	3	3.078	1.0
Union Pacific Railroad	70	45.558	1.5
Atchison, Topeka & Santa Fe Railroad	96	58.450	1.6
Norfolk & Western Railway	50	27.201	1.8
Western Pacific Railroad	12	4.749	2.5
Missouri Pacific Railroad	107	38.103	2.8
Grand Trunk Western Railroad	19	5.815	3.3
Duluth, Missabe & Iron Range Railway	4	1.084	3.7
Boston & Maine Corporation	17	4.587	3.7
Southern Railway	104	27.388	3.8
Burlington Northern	286	70.922	4.0
St. Louis - Southwestern Railway	32	7.495	4.3
Southern Pacific Transportation	219	46.870	4.7
Seaboard Coast Line Railroad	160	28.938	5.5
Subtotal	1187	386.804	3.1
Bottom Half Railroads			
Chesapeake & Ohio Railway	111	19.084	5.8
Detroit, Toledo & Ironton Railway	11	1.777	6.2
Colorado & Southern Railway	25	4.033	6.2
Elgin, Joliet & Eastern Railway	21	3.161	6.6
Consolidated Rail Corporation	652	95.500	6.8
St. Louis - San Francisco Railway	99	13.487	7.3
Louisville & Nashville Railroad	215	27.533	7.8
Blatimore & Ohio Railroad	184	22.603	8.1
Ft. Worth & Denver Railway	20	2.339	8.6
Soo Line Railroad	60	6.902	8.7
Western Maryland Railway	14	1.545	9.1
Kansas City Southern Railway	43	3.683	11.7
Illinois Central Gulf Railroad	303	25.869	11.7
Delaware & Hudson Railway	28	2.383	11.8
Chicago, Milwaukee, St. Paul & Pacific Railroad	204	14.807	13.8
Missouri - Kansas - Texas Railroad	63	4.550	13.8
Chicago & Northwestern Trans.	337	21.420	15.7
Pittsburgh & Lake Erie Railroad	28	1.480	18.9
Clinchfield Railroad	29	1.281	22.6
Subtotal	2447	273.437	8.9
Total	3634	660.241	5.5

*Totals do not equal all Class I Railroads as the figures exclude Amtrak and Chicago, Rock Island and Pacific Railroads.

2.0 HISTORY OF ATIP

2.1 ACQUISITION OF T-CARS

In 1965, the Department of Commerce Office of High Speed Ground Transportation (OHSGT) purchased four Budd Silverliners designated T-1, T-2, T-3 and T-4. These vehicles were used by OHSGT to study high-speed (greater than 150 mph) effects on equipment, track, roadbed and pantographs/catenaries. The vehicles were then used as test platforms for prototype devices.

2.2 CONVERSION OF THE T-CARS TO SURVEY VEHICLES

After the high-speed studies were completed in 1968, T-1/T-3 was equipped with a state-of-the-art automated track geometry measurement system. This system was used to evaluate the track used in the Washington-Boston Corridor where maintenance had been neglected over a period of years.

The automated system on the T-cars advanced the state-of-the-art in automated track geometry inspection. Prior to the T-cars, measurement vehicles used contact systems restricting the speed of operation. The data collected by these early systems were recorded on paper charts and analyzed by hand. The T-car system, developed by Melpar, Inc. under contract to OHSGT, was the first high-speed non-contact system with automated data processing.

2.3 GROWING USE OF THE T-CARS FOR TRACK INSPECTION

2.3.1 FEDERAL RAILROAD SAFETY ACT

In testimonies before the committee on the Federal Railroad Safety Act in 1969, the need for track inspections and regulations was clearly made.

> "... that the railroad industry employ to a greater degree the available rail flaw detector equipment. It is further recommended that complete use be made of the available technical

knowledge to insure the development of more dependable means of detecting rail defects---..." Recommendation of the NTSB as presented by John H. Reed, Chairman at hearings on the Federal Railroad Safety Act of 1969.

"Track deterioration is a gradual phenomenon, and the resulting increase in track related accidents was quite gradual - but it was continuous."

"I think that the legislation (S.1933) would have to require that there be, first higher maintenance standards. That better level and alined track would of necessity be maintained and then, following the establishment of a better maintained roadbed, it would have to be periodically inspected by employees of the railroad whose inspection was verified in some manner and to some degree by representatives of the Department of Transportation."

"In other words, the whole key to this, Mr. Chairman in my book is better maintenance standards and inspection to insure that those maintenance standards are continued." Harold C. Crotty, President, Brotherhood of Maintenance of Way Employees at hearings on the Federal Railroad Safety Act of 1969.

The proposed act stated in part:

"In carrying out his functions under this Act, the Secretary (DOT) is authorized to perform such acts including ... delegating to any public body or qualified persons, functions respecting examination, inspecting, and testing of facilities or equipment, or persons, as he deems necessary to carry out the provisions of this act." Sec 8(a) of S.3061, Federal Railroad Safety Act of 1969.

2.3.2 BASIS FOR ATIP

The Federal Railroad Safety Act of 1970 gave the Secretary of Transportation the power to

> "... conduct as necessary, research, development, testing, evaluation, and training for all areas of railroad safety."*

"To carry out the Secretary of Transportation's ... responsibilities ... officers, employees, or agents of the Secretary ... are authorized to enter upon, inspect, and examine rail facilities, equipment, rolling stock, operations and pertinent records at reasonable times and in a reasonable manner."**

With the authority granted to the Secretary of Transportation by the Federal Railroad Safety Act, ATIP was incorporated into the overall detection and monitoring process to assist the Federal Track Safety Inspectors.

The need for safety inspections was again brought out in "A Review of the U.S. Freight System Phase 1 and 2", prepared by the Committee of Transportation, Assembly of Engineering, National Research Council in 1980, in which they said:

> "In regard to safety, public users of airlines, ships, railroads, buses and airplanes demand public supervision of safety."
>
> "As new practices are developed and tried, it can be expected that safety will improve. In the interim, labor may be frustrated by slow progress, management by high costs, and consumers by high costs and confusing information. ... The Department of Transportation must ensure effective safety regulation ... or risk losing their responsibilities for safety to other agencies."

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* Section 202(a) Federal Railroad Safety and Hazardous Materials Transportation Control Act of 1970.

** Section 208(c) ibid.

2.3.3 USE OF THE T-CARS

In March of 1971, survey operations were expanded beginning with the Santa Fe Railroad. Later in 1971, survey operations for a maintenance-of-way study were begun on the Bessemer and Lake Erie and the Denver and Rio Grande Western railroads to

- Improve long-range maintenance planning.
- Determine the cost to maintain track to a certain standard.
- Establish quality control of track maintenance procedures.
- Develop data displays for different management levels.

During this period, limitations were found in the non-contact sensors in use at the time and development of new sensor systems was undertaken. By 1974, the track geometry measurement system was improved to the point that the system could be used by FRA, Office of Safety to enforce the Federal Track Safety Standards (FTSS) (49CFR213).

The value of the T-cars was demonstrated in August 1974 when, because of excessive derailments, the FRA Administrator ordered the test cars to survey Penn Central track between Chicago and Louisville. After analyzing the data, FRA found that the track did not meet Class 1 standards and ordered the track closed until improvements were made to the track.

2.4 LEGALITY OF ATIP CHALLENGED

In 1976, the Missouri Pacific Railroad opposed an ATIP survey of their track. "On March 19, 1976, Missouri Pacific Railroad Company (MoPac) was informed by letter that the FRA planned to inspect MoPac's tracks under the measurement program.

MoPac requested a meeting with FRA officials to discuss the nature and terms of the inspection. At this meeting, the parties were unable to resolve differences over the risk of liability for accidents arising out of the negligence of crew members. On April 15, 1976, MoPac advised the FRA that the inspection could proceed if the FRA supplied its own crew or provided insurance coverage for crew members provided by MoPac. Upon receipt of this response, the government sought an injunction against MoPac and a declaratory judgment that the FRA need not comply with the stated conditions. The District Court concluded that the FRA could require MoPac to provide the crew to operate the test cars and to assume liability for accidents arising out of their negligence. United States vs. Missouri Pac R. Co., 417 F.Supp. 312 (E.D. Mo. 1976)."*

This decision was later upheld by the U.S. Court of Appeals who said, " ... We should note that both the public and the railroads benefit substantially from the FRA's inspection program... the anticipated results include not only safety considerations but also... railway maintenance, improved ride quality for passengers and freight... MoPac's contentions must... be considered in light of the substantial benefit they stand to gain from cooperating in the program."*

2.5 DEDICATION OF THE T-CARS TO OFFICE OF SAFETY SERVICE

In July 1976, T-1/T-3 was dedicated to FRA Office of Safety service. The survey fleet was increased to three consists in 1978 with the addition of T-2/T-4 and T-6.

*From the decision of the U.S. Court of Appeals for the Eighth Circuit, No. 76-1653. U.S. vs Missouri Pacific Railroad Company and the Texas and Pacific Railway Company.

In July 1978 rail flaw detection vehicle number 2 (RFDV No. 2) performed its first Office of Safety survey on the Alaska Railroad. It continued to perform Office of Safety surveys until November 1979 when the rail flaw system was refurbished to improve reliability. The refurbishment was completed in May 1980 and RFDV No. 2 returned to full-time Office of Safety service.

In February 1979, following numerous accidents on the Louisville and Nashville Railroad Company involving hazardous material, the FRA issued Emergency Order No. 11 to limit the movement of hazardous materials over this railroad. The decision to issue the emergency order was based on the L&N's poor safety record, and track geometry data obtained from T-car surveys and visual inspections. The FRA later used the T-cars to enforce portions of this order (see Appendix C).

In July 1979, a contract to build the first truely integrated survey vehicle (T-10) was awarded to ENSCO, Inc. The T-10 vehicle was made fully operational on May 12, 1981 and uses advanced software design to collect and process data. The advancements give the system more accuracy be eliminating much of the noise induced by the equipment. T-10 also has a realtime exception report editing capability adding to the realtime capabilities of the other two consists.

Three survey vehicles (T-1/T-3, T-2/T-4 and T-10) and one Rail Flaw Detection Vehicle (RFDV No. 2) are currently in operation for FRA Office of Safety (See Appendix F).

3.0 EFFECTIVENESS OF ATIP

3.1 INTRODUCTION

"The federal inspection program's justification is based on legal requirements and the unprovable but very tangible likelihood of preventing the one big accident that may happen any day and take a large toll in lives or injuries."*

"Increased safety and accident reduction are the goal of government inspection, but it is not easy to establish what exact nature or frequency of inspection will best accomplish this goal."*

"FRA's inspection of track, resulting in demands on a railroad to perform maintenance or issue a slow order if violations of the Federal Track Safety Standards are found, undoubtedly prevents some accidents that would otherwise occur."*

"A second viewpoint is that even a few deaths and several hundred injuries are too many; ... and that the law requires accident reduction efforts regardless of the reasons therefore."*

3.2 EFFECTIVENESS

Since the start of ATIP and the parallel increase in the number of FRA field inspectors, the previous upward trend of the track-caused accident rate has been reversed. The correlation between the increase in inspection efforts and the improvement in safety is impressive when plotted graphically on the same chart (see Figure 3-1).

The number of miles inspected under ATIP represents less than 1% of the track inspected annually by the railroads. The Standards require that track Classes 4, 5 and 6 be inspected twice weekly

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*"The Role of Automated Vehicles in the National Track Inspection Program", Mitre Corporation, MTR-79W00423, December 1979.

and lower classes less frequently but not less than monthly. Compared with the total industry-wide inspection effort, the 70,000 miles per year inspected under ATIP can be considered at best spot-checking. The benefit of Government-sponsored track inspection is therefore not achieved through the use of the data collected during the survey operations but rather through the presence of the monitoring action and the demonstration of new technology applications to improve maintenance-of-way techniques. During the 1970's a few railroads have acquired their own track inspection equipment; the number of railroad-owned track geometry inspection cars increased from less than five in 1970 to 9 by 1980. The use of automated data processing and analysis techniques to develop better MOW methodology has also been accepted by the railroad industry as the more cost-effective method of the future.

3.2.1 IMPROVEMENTS IN AUTOMATED TRACK GEOMETRY INSPECTION TECHNIQUES

The Federal Railroad Administration research and development in automated track inspection and data processing has led to the development of new and improved systems:

- An inertial-based, all-weather, high speed, non-contact sensor system.
- Real time display of collected data.
- Generation of a real-time exception report which lists deviations from the FTSS. The data collection system functions at track speed.
- The most sophisticated and accurate cross-level system in use.

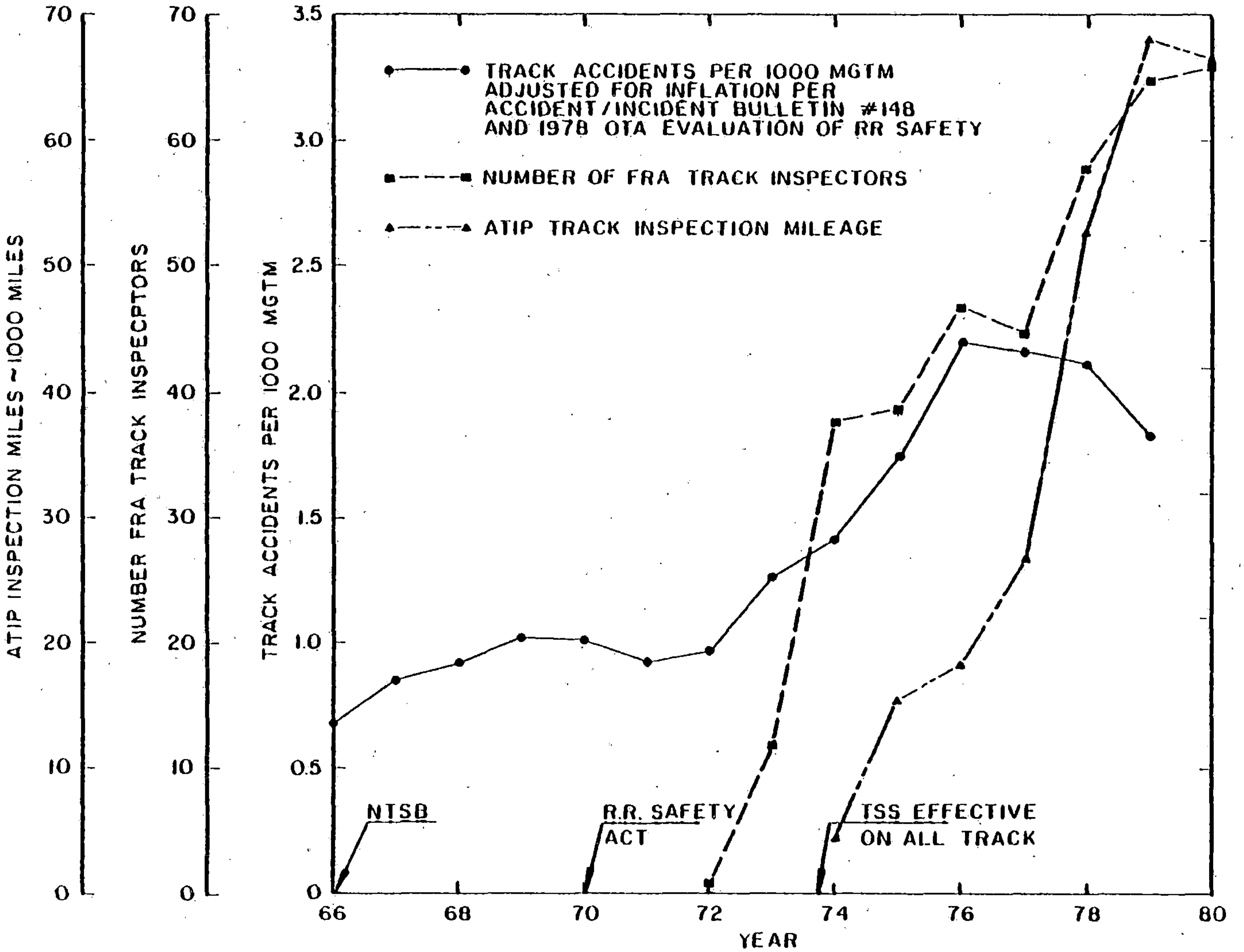

Figure 3-1. Comparison of Track Related Accidents and FRA Inspection Programs

The developments in automated track inspection have resulted in highly reliable automated systems. For 1980 the overall annual utilization for the survey vehicles was 94 percent.* For that year the three survey vehicles covered an average of 160 miles per day. In addition, the improvements in the instrumentation have increased operational effectiveness. In 1980 the survey vehicles surveyed 66,365 miles at a contract cost of $40.03 per mile while in 1974, only 4,722 miles were surveyed and at a contract cost of $134.14 per mile.

3.2.2 IMPROVEMENTS IN DATA HANDLING

Prior to January 1980, all data processing was performed off-line which caused a delay of several days before the reports were received by the railroad and FRA Field Inspectors.

The survey vehicles currently generate real-time Exception Reports which list exceptions to the FTSS in addition to the continuous strip chart tracings. These reports are available to the railroad and FRA Field Inspector within one hour after the survey. The real-time Exception Report lists by milepost and feet from the milepost, exceptions to the posted class for gage, crosslevel, profile, warp, alignment and limiting speed (See Appendix D).

To make the data collected by the survey vehicles easily accessible, a computerized data base and data retrieval system was established. This data base contains summary information from every survey performed since 1978. The data can be accessed by entering key words which are used to locate all related information based on the key word.

*This is the percent of the time the vehicle is available for survey.

3.2.3 INCREASE IN SURVEYED MILES

Since 1974, the number of miles surveyed has been increasing as shown in Table 3-1.

TABLE 3-1
SURVEY MILES

Year	Miles Surveyed
1974	4,722
1975	15,499
1976	18,022
1977	26,889
1978	56,290
1979	68,155
1980	66,365
1981	70,000 (Estimated)

3.2.4 EXCEPTION DETECTION

The T-cars sample track every foot. For every 100 miles of track 528,000 measurements of gage, crosslevel, curvature, profile, warp and alignment are collected and processed at track speed. To obtain the same volume of data would require a track inspector to work 24 hours per day for approximately 28 days.

3.2.5 INSPECTOR TRAINING TO IMPROVE EFFECTIVENESS

A comprehensive training program for Federal and State Inspectors was conducted in 1980 to teach the Inspectors

- How to read the Exception Reports and strip charts generated by the T-car.
- The theory of operation of the hardware and the cars.

A total of 16 training classes were held in eleven cities. Attendance at these classes included

- 101 Federal Personnel
- 35 State Track Inspectors.
- 9 Others (Railroad Personnel).

4.0 COST OF ATIP

4.1 CONTRACT COST PER MILE

ENSCO, INC. of Springfield, VA has been operating and maintaining the ATIP fleet under contract to the FRA since 1970. The ENSCO contract cost per mile has been declining since the survey vehicles began operating in Office of Safety service as shown in Table 4-1.

TABLE 4-1

CONTRACT COST PER MILE PER CALENDAR YEAR

Calendar Year	Contract Cost Per Mile	Miles
1974	$131.14	4,722
1975	98.73	15,499
1976	80.46	18,022
1977	72.47	26,889
1978	60.32	52,690
1979	50.77	68,155
1980	40.03	66,364

The capital cost per mile is approximately $3.20*

4.2 ANALYSIS OF FISCAL YEAR 1980

For Fiscal Year 1980, the Automated Track Inspection Program ATIP budget was $5,100,000. An additional $779,543 was carried over from Fiscal Year 1979 which brought the total available funds for Fiscal Year 1980 to $5,879,543.

*This represents the approximate hardware and instrumentation acquisition cost of $1,600,000 amortized over 25,000 miles per year for 20 years.

Of available funds, $3,756,858 were obligated to the ENSCO contract, of which $3,014,482 were expended for operation, maintenance and data processing of survey consists T-1/T-3, T-2/T-4 and T-6 to survey 68,691 miles of track. The breakdown is as follows:

Task 2.1 - T-Car Operations*	$1,530,935
Task 2.2 - T-Car Maintenance*	1,181,608
Task 2.6 - Data Processing*	301,039
	$3,014,482

These costs resulted in a contract cost per mile of $43.88 for Fiscal Year 1980.

In addition, $1,000,000 was obligated in Fiscal Year 1980 into a railroad cost holding account to cover locomotive and crew rentals, fuel and security of the T-cars. A total of $595,354 in charges were received and paid during FY80. The annual railroad cost figure is the total divided by FY 1980 mileage which results in a cost per mile of $8.67. The total cost per survey mile for FY80 therefore is $43.88 plus $8.67, or $52.55.

During FY80 the Office of Safety was requested to provide support from the ATIP budget for TX and RFDV No. 3 development. A total of $430,973 was transferred to the Office of Research and Development to support the TX project and $180,000 were appropriated to the Transportation Systems Center in Cambridge, MA to support RFDV No. 3 development.

The remaining $742,376 of the $3,756,858 in obligated ATIP contract funds were used to develop software for real-time track geometry data processing; to retrofit and operate Hi-Rail Inspection vehicle RFDV No. 2; to develop the computerized ATIP data base; to train

*Including management and administrative costs.

FRA and State Track Inspectors to better understand the data collected by the T-cars; and to make demonstration runs for Senators, Congressman, dignitaries, and the public.

Of the $5,879,543 available at the start of Fiscal 1980 only $4,352,212 were used for the entire Office of Safety Automated Track Inspection Program. A total of $916,358 was carried over to Fiscal Year 1981.

If the Office of Safety had not been required to provide $180,000 to support RFDV No. 3 development, $430,973 to support the TX project and elected not to spend $459,226 to train field inspectors, and to make hardware and software improvements, and to increase the accuracy and reliability of the T-cars, then the cost of ATIP would have been $3,892,986 for Fiscal 1980.

4.3 AUTOMATED VERSUS MANUAL SURVEY COSTS

Automated track surveys more thoroughly inspect track at a lower cost than manual inspections. The total estimated cost to survey 70,000 miles of track using the automated survey vehicles is $4.2 million. The total estimated cost to manually survey 70,000 miles of track using track inspectors is $18.7 million which is more that four time higher than the cost of using the ATIP vehicles to survey the track. Appendix A contains a detailed cost comparison between automated and manual survey operations.

5.0 DEVELOPMENT OF OPTIMUM FLEET

In 1979, MITRE Corporation studied a number of plans to determine the best vehicle configuration for FRA's ATIP.

- Plan A - Use two of the existing survey vehicles add one new heavy vehicle and five hi-rail vehicles.
- Plan B - Obtain three new large-size vehicles and five hi-rail vehicles.
- Plan C - Obtain four new medium-size vehicles and eleven hi-rail vehicles.

The MITRE study concluded that a program calling for three new self-propelled full-size measurement vehicles plus five hi-rail vehicles will provide the lowest annual cost and will also provide a good base on which to build a larger fleet if the need arises. Plan B was the best choice because:

- With the three heavy vehicles it will provide the minimum required inspection capability.
- It provides the lowest annual life cycle cost and lowest operating cost of the alternatives.

As of May 1981, one self-propelled heavy vehicle has been acquired which along with two towed heavy consists and one hi-rail vehicle make up the current ATIP configuration. Until capital acquisition funds are available this equipment will represent the ATIP configuration.

A summarization of the MITRE decision is included in Appendix B.

6.0 CONCLUSION

Safety is always measured on a relative basis (relative to the economy, productivity, frequency, loss of life and location of accidents.) The cost to achieve a certain level of safety as well as the mood of the public dictates what is the acceptable level of safety in any public service. The level of acceptability changes as the public mood or the economics shift.

Current ATIP operations are very streamlined and efficient compared with its early years. The contract cost per mile inspected was approximately $40 in 1980 compared with $130 in 1974. The total cost per year of the ATIP program is less than 0.1% of the industry's MOW expenditures and less than 5% of the track, equipment, signal and communications damage due to track-caused accidents, (does not include fatalities, injuries, loss or damage to lading, loss due to traffic interference and any disturbance to the general public). The benefits of the inspection program as shown by historical data demonstrates that the program is well worth the cost and efforts.

7.0 REFERENCES

1. "A Review of the U.S. Freight Systems Phase 1 and 2", Committee on Transportation, Assembly of Engineering, National Research Council, DOT/RSPA/DPB-20/80/1.

2. "Hearings Before the Subcommittee on Surface Transportation of the Committee on Commerce, United States Senate, Federal Railroad Safety Act of 1969 First Session on S.1933, S.2915 and S.3061.", Serial No. 91-32.

3. "The Tenth and Final Report on the High Speed Ground Transportation Act of 1965," FRA/ORD-77/27, May 1977.

4. United States Court of Appeals for the Eighth Circuit; "United States of America vs Missouri Pacific Railroad Company and the Texas and Pacific Railway Company"; April 20, 1977.

5. "Federal Railroad Safety and Hazardous Materials Transportation Control Act of 1970"; PL 91-458; 84 STAT.971; Law of 91st Congress - 2nd session.

6. "Accident/Incident Bulletin" Nos. 145, 146, 147 and 148. U.S. Department of Transportation, Federal Railroad Administration, Office of Safety, 1977, 1978, 1979 and 1980.

APPENDIX A
COMPARISON OF AUTOMATED AND MANUAL SURVEY COST

A.1 AUTOMATED SURVEY COSTS

Using an estimated cost per mile of $50 and add $10 per mile in carrier costs (locomotive and train crew costs) for an estimated 70,000 miles per year, the estimated yearly cost for automated inspection is

$$(\$50 + \$10) \times 70{,}000 = \$4{,}200{,}000 \text{ per year}$$

A.2 MANUAL SURVEY COST

The estimated cost to manually inspect the same 70,000 miles of track taking data every foot is figured as follows.

If one inspector places a gage/level board on the track every foot and records and analyzes the data to include displacements under load, the inspector would optimistically cover a 39-foot rail length in 3 minutes. Therefore, to cover 70,000 miles of track would require:

$$\frac{70{,}000 \text{ miles } (5{,}280 \text{ feet/mile})}{39 \text{ feet}} \times 3 \text{ minutes} =$$

28,430,769 minutes of inspector time.

At 6 hours per day per inspector for 230 days per year,

$$\frac{28{,}430{,}769 \text{ minutes}}{(6 \text{ hrs/day})(60 \text{ min/hrs}) \ 230 \text{ days}} =$$

343 inspectors required to survey the same distance as thoroughly as the ATIP vehicles.

The estimated cost of these 343 inspectors is (assuming a GS 12 step 5 average salary equals $30,543 plus 40% overhead cost equals $42,760/yr).

$42,760/yr/inspector x 343 inspectors =

$14,666,680 per year

plus local inspector per diem of

$50/day/inspector x 4-1/2 days/week x 52 weeks/year =

$11,700 per inspector

for a total per diem cost of

$11,700 per inspector x 343 inspectors =

$4,013,100 per year.

The total estimated cost to manually survey the 70,000 miles of track is

$14,666,680 + $4,013,100 = $18,679,780

which is more than 4 times higher than the cost of using the ATIP vehicles to survey 70,000 miles of track.

APPENDIX B

COMPARISON OF THE ALTERNATIVES FOR DEVELOPMENT OF AN OPTIMUM FLEET*

B.1 PLAN A

- Use two of the current ATIP vehicles.
- Procure a new self-propelled heavy vehicle (TX).
- Retrofit T-2/T-4 with a rail flaw system. (Note: The rail flaw system on T-6 proved to be unworkable and was removed. Any use of rail flaw equipment on the two current ATIP vehicles would require retrofitting both vehicles.)
- Purchase five new hi-rail vehicles with rail flaw and track geometry capabilities.

The advantages of Plan A are

- Least capital investment.
- Sufficient dynamic loading for track geometry measurement on high speed track.
- Provides the inspection support currently identified as being sufficient.

The disadvantages of Plan A are

- Large post-processing work load. (Note: Since the MITRE report was written, on-line processing on T-1/T-3 and T-2/T-4 was started which has eliminated the large post-processing work load.)

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*Excerpted from "The Role of Automated Vehicles in the National Track Inspection Program" MITRE Corporation, MTR-79W00423, December 1979.

- T-2/T-4 and T-6 are expensive to operate because both require a locomotive and train crew plus a large operating crew. (Note: At the time of the MITRE report, T-1/T-3 was planned to be retired when TX was completed. However, the plans were changed and T-6 was retired.)

- Four different vehicle configurations. (Note: T-6 was retired instead of T-1/T-3 thus there are only two different vehicle configurations since T-1/T-3 and T-2/T-4 are practically identical.)

B.2 PLAN B

- Phase out T-1/T-3, T-2/T-4 and T-6 over a three to four year period and replace them with three new TX class vehicles equipped with rail flaw systems. (Note: Rail flaw was not installed on T-10.)

- Procure five hi-rail vehicles with rail flaw and geometry capabilities.

The advantages of Plan B are

- The new TX class vehicles will have a lower operating cost and will have rail flaw detection capabilities at little extra cost. (Note: Current rail flaw technology is not compatible with track survey operations because of the low (25 mph) maximum operating speed for rail flaw.)

- Higher fleet mobility because all vehicles are self-propelled.

- Sufficient dynamic loading for track geometry measurement.

- Lowest total annual life cycle cost.

- Only two types of instrumentation and vehicle configurations.

The disadvantages of Plan B are

- Highest initial capital cost.

B.3 PLAN C

- Phase out T-1/T-3, T-2/T-4 and T-6 over a three to four year period and replace them with four Plasser/Matisa type cars.
- Purchase six hi-rail vehicles with rail flaw capability.
- Purchase five hi-rail vehicles with rail flaw and track geometry capabilities.

The advantages of Plan C are

- Highest fleet mobility.
- Less capital cost than Plan B.

The disadvantages of Plan C are

- Insufficient dynamic loading for mainline track measurements.
- Unknown track geometry accuracy and repeatability.
- Largest number of vehicles.

APPENDIX C

EFFECTS OF EMERGENCY ORDER NO. 11

Figures C-1 and C-2 and Table C-1 show defect-feet per mile and track quality for five surveys between Corbin, Kentucky and Etowah, Tennessee, a distance of 162 miles on the Louisville and Nashville Railroad, between July 1977 and November 1980. The area, Duff Mountain, lies just to the south of Corbin between mileposts 190 and 225, a distance of 35 miles. Corbin to Etowah is a portion of the continuous L&N mainline between Cincinnati, Ohio and Atlanta, Georgia, a primary North-South route of hazardous material movement.

In July of 1977 an average of 8 feet per mile fell below FRA posted track class while Duff Mountain only registered a little over 4-1/2 feet per mile. Increased tonnage during the next year and one-half, but without apparent increase in carrier surveillance or maintenance, resulted in a dramatic rise in track-feet exceptions to 26, with a disproportionate increase in track-feet defects over Duff Mountain to approximately 82. At the time of the January 1979 survey the Administrator of FRA was considering issuance of an Emergency Order to the L&N Railroad.

Among numerous accident statistics detailed within the Draft E. O. were:

1. During the period between January 1, 1976 and June 30, 1978, the L&N reported release of hazardous materials from 42 placarded hazardous materials cars at various locations within seven different states. Those accidents resulted in 19 deaths, approximately 71 serious injuries, and necessitated the evacuation of approximately 7,280 people.

2. On November 9, 1977 two locomotives and 35 cars of 128-car L&N freight train, including 17 placarded hazardous materials cars containing anhydrous ammonia, derailed on a 6°04' curve near Pensacola, Florida. Contents of three of those cars were released into the atmosphere creating a toxic gas cloud that killed two people, seriously injured 46 others, and forced the evacuation of approximately 1,500 people. The NTSB's investigation revealed that in June 1977, the L&N's track geometry vehicle had indicated that track gage and crosslevel conditions in the area of the derailment did not conform to the L&N's own track standards, and that no further action was taken by the L&N to correct those conditions.

Emergency Order No. 11 was issued to the Louisville and Nashville Railroad Company on February 5, 1979.

While the ATIP survey in January 1979 was routine in nature, scheduled six months in advance, an L&N system survey was initiated following issuance of E. O. #11. This effort provided FRA Office of Safety with a unique opportunity to compare car measurements, and measure their effectiveness in gaining compliance with FRA Standards.

Following the January 10, 1979 survey the L&N commenced a program of remedial action, with particular emphasis on wide gage on Duff Mountain. Forty days later, on February 21, 1979 an FRA geometry measurement vehicle re-surveyed, Corbin, Kentucky to Etowah, Tennessee. Defect feet per mile over the 162 mile sub-division fell from 26.3 to 7.6 but even more dramatic was the reduction in defect feet over Duff Mountain; from 81.8 to 5.5 feet per mile, a 93-1/4% reduction in track defects. Correspondingly, the number of derailments over Duff Mountain, during the period February 1, 1978 to January 31, 1979 decreased 84% during the next suceeding period:

Period	Track Caused Derailments	All Derailments
2/1/78 - 1/31/79	14	25
2/1/79 - 1/31/80	0	4

An ATIP survey on April 13, 1979 reflected still fewer defects over the thirty-five miles of Duff Mountain, only 1.2 defect-feet per mile, an impressive 98-1/2% reduction since January 10. And contrary to thought that percent reduction might be accomplished by slow-orders, the second bar chart indicates an increase in authorized track speed between Etowah and Corbin, and over Duff Mountain, from January 1979 to November 1980 with a corresponding increase in the track quality index over the four surveys.

Office of Safety neither feels compelled nor believes it has the luxury, to repeat survey routes within one to three months. Such a procedure would be contrary to Office of Safety guidelines, vehicle productivity, and uniformity of enforcement. Yet Duff Mountain remains a testament to the flexibility, reliability, usefullness and effectiveness of high-speed, automated track geometry measurement vehicles as utilized by FRA under authority of the Railroad Safety Act of 1970.

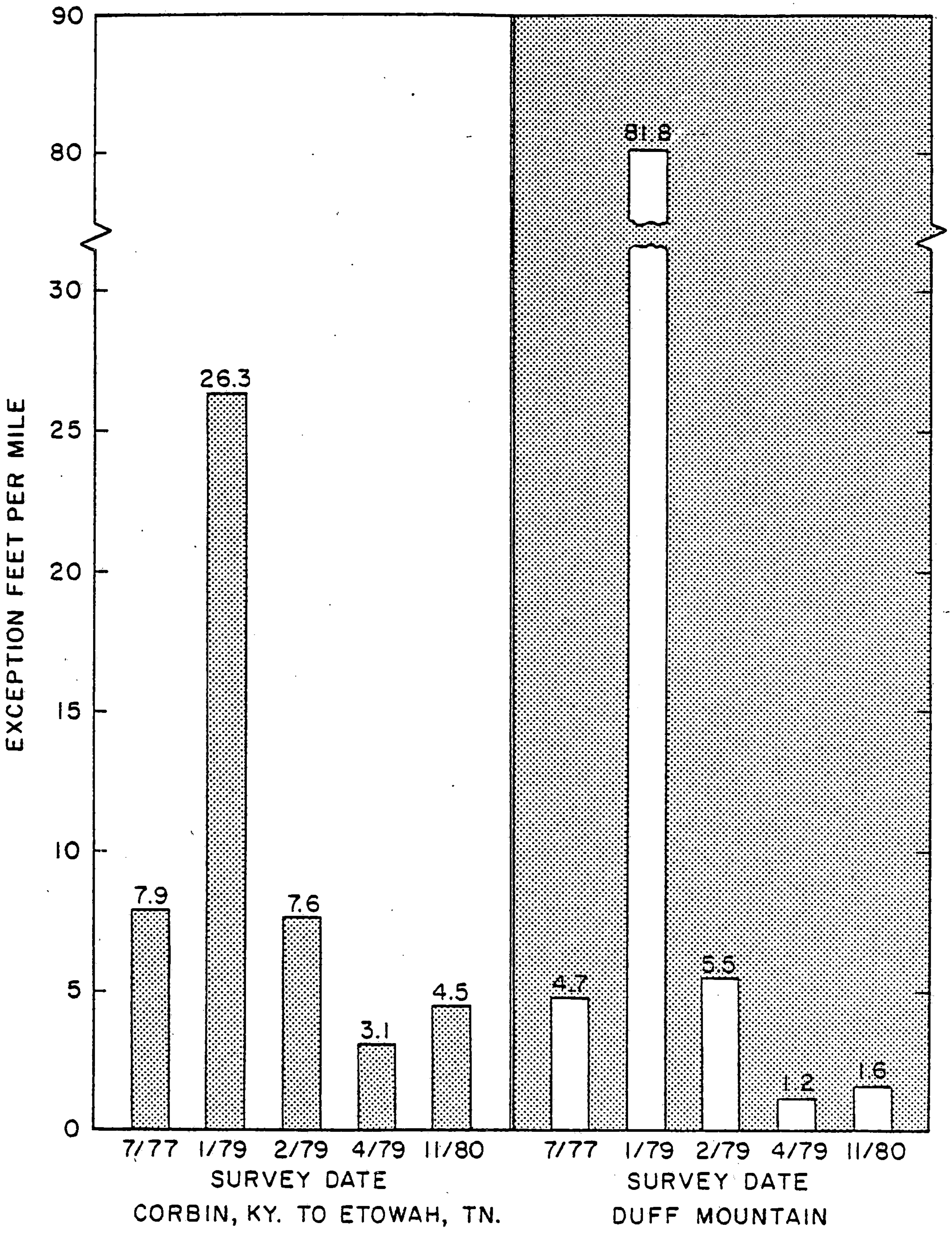


Figure C-1. Exception Feet/Mile Louisville & Nashville Railroad

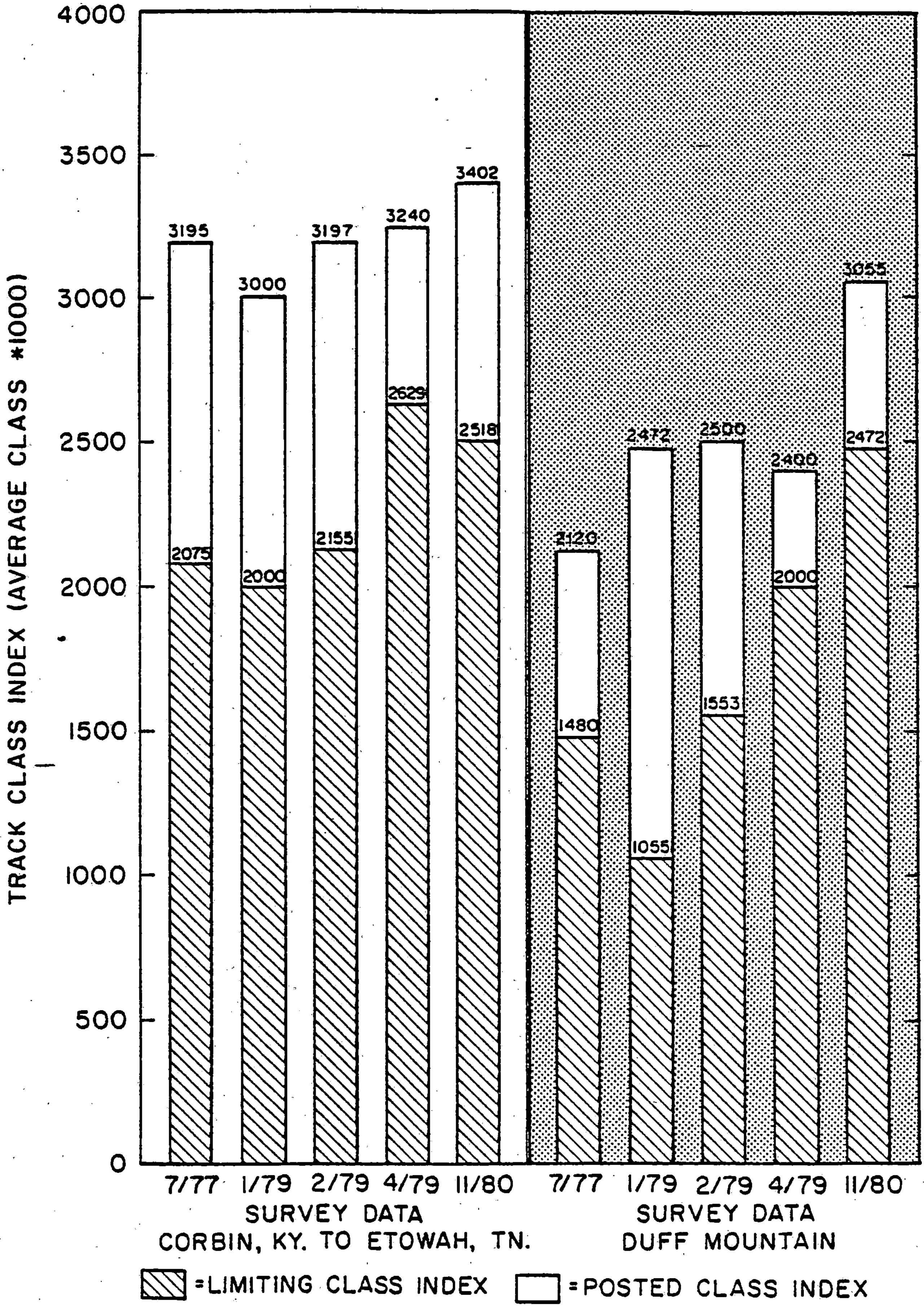


Figure C-2. Track Class Index Louisville & Nashville Railroad

TABLE C-1

LOUISVILLE AND NASHVILLE RAILROAD
SURVEY STATISTICS

Corbin, KY to Etowah, TN

Survey #	Date of Survey	Posted Index	Limiting Index	Index Difference
RG 233	7-77	3195	2075	1120
T3-9027	1-79	3000	2000	1000
T6-9031	2-79	3197	2155	1042
T3-9018	4-79	3240	2629	611
T2-1006	11-80	3402	2518	884

Index = average class *1000

Duff Mt. Division MP190-225

Survey #	Date of Survey	Posted Index	Limiting Index	Index Difference
RG 233	7-77	2120	1480	640
T3-9027	1-79	2472	1055	1417
T6-9031	2-79	2500	1553	947
T3-9018	4-79	2400	2000	400
T2-1006	11-80	3055	2472	583

Index = average class *1000

APPENDIX D

SAMPLE ON-LINE EXCEPTION REPORT

TRACK SAFETY STANDARDS
FRA-OFFICE OF SAFETY

FRA TRACK PARAMETER	FRA TRACK CLASS 1	2	3	4	5	6	REFERENCE
PROFILE (IN.)	3.000	2.750	2.250	2.000	1.250	.500	SECTION 213.63,TABLE, LINE 2
ALIGNMENT (IN.)							
TANGENT	5.000	3.000	1.750	1.500	.750	.500	
CURVES (BODY-SPIRAL)	5.000	3.000	1.750	1.500	.625	.375	SECTION 213.55,TABLE
GAGE (IN.)							
TANGENT	57.75	57.50	57.50	57.25	57.00	56.75	
CURVES (BODY-SPIRAL)	57.75	57.75	57.75	57.50	57.50	57.00	
TIGHT GAGE (IN.)	56.00	56.00	56.00	56.00	56.00	56.00	SECTION 213.53,TABLE
CROSSLEVEL (IN.)							
TANGENT-CURVE BODY	3.000	2.000	1.750	1.250	1.000	.500	SECTION 213.63,TABLE, LINE 5
SPIRAL	1.750	1.500	1.250	1.000	.750	.500	SECTION 213.63,TABLE, LINE 7
WARP (IN.)							
TANGENT-CURVE BODY	3.000	2.000	1.750	1.250	1.000	.625	SECTION 213.63,TABLE, LINE 6
SPIRAL	2.000	1.750	1.250	1.000	.750	.500	SECTION 213.63,TABLE, LINE 4

MAXIMUM ALLOWABLE SPEED(MPH)							
PASSENGER	015	030	060	080	090	110	
FREIGHT	010	025	040	060	080	110	

NOTES

EXPLANATION OF SYMBOLS USED IN THIS REPORT

F - IN THE CURVE ANALYSIS SECTION THIS INDICATES THAT THE SPIRAL OUT OF A CURVE WAS NOT DETECTED. DATA VALUES TO THE POINT OF TANGENT ARE USED IN THE COMPUTATION OF AVERAGE CURVATURE AND AVERAGE ELEVATION.

R - IN TSS TRACK GEOMETRY EXCEPTION SECTION, THIS INDICATES THAT (1.) A CROSSLEVEL EXCEPTION WAS IN PROGRESS DURING A TANGENT-SPIRAL TRANSITION OR (2.) A GROUP EXCEPTION BEGINS ON TANGENT IMMEDIATELY AFTER A SPIRAL-TANGENT TRANSITION. THESE EXCEPTIONS ARE NOT INCLUDED IN THE SUMMARY SECTION.

*SC - IN ALL SECTIONS THIS MESSAGE INDICATES GAGE SENSORS LIFTED AND GAGE EXCEPTIONS ARE NOT REPORTED. LOCATION DENOTES POINT OF CYCLE. LENGTH OF SENSOR CYCLE IS INCLUDED IN MESSAGE.

*MP - IN ALL SECTIONS THIS MESSAGE INDICATES THAT A MILE POST WAS ENTERED. THE LENGTH OF THE PREVIOUS MILE IS INCLUDED IN THE MESSAGE.

C - IN TSS TRACK GEOMETRY EXCEPTION SECTION, THIS INDICATES THAT A CROSSLEVEL EXCEPTION GROUP EXCEEDS 78 FEET AND THAT IF A CURVE EXISTS, IT IS TOO SHALLOW TO DETECT. THESE EXCEPTIONS ARE NOT INCLUDED IN THE SUMMARY SECTION.

T - IN THE EXCEPTION SUMMARY SECTION, THIS INDICATES THAT ALL GAGE EXCEPTIONS IN THIS MILE WERE TIGHT GAGE.

MISCELLANEOUS

EXCEPTIONS ARE NOT REPORTED FOR PROFILE WHEN TEST VEHICLE SPEEDS ARE BELOW 5 MPH.

EXCEPTIONS ARE NOT REPORTED FOR ALIGNMENT WHEN TEST VEHICLE SPEEDS ARE BELOW 15 MPH.

EXCEPTIONS ARE NOT REPORTED FOR GAGE AND ALIGNMENT WHEN GAGE SENSORS ARE RETRACTED.

TRACK CLASS TABLE MAY NOT NECESSARILY REFLECT TRACK CLASS CHANGES IN REPORT OUTPUT DUE TO POSSIBLE MANUAL CLASS ENTRIES.

SAMPLE INTERVAL IS 1.0 FT.

IN CURVE ANALYSIS SECTION, CURVE LENGTH INCLUDES SPIRALS.

IN EXCEPTION SUMMARY SECTION, EXC FT. IS THE ABBREVIATION FOR EXCEPTION FEET.

MP	FEET	TRACK 1 CLASS	TRACK 2 CLASS	TRACK 3 CLASS	TRACK 4 CLASS	TRACK 5 CLASS	TRACK 6 CLASS
135	528	3					
134	0	3					
133	0	3					
132	0	3					
131	2640	4					
130	0	4					
129	0	4					
128	0	4					
127	0	4					
126	3696	4					
125	0	4					
124	0	4					
123	0	4					
122	0	4					
121	0	4					
120	0	4					
119	0	4					
118	0	4					
117	0	4					
116	3696	2					
116	4752	4					
115	0	4					
114	0	4					
113	0	4					
112	0	4					
111	0	4					
110	0	4					
109	0	4					
108	0	4					
107	0	4					
106	4224	3					
105	0	4					
104	0	4					
103	0	4					
102	0	4					
101	0	4					
100	0	4					
99	0	4					
98	0	4					
97	0	4					

TRACK NUMBER : 1 POSTED TRACK CLASS : 4

TSS THRESHOLDS	PROFILE	ALIGNMENT	GAGE	XLEVEL	WARP	
	2.000	1.500	57.25	1.250	1.250	TANGENT (T)
	2.000	1.500	57.50	1.000	1.000	SPIRAL (S)
	2.000	1.500	57.50	1.250	1.250	CURVE (C)

LOCATION		PROFILE				ALIGNMENT				GAGE		XLEVEL		WARP		EXCEPTION QUALIFICATION	
		W RAIL		E RAIL		W RAIL		E RAIL								TRACK(T/S/C)	LIMITING
MP	FEET	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	REFERENCE	CLASS
99	4182													1.35	37	T	3
99	4203									57.46	7					T	3
98	0									* MP	5252						
98	193											-1.48	2			T	3
97	0									* MP	5334						
97	840													-1.35	51	T	3
96	0									* MP	5272						
95	0									* MP	5276						
95	368													-1.35	61	T	3
95	371											-1.54	5			T	3
95	431													1.46	19	T	3
95	3537													1.38	41	T	3
95	3579											1.49	2			T	3
95	3600													-1.46	23	T	3
95	3631									* SC	102						
95	3564									* SC	145						
94	0									* MP	4004						
94	111													-1.39	23	T	3
94	174													1.67	42	T	3
94	255									57.39	3					T	3
94	297									57.43	4					T	3
94	333													1.37	35	T	3
94	710													-1.36	62	T	3
94	853									* SC	83						
94	3008													-1.35	26	T	3
93	0									* MP	5292						
93	714									* SC	103						
93	1271													-1.37	29	T	3
93	1371									* SC	95						
93	2414									* SC	110						

CROSSLEVEL : + = W RAIL HIGH   CURVATURE : + = CURVE TO E
             - = E RAIL HIGH   - = CURVE TO W

DATE 08/12/81

TRACK NUMBER : 1

START MP	START DIST	END MP	END DIST	CURVE LENGTH	AVERAGE CURVATURE DEG/MIN	AVERAGE ELEVATION INCHES	POSTED TRACK SPEED	LIMITING SPEED: MAXIMUM ALLOW. MPH	LIMITING SPEED: POINT LIMIT MP/FT	LIMITING SPEED: CURVATURE DEG/MIN	LIMITING SPEED: ELEVATION INCHES	LIMITING SPEED: TOTAL FT./GP
131	3142	131	3549	407	- 1/34	-.04	45	42	131/ 3242	- 2/12	.19	43/ 3
131	3549	131	3863	314	3/25	.36	45	36	131/ 3667	3/29	.30	93/ 1
131	4711	131	5211	500	2/20	1.33	45					0/ 0
131	5211	130	1431	1471	1/41	3.01	45					0/ 0
129	316	129	555	239	- 0/24	-.59	45					0/ 0
129	960	129	1230	270	0/22	.22	45					0/ 0
129	1477	129	2690	1213	2/ 2	2.05	45					0/ 0
122	1684	122	2673	989	0/58	1.30	45					0/ 0
120	992	120	2187	1195	0/58	1.58	45					0/ 0
118	1623	118	2672	1049	- 0/58	-1.56	45					0/ 0
117	2846	117	4028	1182	- 0/59	-1.69	45					0/ 0
113	5009	112	1001	1283	- 2/ 3	-1.79	45					0/ 0
110	2865	110	3737	872	- 1/ 1	-2.39	45					0/ 0
109	1753	109	2543	790	0/28	.83	45					0/ 0
106	4839	106	5073	234	2/ 3	-.08	35	0	106/ 5044	0/40	-1.11	7/ 1
106	5073	105	103	271	2/ 3	-.23	35	0	106/ 5106	- 1/22	1.01	14/ 1
93	917	93	1208	291	0/37	.30	45					0/ 0
93	1399	93	1688	289	- 0/49	-.51	45					0/ 0
92	2121	92	2294	173 F	- 0/25	-.36	45					0/ 0
92	2657	92	2934	277	0/23	.85	45					0/ 0
90	3315	90	5244	1929	- 1/51	-2.71	45					0/ 0

DATE 08/12/81

TRACK NUMBER : 1

MILEPOST START	MILEPOST DIST	PROFILE TOT EXC	PROFILE EXC FT.	PROFILE CL1 EXC	ALIGNMENT TOT EXC	ALIGNMENT EXC FT.	ALIGNMENT CL1 EXC	GAGE TOT EXC	GAGE EXC FT.	GAGE CL1 EXC	XLEVEL TOT EXC	XLEVEL EXC FT.	XLEVEL CL1 EXC	WARP TOTAL COUNT	WARP CL1 EXC	LIMITING TRACK CLASS	POSTED TRACK CLASS
108	5286			0			0			0			0	1	0	3	4
107	5278			0			0			0	2	26	0		0	3	4
106	4224			0			0			0			0	2	0	3	4
106	1017			0			0			0	2	4	0	3	0	1	3
105	1			0			0			0			0		0	3	2
105	5326			0			0	2	4	0			0	2	0	3	4
104	5290			0			0			0			0		0	4	4
103	5285			0			0			0			0	3	0	3	4
102	5289			0			0			0			0	1	0	3	4
101	5285			0			0	4	16	0			0		0	3	4
100	5303			0			0			0			0	1	0	3	4
99	5252			0			0	1	7	0	3	36	0	2	0	2	4
98	5334			0			0			0	1	2	0		0	3	4
97	5272			0			0			0			0	1	0	3	4
96	5276			0			0			0			0		0	4	4
95	3419			0			0			0	2	7	0	4	0	3	4
95	585			0			0			0			0		0	4	4
94	5292			0			0	2	7	0			0	5	0	3	4
93	5282			0			0			0			0	1	0	3	4
92	10574			0			0			0	2	4	0	15	0	2	4
90	5302			0			0			0	2	8	0	4	0	2	4

APPENDIX E

T-10 GENERAL INFORMATION

TRACK GEOMETRY VEHICLE T-10
INFORMATION SHEET

Vehicle Owner - Federal Railroad Administration, Office of Safety

Operations and Maintenance Contractor - ENSCO, Inc.

Vehicle Built By: The Budd Company, Philadelphia, PA (1980)

Survey Speed - Railroad designated maximum track speed up to 80 mph

Track Geometry Parameters Measured:

- Gage
- Profile
- Warp
- Crosslevel - Superelevation
- Curvature
- Alignment

Computer System - Hewlett Packard HP-1000 Series Computer

Geometry Measuring Equipment - Electro-mechanical non-contact sensors

Data Processing - Real-time analog and digital

Normal Operating Crew Compliment:

- 6 contractor personnel
- 2 FRA track safety inspectors
- 2 railroad maintenance-of-way personnel
- 1 or 2 railroad pilots

Power Source - Perkins V8-540 Diesel Lima 75 kW 480 V Alternator

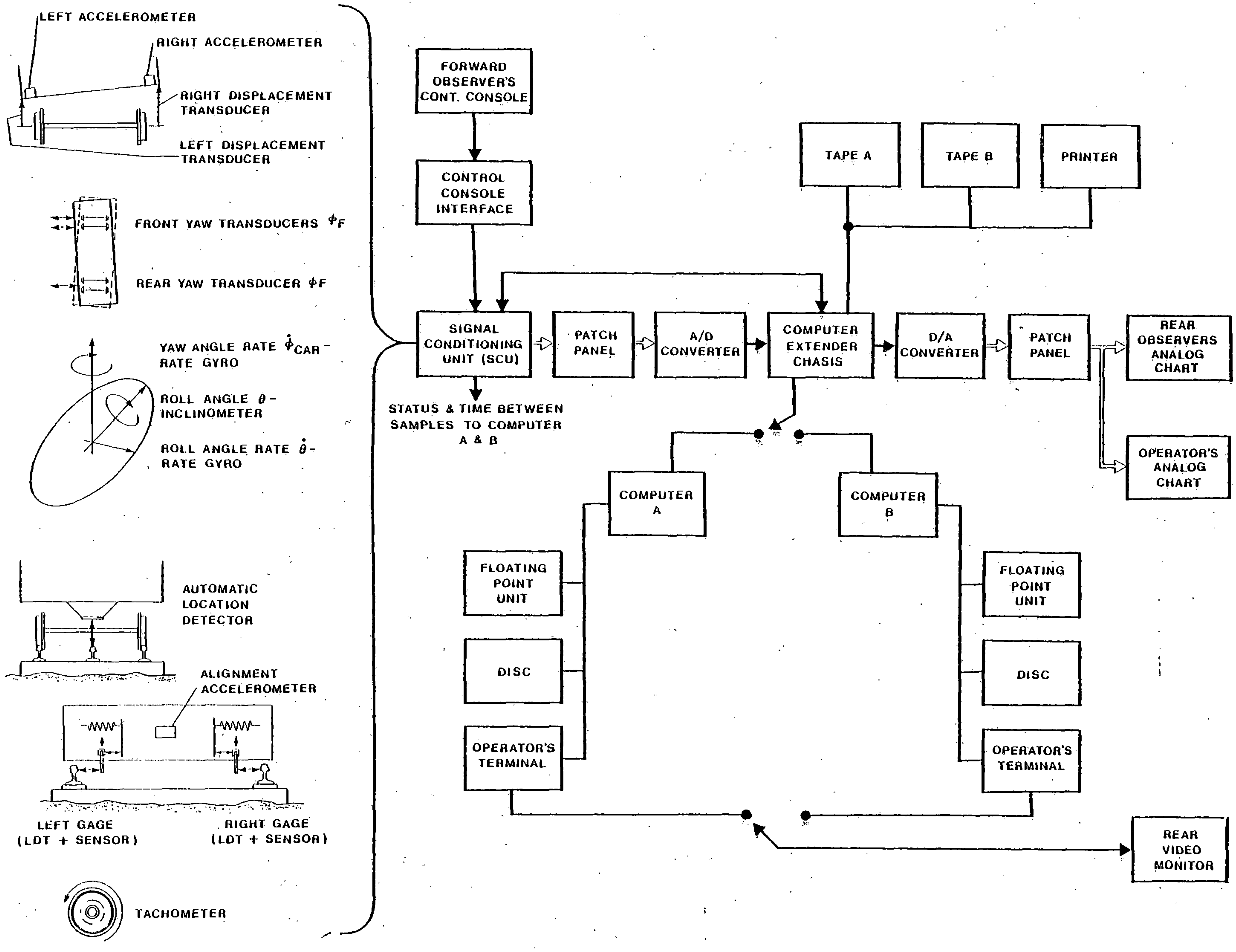
Propulsion - Self propelled by 2 Detroit Diesel Allison 8V-92N Diesels

Vehicle Specifications:

- Length = 85'4"
- Width (max) = 10'6"
- Height (max) = 14'6"
- Weight = 70 tons

TRACK GEOMETRY MEASUREMENT SYSTEM

FOR FEDERAL RAILROAD ADMINISTRATION TRACK INSPECTION VEHICLE T-10



T10 - VEHICLE SPECIFICATION SUMMARY

PHYSICAL

Length - 85.3 feet

Width - 10.5 feet

Height - 14.5 feet

Weight - 70 tons

Wheel base - 8.5 feet

Suspension - Air coil spring suspension

Tanks - 300 gallons fuel; 101 gallons potable water; 125 gallons cooling

Support Facilities - Microphor toilet, kitchen, office, work area, bunk, luggage area

SUBSYSTEMS

Propulsion - Two Detroit Diesel Allison 8V-92N Diesels

Brakes - Tread Type

Heating - Two-Stage Electric Floor Heat

Air Conditioning - Two 6-Ton Air Conditioners

Communications - Internal Public Address and Radio Telephone

ELECTRICAL

Generators - Perkins V8-540 Diesel, Lima 75 kW 480 V Alternator

Converter - 15 kva Topaz Voltage Regulator

Wayside - N/A

Lighting - 120-V, 60 Hz Fluorescent; 32 VDC Emergency Lighting

Batteries - Four 8-V

DATA ACQUISITION SYSTEM

Gage - Servomagnetic (ENSCO) - ±0.1-inch accuracy on normal rail

Profile - Inertial (ENSCO)

Crosslevel - Gyro/Accelerometers (ENSCO) - Range ±10 inches ±0.1-inch

Curvature - (ENSCO) - 0 to 23 degrees

Alignment - Alignometer/Gage System - Range ±6.25 inches ±0.1-inch

T10 - VEHICLE SPECIFICATION SUMMARY (cont)

Distance - Optical Encoder
ALD - Capacitive and Magnetic

DATA PROCESSING INSTRUMENTATION

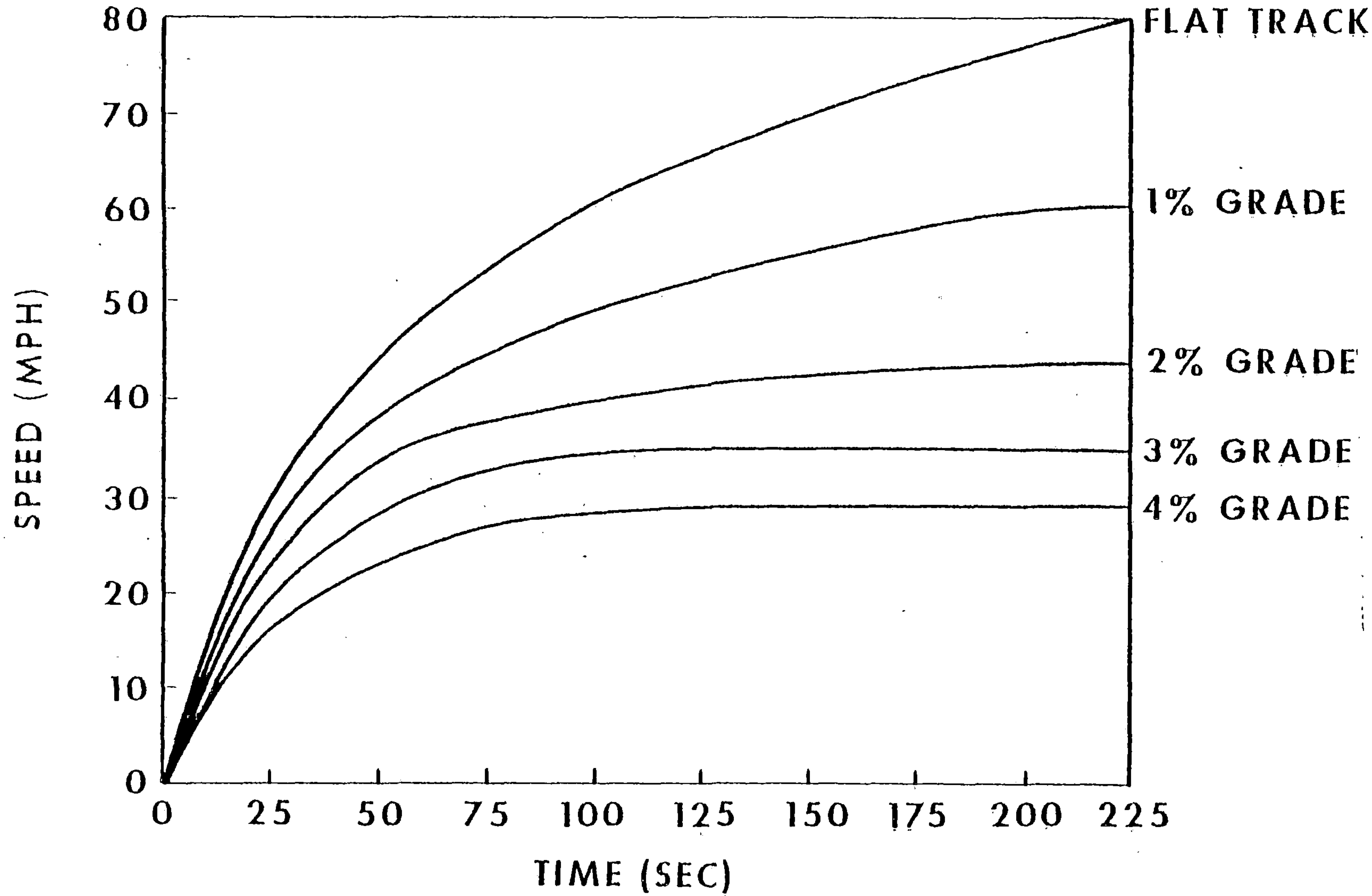
A/D - Analogic AN-5400
Computer - Hewlett Packard HP-1000 Series
Operating System - RTE-IV
Language - Assembly and FORTRAN
Core - 64K Words
Disc - HP 7900A - 5.0M Bytes (Dual-Disc)
Digital Tape - Two 1600 BPI HP 7970E
Console Device - HP 2648A
Printer - HP 2608A
D/A - Analogic AN-5400
Chart Recorder - Three 8-Channel MFE Recorders

AVERAGE UTILIZATION SUMMARY

Fuel - 8.7 gallons/hour
Water - 45 gallons
Magnetic Tapes - 3 per day
Printer Paper - 1-1/2 boxes per day
Chart Paper - 2 rolls per chart per day
Acceleration - 0-80 mph in 3.6 minutes

ONE CAR TRAIN

2 ENGINES/CAR NATURALLY ASPIRATED 80 MPH GEARING AT SEA LEVEL NORMAL ATMOSPHERIC CONDITIONS



APPENDIX F

GENERAL INFORMATION

ATIP

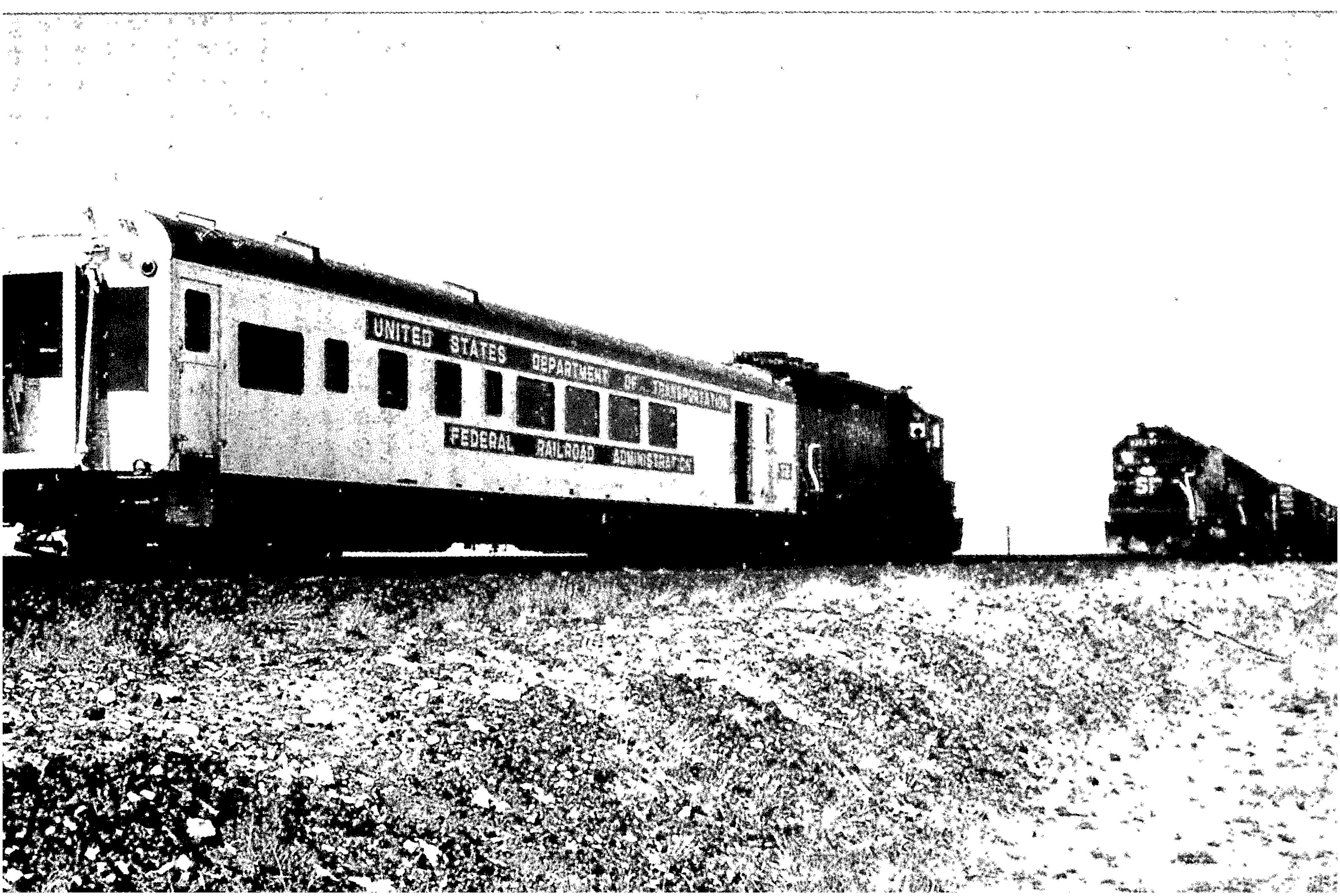
AUTOMATED
TRACK
INSPECTION
PROGRAM

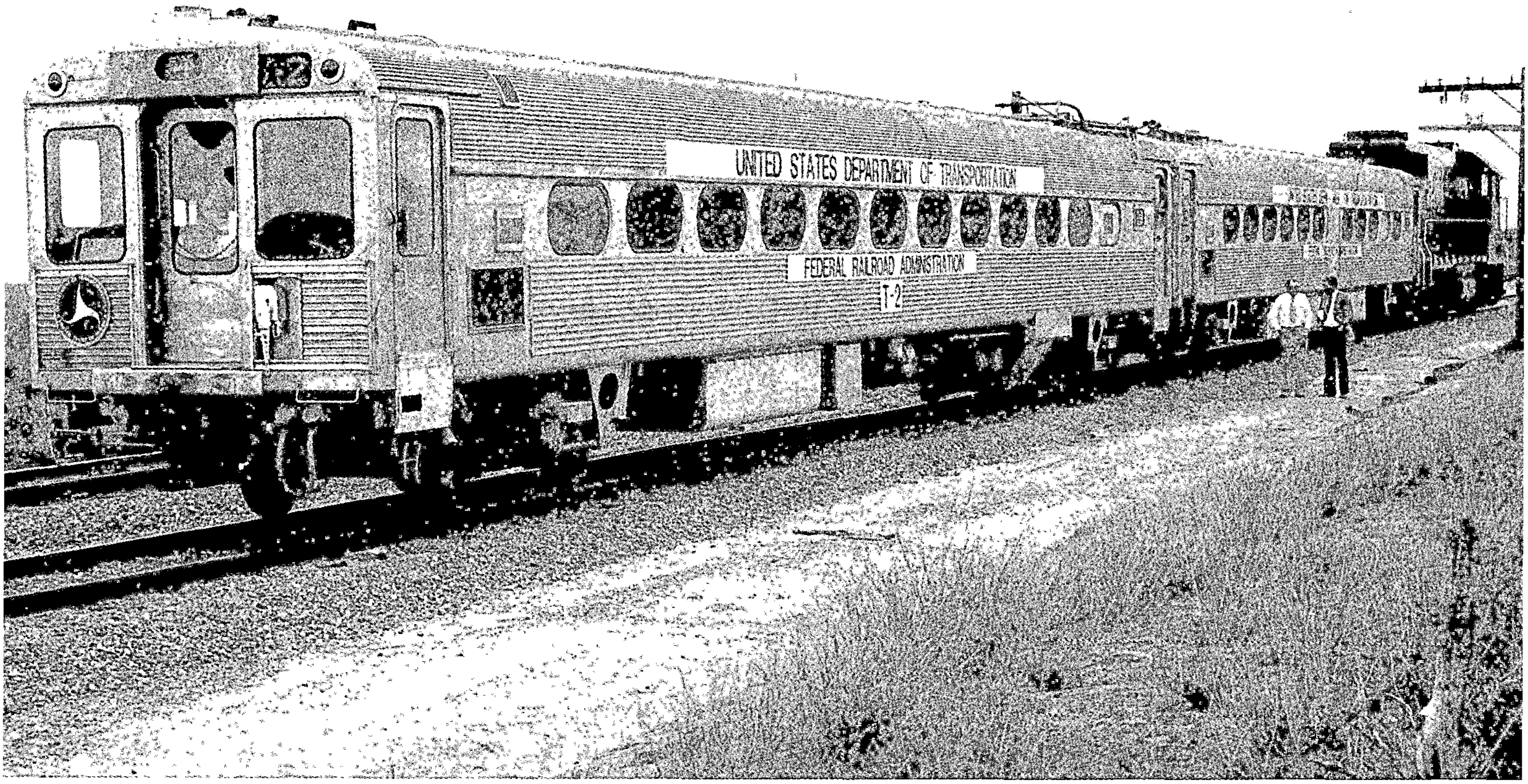
OFFICE OF SAFETY
FEDERAL RAILROAD ADMINISTRATION
UNITED STATES DEPARTMENT OF TRANSPORTATION

TRACK MEASUREMENT FOR TODAY's RAILROAD SYSTEMS

The Federal Railroad Administration's Track Geometry Survey Vehicles, operated by the Office of Safety, help America's railroads increase safety and keep pace with advancing technology. The data, produced by the cars through the precise measurement of existing track systems, are used to monitor compliance with the Federal Track Safety Standards (FTSS) and aid in the efficient, effective track system maintenance planning to support the design of tomorrow's energy efficient, high speed railroads.

Through the use of advanced electronic sensing and data processing, the cars are able to collect track geometry data while traveling at speeds up to 120 miles per hour. In the measurement process, data are recorded on magnetic tape for computer processing, both on-line and offline, and are simultaneously displayed on oscillographs. The oscillographs visually indicate the condition of the track being surveyed and are compared to the actual track as viewed from the rear of the survey vehicle by an FRA Track Safety Inspector and a Railroad representative.





Tables extracted from FRA Track Safety Standards from which exception calculations are made.

SPEED
(in miles per hour)

Class	Freight	Passenger
1	10	15
2	25	30
3	40	60
4	60	80
5	80	90
6	110	110

PROFILE
62′ Midchord Offset
(in inches)

Class	Deviation From Profile
1	3.00
2	2.75
3	2.25
4	2.00
5	1.25
6	0.50

ALIGNMENT
62′ Midchord Offset
(in inches)

Class	Tangent Track	Curved Track
1	5.00	5.00
2	3.00	3.00
3	1.75	1.75
4	1.50	1.50
5	0.75	0.625
6	0.50	0.375

CROSSLEVEL
(in inches)

Class	Spiral (31′ Chord)	Non Spiral (62′ Chord)
1	1.75	3.00
2	1.50	2.00
3	1.25	1.75
4	1.00	1.25
5	0.75	1.00
6	0.50	0.50

CURVATURE

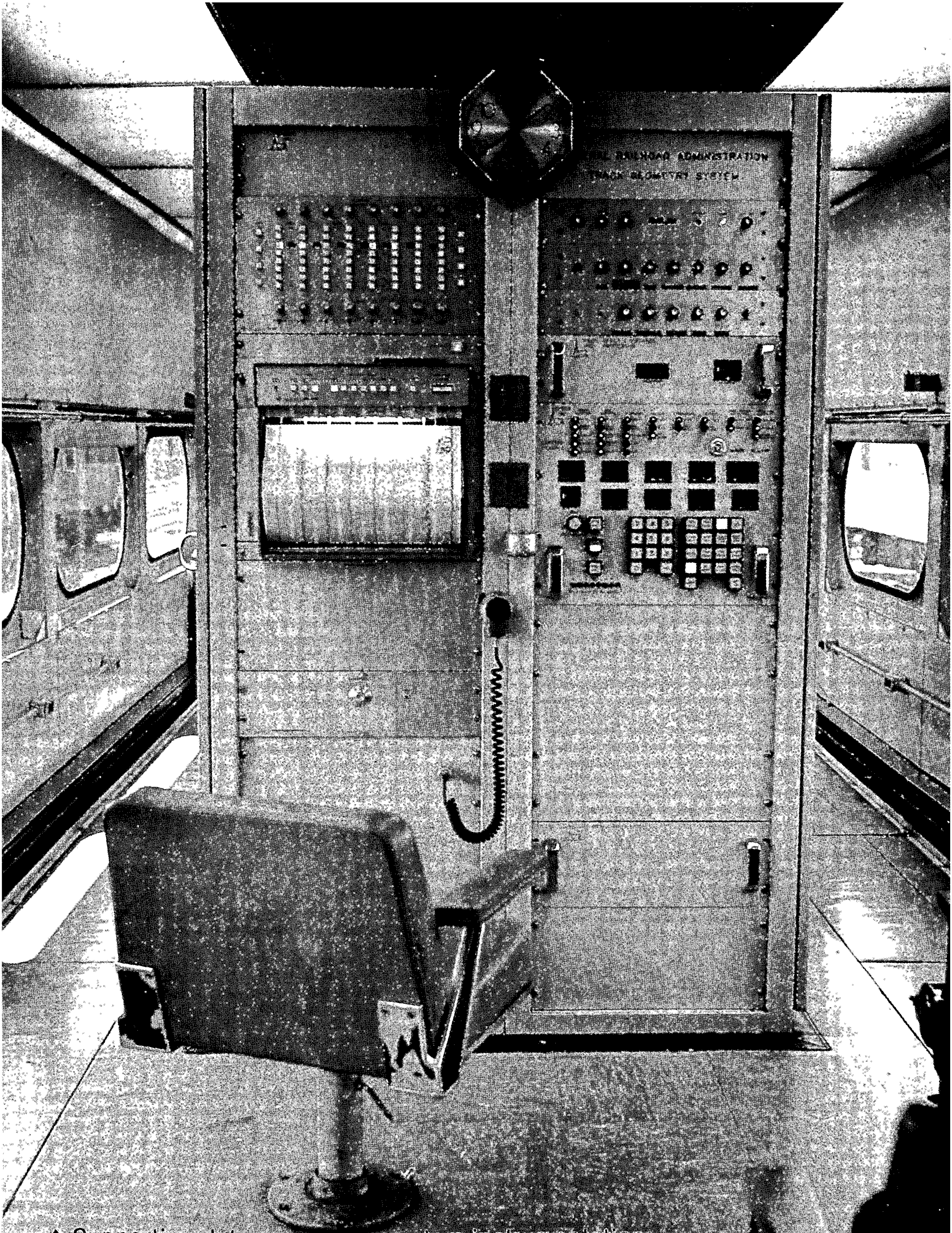
Computation made on basis of 3-inch unbalance formula.

GAGE
(in inches)

Class	Minimum Not less than	Maximum Tangent	Maximum Curve
1	56.0	57.75	57.75
2	56.0	57.50	57.75
3	56.0	57.50	57.75
4	56.0	57.25	57.50
5	56.0	57.00	57.50
6	56.0	56.75	57.00

WARP
(in inches)

Class	Tangent and Curve
1	3.00
2	2.00
3	1.75
4	1.25
5	1.00
6	0.625



▲ Supporting data acquisition system instrumentation.

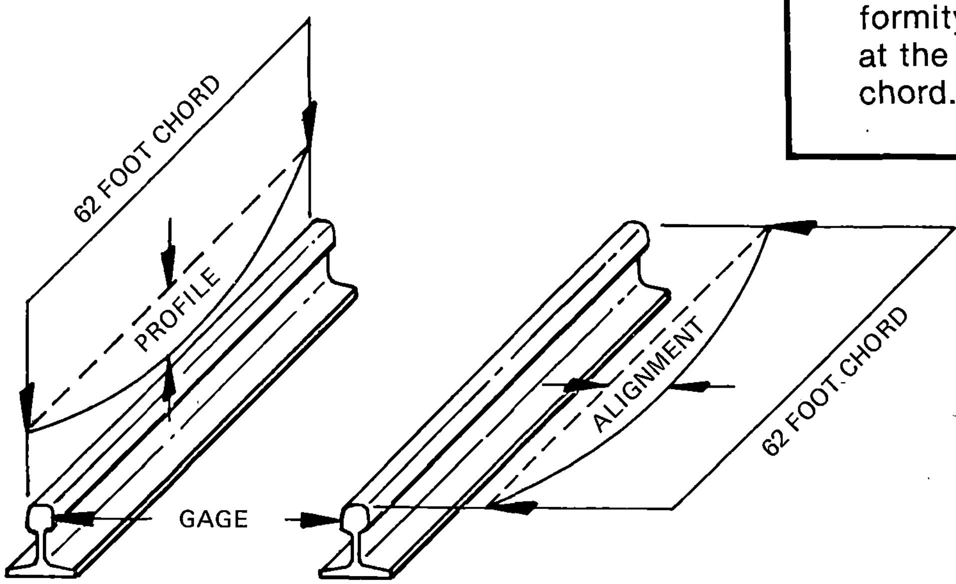
SURVEYING FOR EXCEPTIONS

Ideally, railroad tracks are perfectly uniform. In practice however, weather and geographical conditions, train speeds, tonnage, and continued maintenance requirements contribute to railroad track non-uniformities and, in some cases, defects. The Federal Railroad Administration has developed high speed track geometry vehicles to detect non-uniformities and to identify specific defects.

When Track Geometry Survey Vehicles measure track, the sensors, mounted on the survey vehicles, generate electronic voltages. These voltages are collected at sample lengths of 1-foot intervals, conditioned, and input to a data acquisition system. The data acquisition system consists of a multi-channel analog-to-digital converter, a minicomputer, magnetic tape drive, a printer/plotter, manual data entry devices, and an oscillograph. The data acquisition system processes these signals into six track geometry parameters. These parameters are:

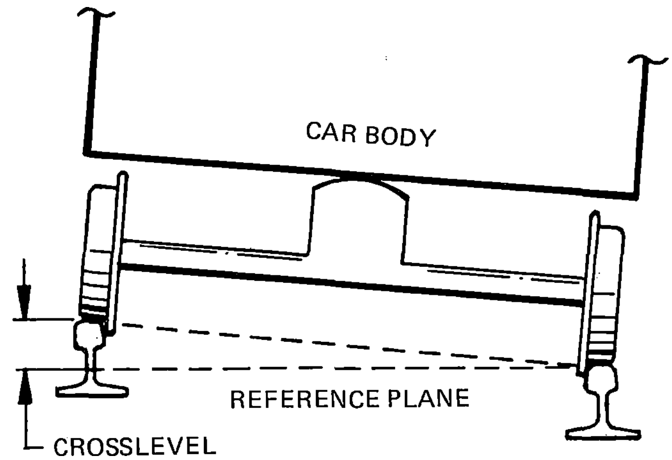
- Profile — the surface uniformity of each rail measured at the mid-point of a 62-foot chord.

- Alignment — the line uniformity of each rail measured at the mid-point of a 62-foot chord.

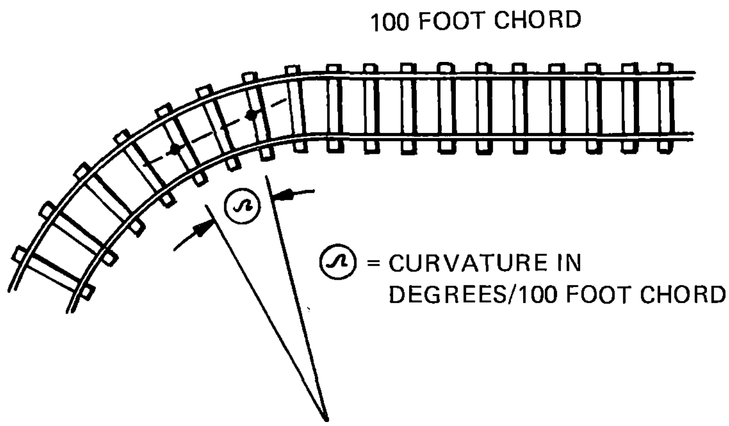


- Gage — the distance between the rails measured five-eighths of an inch below the top surface of the rail.

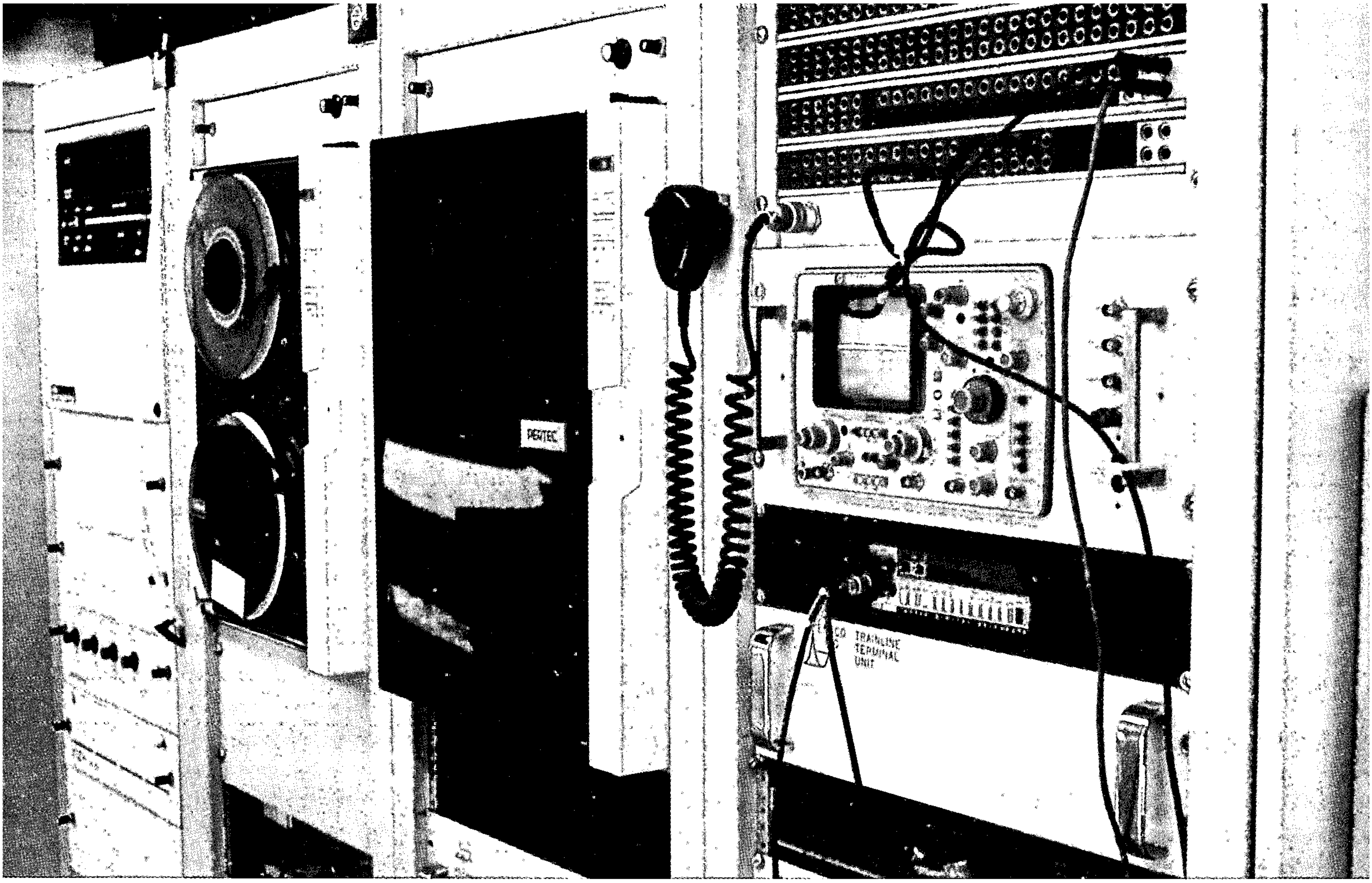
- Crosslevel (superelevation) — the amount of elevation of one rail above the other.



- Warp — the deviation of crosslevel over 62 feet in non-spiral track and 31 feet in spiral track and derived from crosslevel measurements.

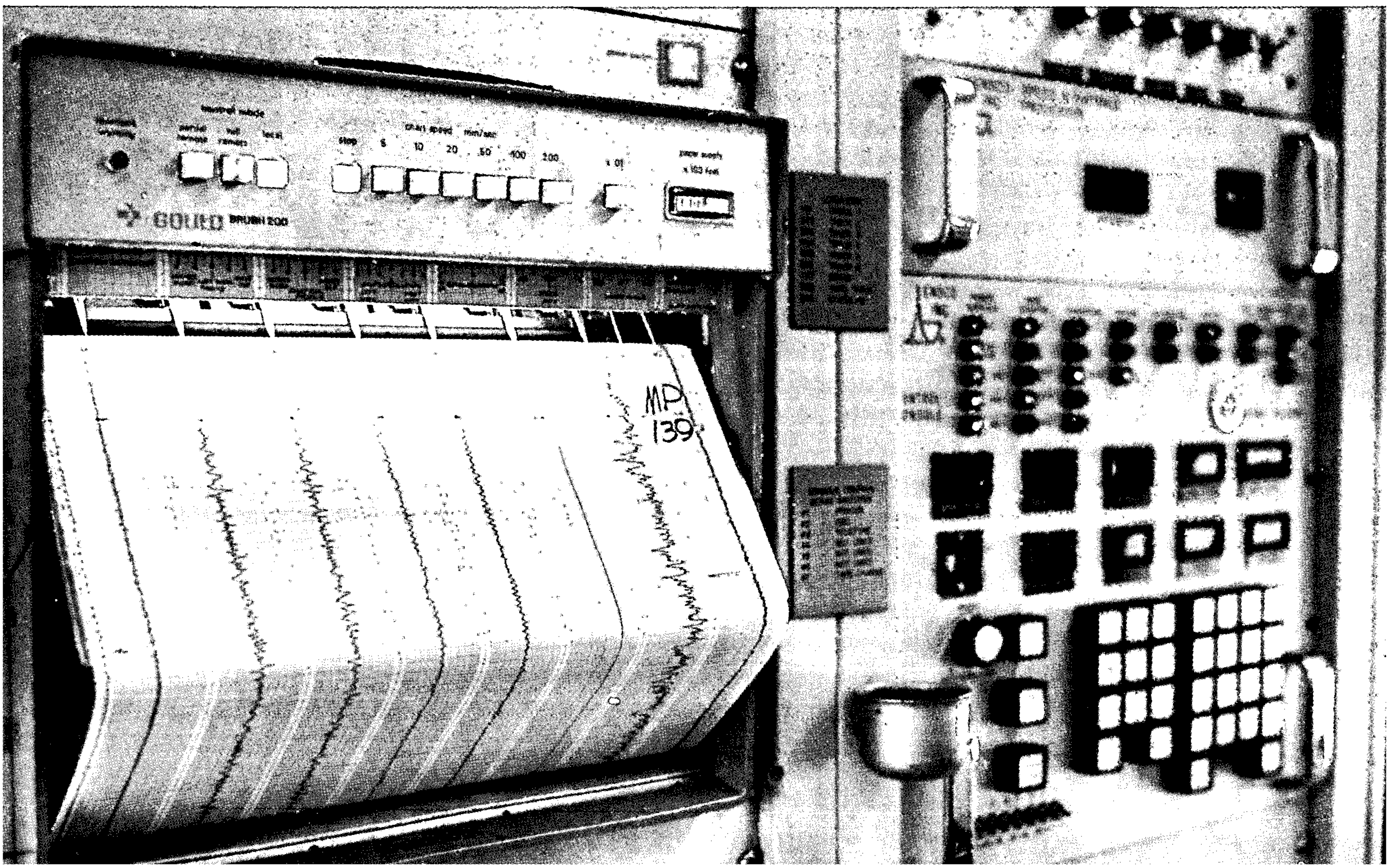


- Curvature — a measure of the angular change in track direction per 100-foot track chord.

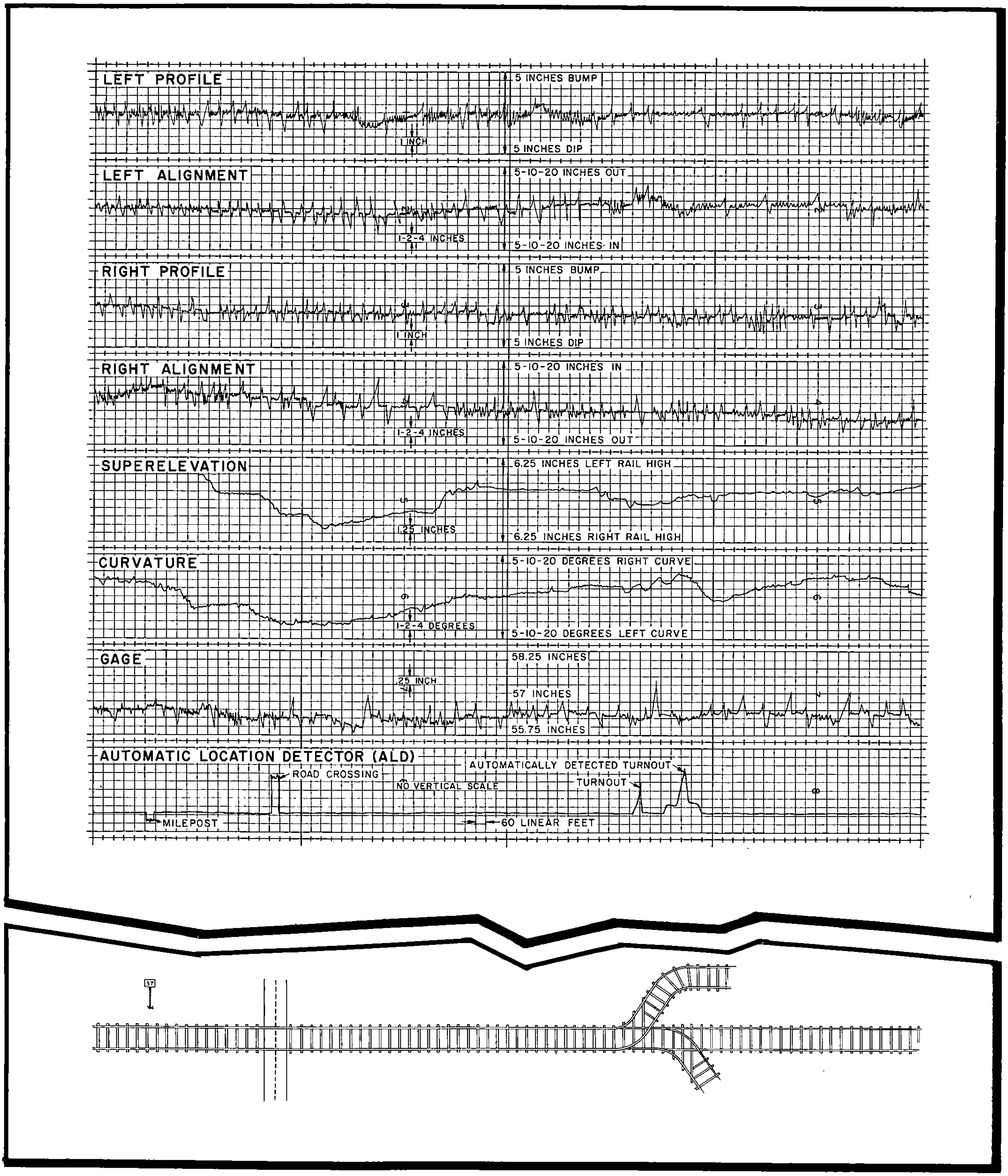


▲ DATA ACQUISITION DIGITAL COMPUTER SYSTEM

▼ TRACK GEOMETRY OSCILLOGRAPH

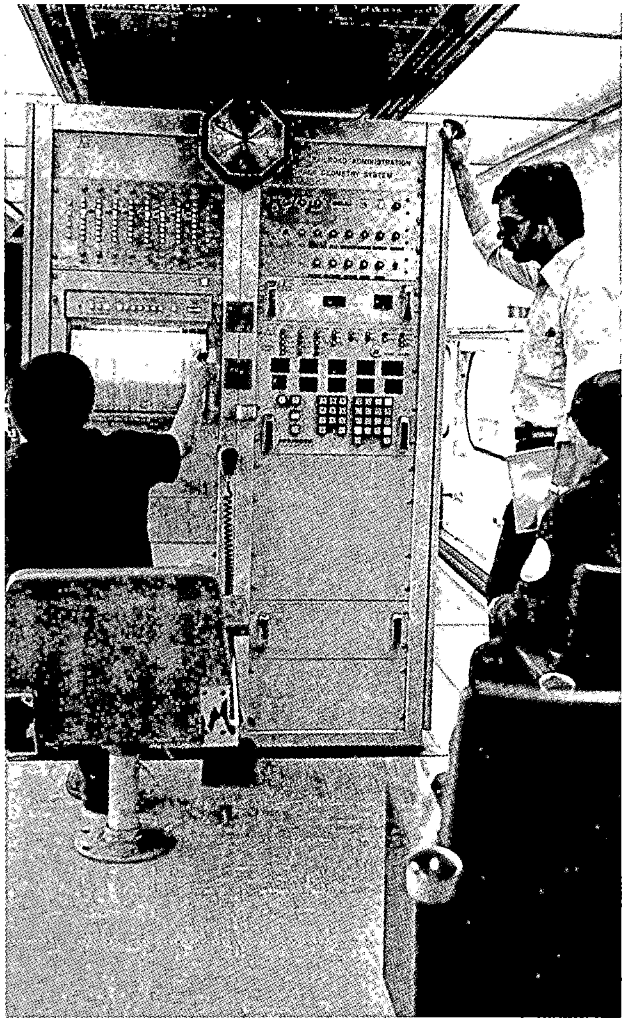


OSCILLOGRAPH RECORDING



An eight channel oscillograph display correlated to the track structures by the Automatic Location Detector (ALD) which automatically detects track structures (switches, road crossings, etc.) and utilizes manually entered data (mileposts, etc.).

PUTTING DATA TO USE

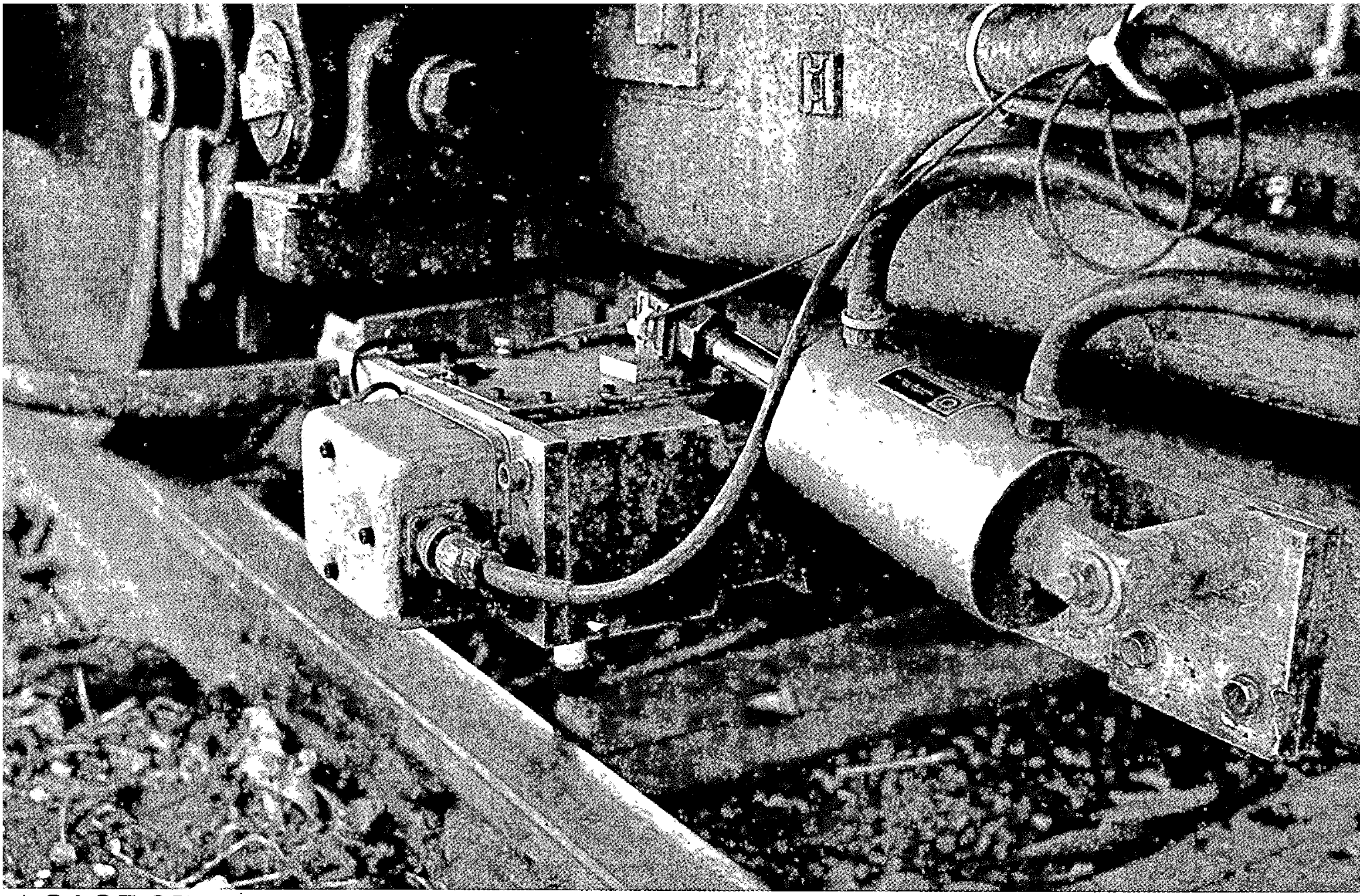


The track geometry data are simultaneously recorded on magnetic tape, displayed on an oscillograph for immediate viewing, and processed to produce the Track Safety Standards Exception Report.

This report documents the magnitude of any exceptions from the established Federal Track Safety Standards (FTSS) for profile, crosslevel, superelevation, warp, curvature, gage, and alignment. The detailed exception listings in this report provide FTSS information keyed to geographic location (i.e. distance from a milepost). The report is used as a tool by the Federal Track Safety Inspector to monitor compliance with Federal Track Safety Standards.

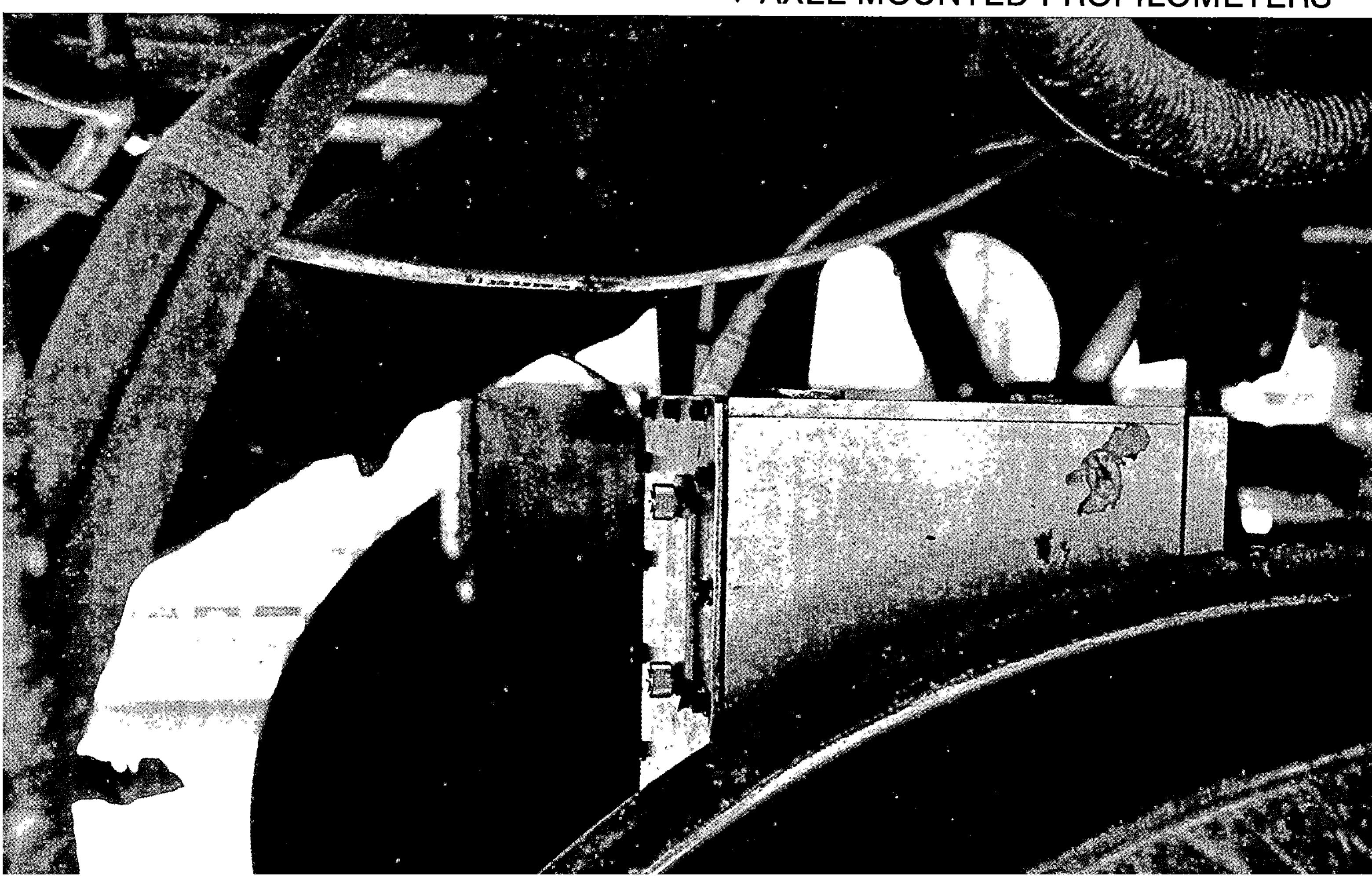
Railroad maintenance planners also use the Track Safety Standards Exceptions Report to pinpoint sections of track that will require maintenance, both short-range (days) and long-range (months), to identify the types of maintenance actions required at specific locations, to prepare work-crew schedules, to estimate future track maintenance work loads and to insure compliance with Federal Track Safety Standards.

Utilizing the data stored on the magnetic tapes additional analysis of the data is performed. This analysis will provide more detailed information on curves, curve limiting speeds, track structure locations, statistical tabulation of the number of exceptions per mile, and an overall mile-by-mile Class summary.



▲GAGE SENSOR SHOWN IN SURVEY POSITION

▼ AXLE-MOUNTED PROFILOMETERS



SURVEY VEHICLES

The five survey vehicles (designated T-1/T-3, T-2/T-4 and T-6) are self-contained measurement vehicles. One car in each pair (T-2 and T-3) is equipped with electronic sensing and data processing equipment, while the other car (T-4 and T-1) provides office space, equipment repair and crew support facilities. T-6 is a single car unit containing both data collection and processing equipment and all support facilities. These cars are a fast, efficient means of obtaining track geometry data to detect exceptions and to document areas of concern.

TABLE 1

DETAILED SURVEY VEHICLE SPECIFICATIONS

CARBODY			
T-1/T-3, T-2/T-4			
Length	Width	Height	Weight
85 feet	10 feet	14 feet	55 tons
T-6			
85 feet	10 feet	13 feet, 6 inches	80 tons

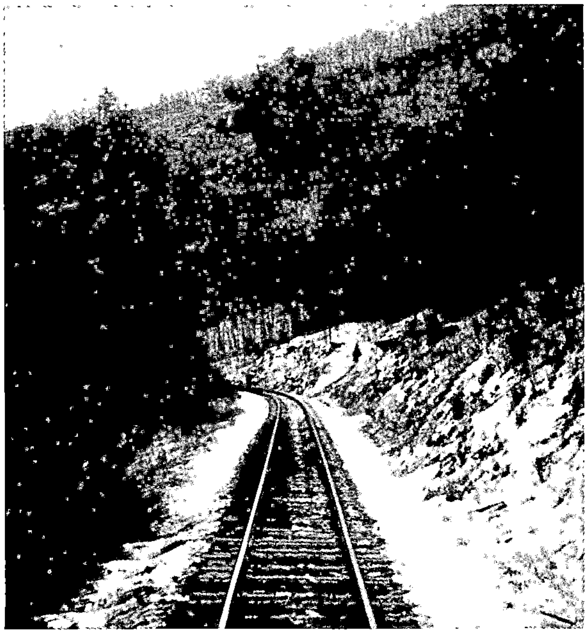
ELECTRICAL SYSTEM		
T-1/T-3	T-2/T-4	T-6
One 72 KW 220V/50 Hz Diesel Generator each car	One 60 KW 220V/60 Hz Diesel Generator each car	Two 33 KW 220V/60 Hz Diesel Generators

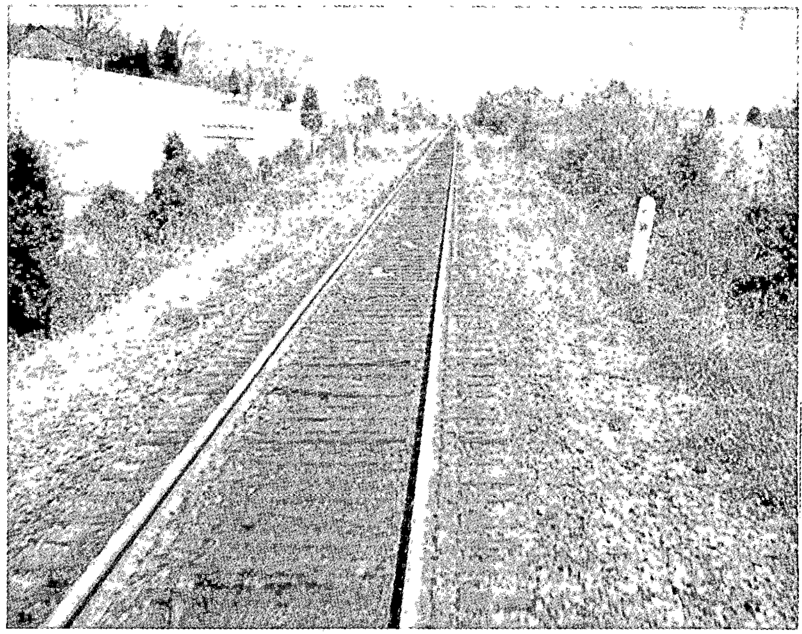
RAILWAY TRUCK			
T-1/T-3, T-2/T-4			
Center Plate Distance	Wheel Base	Wheel Diameter	Axle Loading
59.5 feet	8.5 feet	32 inches	13.5 tons
T-6			
59.5 feet	8.0 feet	36 inches	20.0 tons

TABLE 1 (Continued)

DETAILED SURVEY VEHICLE SPECIFICATIONS

COMMUNICATIONS		
Internal	Public address system links key positions throughout the test car consist.	
External	One train radio in each car; two-way VHF FM radios with master stations on T-2, T-3 and T-6; one radio-telephone in T-1, T-4 and T-6.	
TECHNICAL SPECIFICATIONS FOR TRACK GEOMETRY MEASUREMENT SYSTEM		
	Range of Measurement	Normal Setting Limits
GAGE	55.5-58.5 inches	55.75-58.25 inches
PROFILE (62 feet midchord offset)	±5.0 inches	0 ± 5.0 inches
ALIGNMENT (62 feet midchord offset)	± 20 inches	±1,5,10,20 inches
CROSSLEVEL (in superelevation)	± 10 inches	0 ± 6.25 inches
CURVATURE	± 20 degrees	±1,5,10,20 degrees
SPEED	0-120 mph	0-120 mph
OTHER PARAMETERS	Measurement speed: variable up to 120 mph Data sample interval: 1 foot Oscillograph scale: 17.32 inches equals 1 mile	





TRACK SAFETY STANDARDS EXCEPTION REPORT LISTING EXAMPLE

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TSS TRACK GEOMETRY EXCEPTION SECTION

T2-9027

TRACK NUMBER : 1 | POSTED TRACK CLASS : 3

TSS THRESHOLDS: PROFILE	ALIGNMENT	GAGE	XLEVEL	WARP	
2.250	1.750	57.50	1.750	1.750	----------TANGENT (T)
2.250	1.750	57.75	1.250	1.250	----------SPIRAL (S)
2.250	1.750	57.75	1.750	1.750	----------CURVE (C)

LOCATION		PROFILE				ALIGNMENT				GAGE		XLEVEL		WARP		EXCEPTION QUALIFICATION	
		S RAIL		N RAIL		S RAIL		N RAIL								TRACK(T/S/C)	LIMITING
MP	FEET	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	MAX	LEN	REFERENCE	CLASS
247	-00639									55.88	001					S	0
247	-02273									55.76	007					T	0
247	-03135									55.76	005					T	0
247	-04699									55.87	003					T	0
246	-01246									55.86	002					T	0
246	-05420	-2.48	003													T	2
246	-05944											-2.23	063			S	0
246	-11546									57.85	006					C	0
244	-01926	-2.76	005													T	1
244	-02362									57.65	006					T	1
244	-02721									55.84	004					T	0
244	-03048									55.88	002					T	0
244	-03167									55.82	009					T	0
243	-00154											2.20	024			T	1
243	-00234											2.70	077			T	1
243	-00264											2.23	026			T	1
243	-00419											1.44	062			S	2
243	-01749									--- SENSOR CYCLE		0022		FEET---			
243	-00513			-2.46	005											T	2
242	-00169											-1.94	007			T	2
242	-00204											-1.87	001			T	2
242	-00712											-1.88	001			T	2
242	-01046											-2.11	019			T	1
242	-01078	-2.50	001													T	2
242	-01097											-2.81	034			T	1

Requests for further information on the use of these systems, or additional data related to the data collection techniques described, should be addressed to the Associate Administrator for Safety, Federal Railroad Administration, 400 7th Street, SW, Washington, DC 20590.

DEPARTMENT OF TRANSPORTATION ★ UNITED STATES OF AMERICA ★