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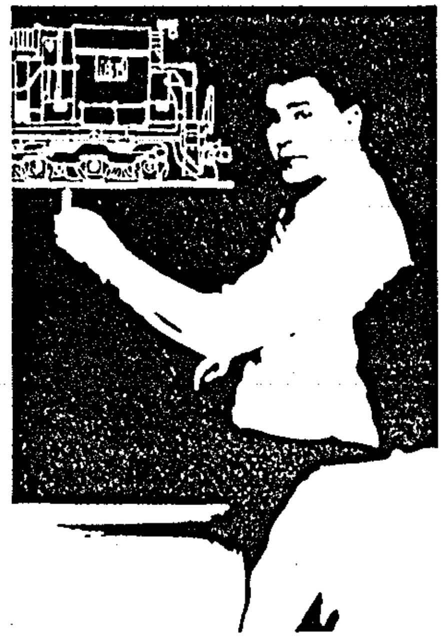

Accomplishments in the 70's, Goals for the 80's

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FUTURE DIRECTIONS IN TRACK EVALUATION AND INSPECTION

BY

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INTRODUCTION

Research, development and innovation in track evaluation and inspection techniques are very important and necessary, if improvements in track performance are to be made. This area represents one that will pay dividends to the railroad industry, both now and in the future. Although strong track does not always represent a strong railroad, a weak track structure does, in fact, represent a weak railroad, and seriously limits it's performance abilities.

Improvements in the performance of track, or the strength of track, have been sporadic, and, in general, late in coming. Many of our present day "improvements" had their origin in situations in which the existing technology was simply not adequate for the requirements of the day. Examples would include the advent of control-cooled rail in the 1930's, to overcome the problem of transverse fissures from hydrogen embrittlement, the development of welded rail to reduce jointed track problems, the development of thermite weld technology for the field welding of rails, the development of alloy and heat-treated rails to reduce the problem of rapid head wear, the refinement of bonding insulated joints to extend service life and the hardening of manganese steel, to provide a longer lasting insert frog structure. Very little has been accomplished in defining, quantitatively, the required strength or performance of track, and the partial vacuum in this area has been filled only by various improvements in the service lives of individual track components. To be sure, research work in the field of track structures has been undertaken, both in this country and in Europe, as, for example, Talbot's work on vertical track modulus in 1918 [1], the French National Railway's (SNCF) work in the late 1940's on their derailer wagon [2], and the U.S. Track Train Dynamics effort that began in 1972, which consolidated and expanded recent track-related research.

In the United States, it has only been in the last ten years that railroads began to take a serious look at measuring the geometric deficiences in their track by automated means (Figure 1). Even today, less than twelve Class I railroads own and operate their own track geometry cars. These cars measure the track irregularities, such as deviations in line, surface, gage and elevation, but not the strength of the track itself. These track geometry cars have probably been worth over one thousand times their initial cost to the railroads, because they have been extremely successful in finding track locations that are unsafe, and in need of repairs. To a lesser degree, they have been successful in the statistical evaluation of geometrical data to compare the relative qualities of long segments of track [3]. No definition or measurement of track strength, however, has been undertaken.

In this paper, the authors would like to discuss present work and future trends in techniques for the evaluation of track performance and strength.

VALUE OF TRACK STRENGTH MEASUREMENTS

Track must be maintained to certain minimum requirements, whether determined by the Federal Government or by the policies of the individual railroad, and this is inherent in any maintenance activity. The use of geometry cars in track maintenance has provided a more precise evaluation of the track, and called attention to deficiencies that need attention.

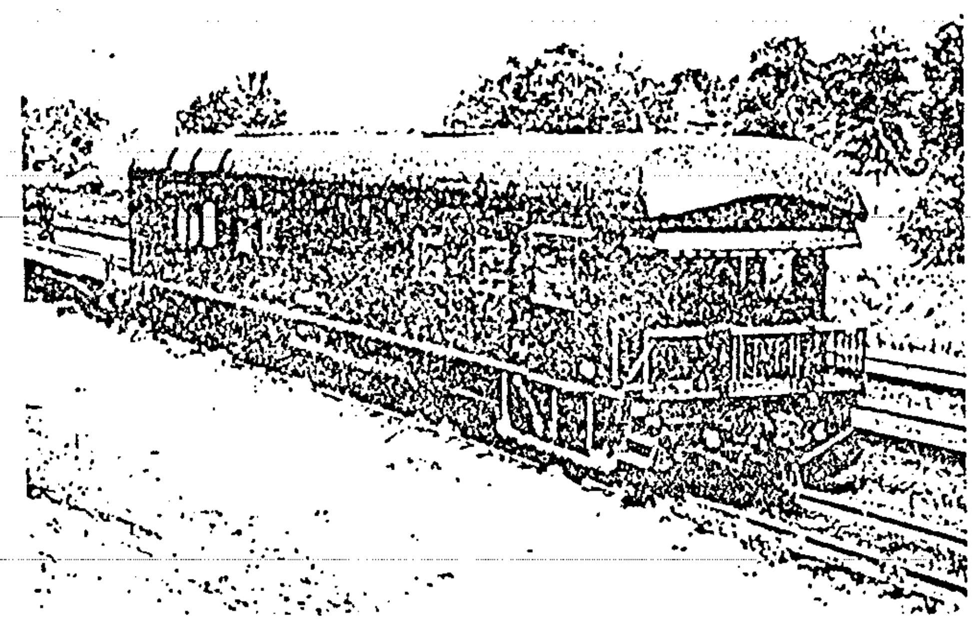

Figure 1. Southern Railway's Track Geometry Inspection Car.

Although these deficiencies or irregularities reduce the track's performance, the actual track performance or strength has not been measured. As an example, when a wide gage location is found, we know that the distance between the running rails has increased, but we do not necessarily know why it occurred, or what it indicates. Did it result from excessive tie plate cutting and loss of proper rail cant? Were the ties weak, which permitted the gage to open? Or, were the rails excessively curve worn? When a track geometry car detects a low joint, was it the result of battered rail ends, deteriorated ties, or perhaps, a ballast condition that could not adequately support the weight of traffic?

Not enough is known at this time to say, with certainty, that measurements of track strength or performance will add to our knowledge and abilities to maintain track. In fact, we do not yet know exactly how to make these measurements. It is reasonable, however, to believe that accurate and reliable track strength information will enhance our abilities to maintain safe track. Every time a heavily-loaded car negotiates a curve, or travels over a rail joint, it is testing the lateral and vertical strength of the track structure. Considering the limited capabilities of modern track geometry cars, which measure only physical track parameters, but cannot determine the track's ability to meet a given performance level, the existence of reliable track strength measurements would supplement this data, and better determine the true track conditions. An example of this dilemma is the fact that geometry cars routinely operate over thousands of track miles, but the railroads are still vulnerable to occurrences of buckled track, because there is not, as yet, any practical method for measuring it's buckling strength, or resistance to buckling.

CURRENT TRACK STRENGTH RESEARCH ACTIVITIES

Under the direction of Phase III of the Track-Train Dynamics Program, the Track Strength Characterization Committee was formed to coordinate and progress track strength research activities. This Committee was formed in December 1977 to investigate and further explore various issues that developed during the earlier Phase II work of TTD. The Committee has sixteen members, including railway and supply industry engineers, AAR research personnel, and representatives of the FRA and TSC. The Track Strength Committee has been working in cooperation with the AAR-FRA Ad Hoc Committee on Track Standards, to define the functional requirements of track. This Committee receives support from the AAR Technical Center, Transportation Systems Center, the AREA, the Engineering Division of the AAR, the Track-Train Dynamics Program, various individual railroads and suppliers, and the FRA.

The primary concern of railroad engineering departments is to provide a track structure, which is both safe and reliable, but at minimum cost. To attain this goal in maintaining track, it is essential to know the load bearing capacity of the track to support various vertical, lateral and longitudinal loads, imposed by train operations and environmental conditions.

It is very difficult to improve a track structure and to gain more stable, reliable and safer track, without a quantitative definition of *what factors* affect track strength, or *how to measure* these factors. As a better understanding of these track strength factors is obtained, the ability to provide safe and reliable track *at minimum cost* will increase.

The four overall objectives of the Track Strength Characterization program can be defined and illustrated in the following activities:

1. Determination of Factors that Influence Track Strength.
   This involves a definition of the parameters that influence track strength, i.e., the track's load-carrying capacity.

2. Measurement of the Parameters Affecting Track Strength.
   Once these various parameters have been established, their relative effects upon track strength can then be measured, so that their effects can be better understood.

3. Development of Practical Methods for Track Strength Determinations.
   Practical techniques and equipment must be developed to accurately determine track strength characteristics *in the field*. It does little good to measure track in a laboratory, if we are unable to measure the same parameters out in the real world.

4. Demonstration of the Benefits Derived From Quantifying Track Strength.
   This will include investigations and demonstrations of the benefits to be obtained from track strength measurements, such as:
   (a) an aid to maintenance planning.
   (b) inputs to traffic planning.
   (c) inputs for equipment design.
   (d) an aid in derailment prevention.

The Track Strength Characterization Committee is proceeding towards attaining their objectives by a combination of both laboratory and in-track field tests.

Tests in the AAR's new Track Laboratory in Chicago, Illinois have been underway since April 1978. These tests are being conducted to determine and evaluate both track modulus values [4], and track gage restraint characteristics [5], under various static loading and track conditions. A full range of vertical, lateral and longitudinal loads have been placed on a 39 foot long section of mainline track, and the resulting displacements measured. These tests are proving to be of considerable value in establishing a base line for track strength data (Figure 2). In addition to these laboratory tests, static load-deflection tests have been conducted in-track on two railroads, in order to further examine and confirm the behavior of track under static loading conditions [6,7].

In December 1978, a series of perturbed track tests were conducted at the Transportation Test Center in Pueblo, Colorado, for the purpose of evaluating locomotive response to various track irregularities. Extensive wayside measurements were made at locations where horizontal misalignments had been introduced into the track structure. By monitoring the equipment forces and associated track displacements at these particular locations, a significant insight into the force levels, imposed upon mainline track, was obtained. The evaluation of this data is still in progress.

In November 1978, a prototype gage-widening

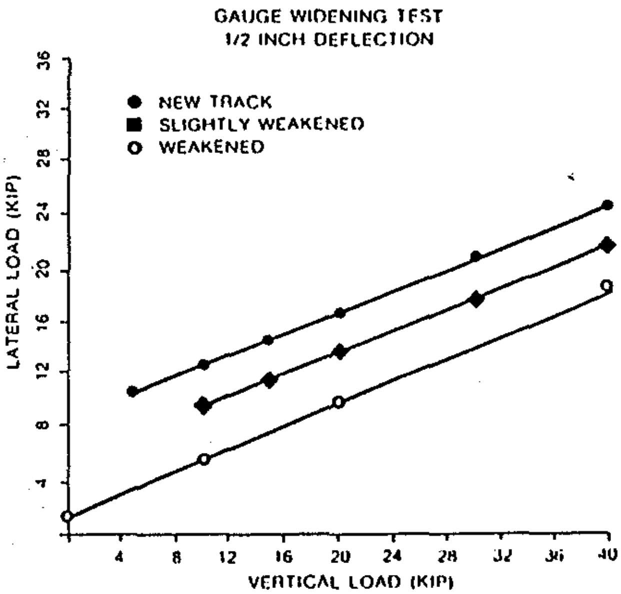

Figure 2.

Vertical Load Vs. Lateral Load, For 1/2 Inch Rail Head Deflection and Different Levels of Damaged Track.

device, designed by Mr. Gerald Magee, retired Assistant Vice President of Research for the AAR, was used to evaluate the concept of rolling a wheelset along the track, with a constant lateral force trying to spread the rails apart. The results from this unique test were most interesting, and showed the potential for measuring, simultaneously, both gage widening and lateral track strength [8].

Using FRA derailment data for the years 1977 and 1978, a review of derailments caused by buckled track is also being undertaken. A detailed summary is being made of the track, operating and environmental conditions that prevailed at the time of each derailment. With the help of several railroads' engineering departments, this data will be compiled and analyzed, in an attempt to determine those common characteristics that led to the buckled-track conditions.

Based upon the success of these initial laboratory and field tests, plans were then developed to further explore in-track testing methods, by use of an experimental vehicle, capable of applying static or dynamic gage-widening forces to the rails over which it is operated. A prototype test vehicle is now in the final stages of construction at Alexandria, Virginia, and will soon be field tested.

TRACK STRENGTH INSPECTIONS AND EVALUATIONS

The track strength measurement tools that are being developed will both supplement and complement current track geometry measurements. These track strength measurement devices may be installed on modern track geometry cars, with varying degrees of alteration, or used on dedicated "track strength" vehicles, which can be operated in conjunction with conventional geometry cars.

One method involves lateral track strength measurements, in which a predetermined lateral load, in conjunction with a fixed vertical load, is applied to each running rail in the track. By measuring the lateral load-rail head deflection relationships, a general evaluation of the gage-restraint characteristics of the track can be obtained, and it may also be possible to identify ties or fasteners in "poor" condition. By incorporating this measurement technique into the design of an appropriate vehicle, long stretches of track could be quickly inspected, without causing excessive interference with revenue traffic.

Preliminary investigations into the feasibility of this measurement technique were carried out at the AAR Technical Center in October 1978. These tests utilized a rail spreading apparatus, developed earlier at the AAR, and mounted under one end of a 50-ton capacity flat car (Figure 3). A hydraulic cylinder mounted between the rail-spreader's wheels exerted a uniform lateral load on each rail head, under fixed vertical load conditions. By monitoring the cylinder pressure, i.e., the lateral load, and the corresponding rail head deflections, the gage-restraining "strength" of the track could be measured. Furthermore, as shown in a typical data record in Figure 4, it appeared that the observed cylinder pressure variations coincided with the passage of the rail-spreading wheels over ties and/or fasteners in various conditions. More specifically, when the vehicle encountered a tie in "fair" or "poor" condition, a decrease in cylinder pressure was recorded. In addition, by monitoring the corresponding rail head displacements, individual rail support information could also be obtained. Finally, it should be noted that, although significant dynamic gage widening was observed under the test vehicle, the nominal track gage, when the load was removed, was quite "reasonable." Thus, the development of this type of non-destructive tie and fastener inspection technique was shown to be feasible, at least from a mechanistic viewpoint.

Another application of this lateral strength measurement technique would involve the detection of weakened shoulder and crib conditions, by applying a net lateral force to the track structure in the appropriate direction, and measuring the corresponding lateral displacement. Such a technique was originally developed by the French National Railway in the mid-1950's and 1960's [2,9], and has recently been extended by British Rail, with the development of their "Decapod" test car [10].

Still another related track strength technique involves the continuous measurement of the vertical track modulus, which represents the vertical strength of the track structure. This measurement, which was applied to U.S. trackage as early as 1918 [1], has only recently been attempted by use of a moving vehicle [11]. The preliminary test results appear to show good correlations between the observed variations in track stiffness, i.e., modulus, and the actual track structure and subgrade conditions.

COMPLEMENTARY INSPECTION TECHNIQUES

In addition to research activities directed towards track strength measurements, other work is concerned with the development of track inspection and evaluation techniques that can complement existing geometry and strength measurements.

One such area involves the simultaneous measurements of rail temperature and the associated longitudinal rail forces. The detection and prevention of track buckling, or rail pull-aparts, is a major track problem, because these failures often occur without warning. This is caused by the build-up of

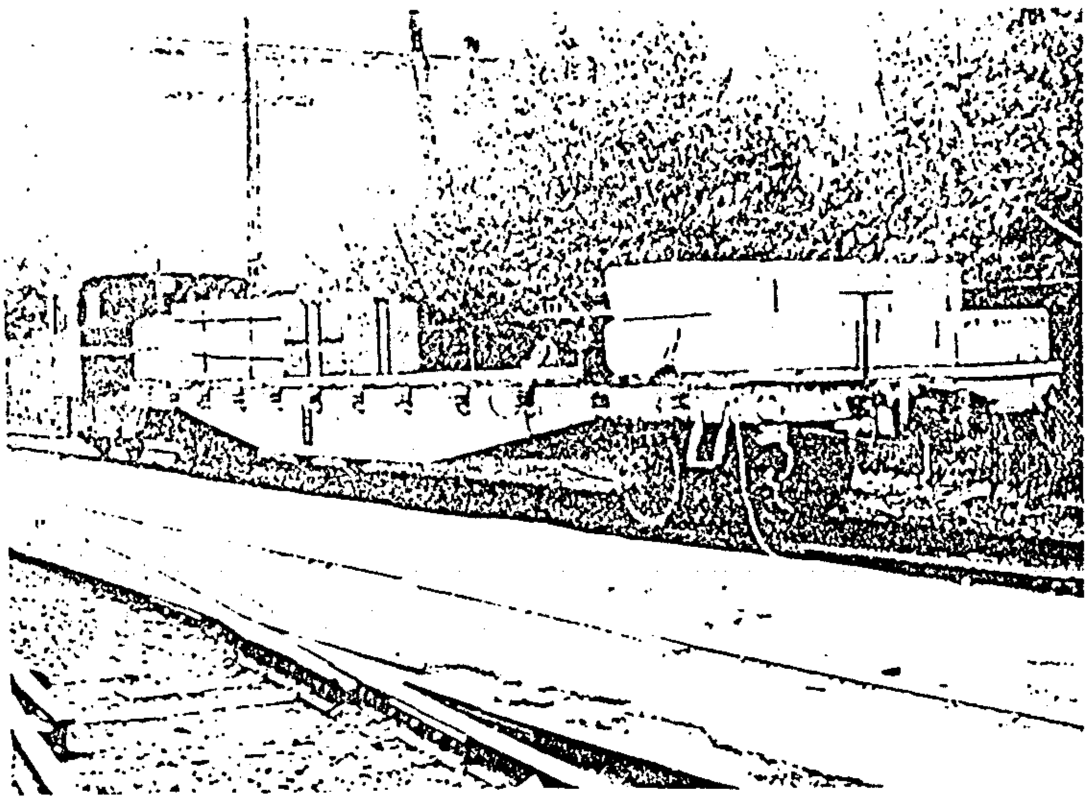

Figure 3. AAR's Test Vehicle With Rail Spreading Device

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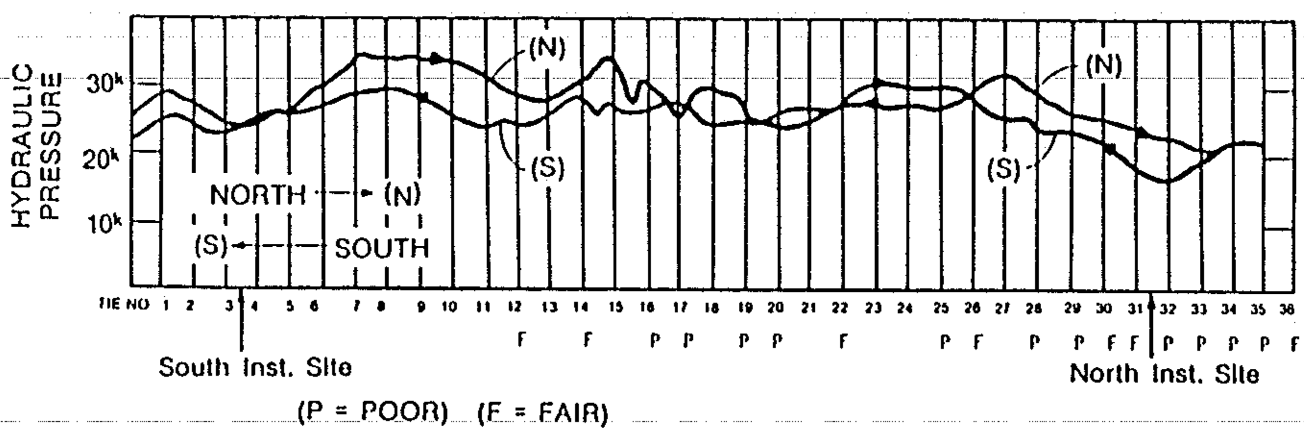

Figure 4. Typical Test Data Obtained During Track Tests with the A.A.R.'s Rail-Spreading Test Vehicle.

potentially dangerous longitudinal rail forces in track that is in good condition, especially continuously welded rail track, where the problem will not be evident until it reaches a magnitude where sudden track failure occurs. Furthermore, the performance of maintenance activities, at those times when the potential for failures are greatest, such as during periods of very hot weather, contributes significantly to the possibility for track failure. This potential for sudden failure, combined with the fact that the force-free state* of the track changes with time and traffic conditions, all point to the need for a suitable longitudinal force monitoring technique [12].

Current research activities, under the sponsorship of both the AAR and the TTD's Track Strength Program, have been directed towards the development of nondestructive measurement techniques and instrumentation that can be mounted on an inspection vehicle, to provide continuous measurements of longitudinal in-track forces. In conjunction with these research activities, three field and laboratory tests were conducted, using different measurement techniques.

In January 1979, a test was conducted on Chessie System trackage near Grafton, Ohio, using a portable X-ray diffraction unit, shown in Figure 5, to measure rail stresses. A hydraulic rail puller was used to vary the longitudinal rail forces, in order to determine if the X-ray unit could monitor them. The preliminary test results indicated that the existence of residual stresses at the surface of the rail, where the X-ray unit was also located, introduced significant measurement problems.

A second test was conducted at the AAR's Track Laboratory in Chicago, Illinois in January 1979. A hydraulic rail puller was used to vary the longitudinal rail forces, as shown in Figure 6, while a lateral impact load was applied to the rail head, and the corresponding rail response measured. The preliminary test results indicated that the dynamic lateral response of the rail was affected by the presence of the longitudinal load, as shown in Figure 7. A second series of tests were conducted in the Fall of 1979, and additional work is continuing in this area.

In June 1979, a third series of tests were conducted on the Santa Fe Railroad near San Bernardino, California. In this test series, the ability of a magneto-mechanical acoustic emission technique to monitor rail forces was investigated, as shown in Figure 8, using a recently-laid section of track, where the laying temperature was well documented. The natural temperature variations, during one day of testing activities, created the longitudinal force variations that were measured. The preliminary test results indicated that this method may be able to monitor rail forces, and additional work using this technique is being planned.

There are presently available various types of infrared camera systems that could be mounted on an inspection vehicle to provide continuous measurements of ambient rail temperature. These camera

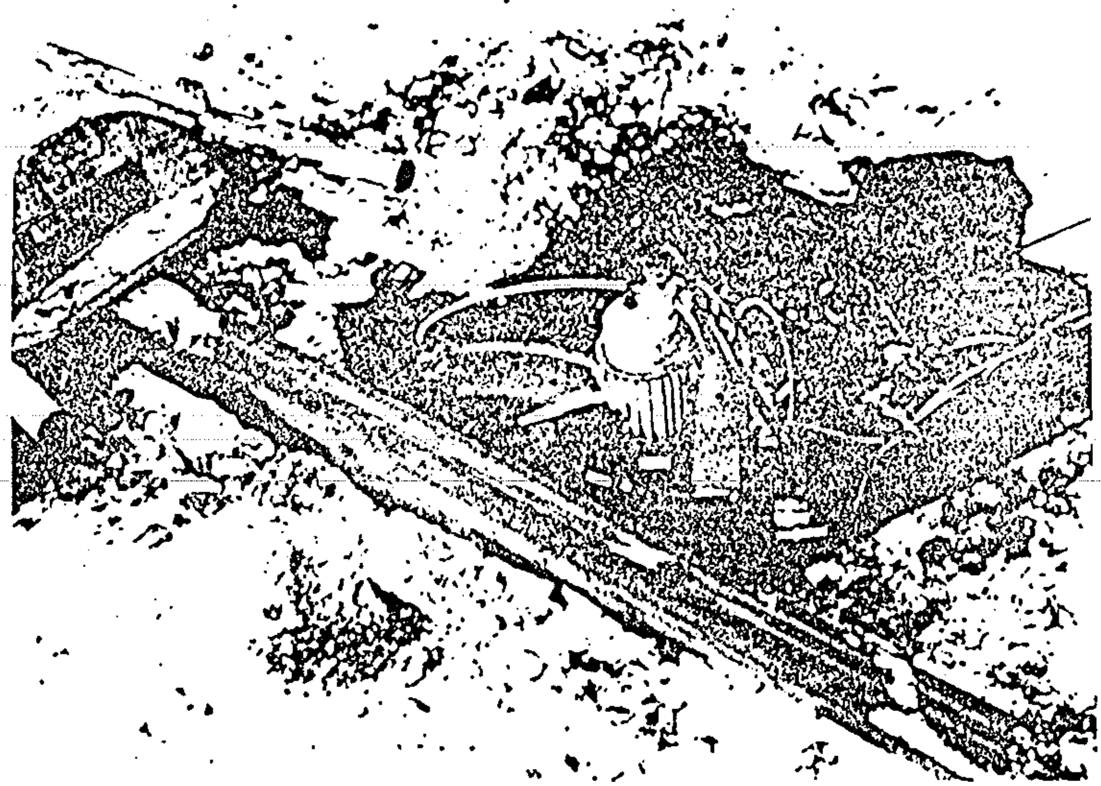

Figure 5.

Portable X-ray Diffraction Unit During Chessie System Tests of Longitudinal Rail Forces, Near Grafton, Ohio.

* A force-free state exists when there are no thermally-induced longitudinal stresses in a rail.

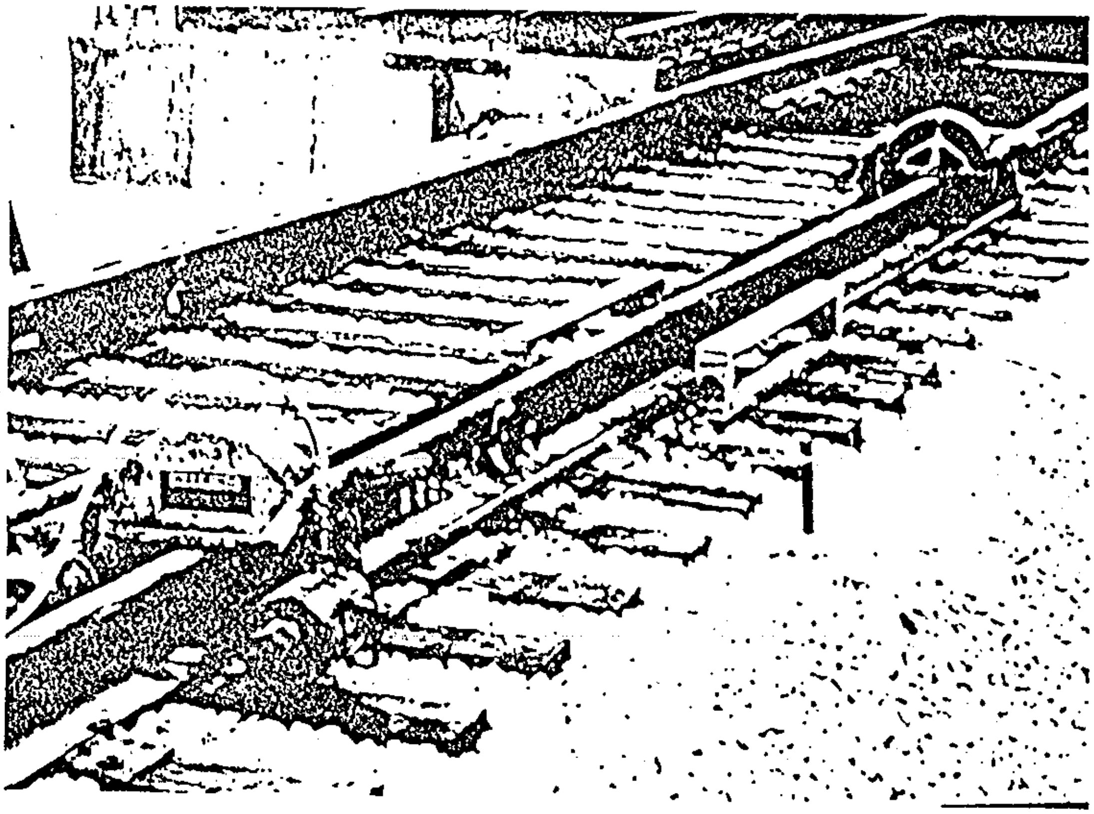

Figure 6.

Hydraulic Rail-Puller Used to Produce Various Longitudinal Rail Forces During AAR Track Laboratory Tests.

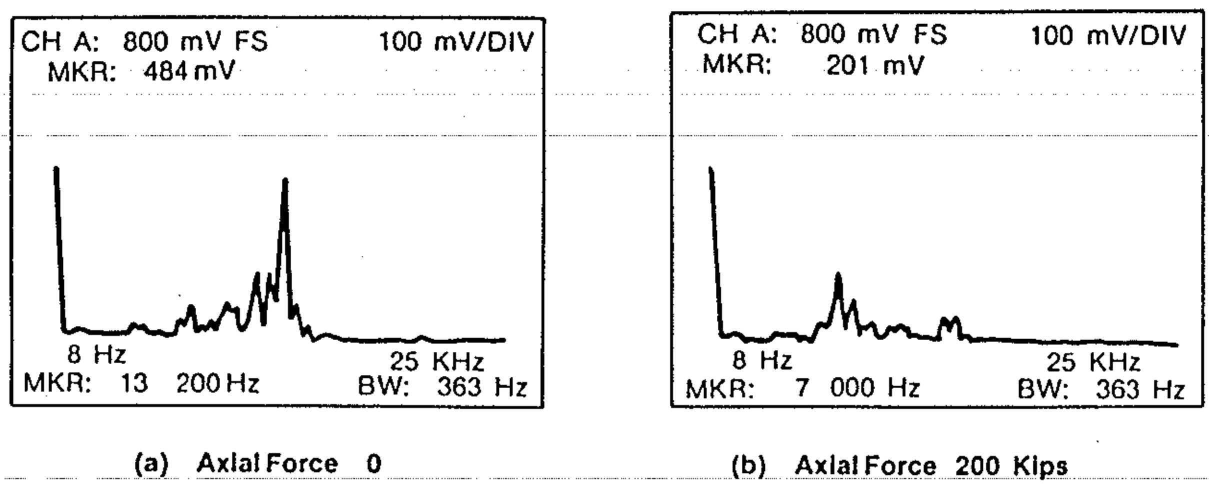

Figure 7.

Frequency Spectra Showing the Dynamic Response of a Rail Head to a Lateral Impact Force, in the Absence and Presence of a 200 Kip Longitudinal Rail Load. AAR Track Laboratory Tests.

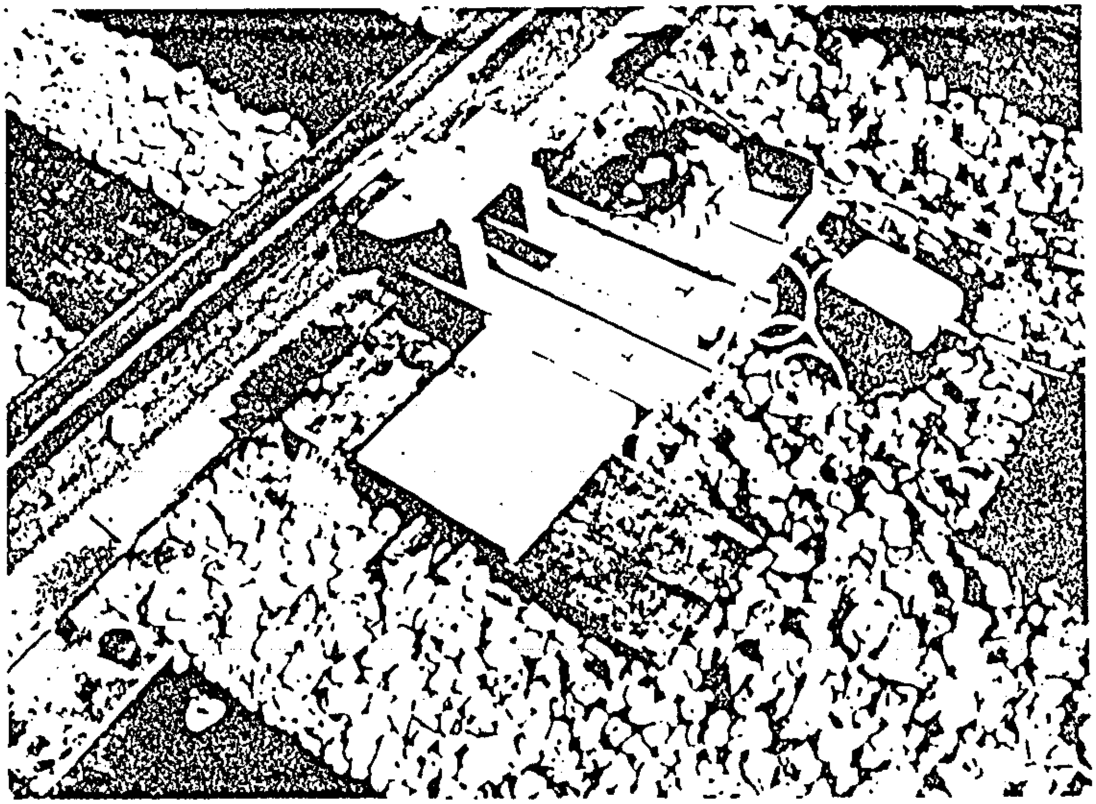

Figure 8.

Magneto-Mechanical Acoustic Emission Transducer, Installed on Santa Fe Railroad Trackage Near San Bernardino, California.

systems, if combined with a suitable longitudinal force measurement device, could provide the track engineer with a continuous readout of the force-free temperature of the rail, thus providing him with a more objective basis for planning maintenance activities during the "buckling season," and warning him of potentially dangerous locations for track buckling, or rail pull-aparts.

Still another track inspection tool being developed is a ground-penetrating radar system for inspecting the ballast, subballast and subgrade. This system, using swept frequency or pulse radar techniques, could be used to detect water pockets, fouled ballast, cemented ballast, or other types of railway embankment problems. In addition, it could also be used for subsurface profiling of the various embankment layers.

Preliminary investigations and testing activities at the U.S. Corps of Engineers' Waterways Experiment Station [13], and at the University of Missouri - Rolla [14], have shown that such subsurface inspection systems are feasible, and represent the state-of-the-art in this area. Consequently, work is presently underway to construct a prototype ground-penetrating radar system, and field testing is being planned to verify and evaluate its use.

FUTURE RESEARCH ACTIVITIES

Several distinct activities, aimed at developing these track inspection capabilities, are currently planned, or underway, under the direction of various research programs, such as the TTD's Track Strength Program.

In order to build upon the lateral track strength measurement experience, obtained during the preliminary AAR rail-spreader tests, a new track strength measurement test vehicle, shown diagrammatically in Figure 9, is being constructed at the Southern Railway's Research and Test Laboratory in Alexandria, Virginia. This vehicle will be capable of independently applying various lateral and vertical loads to each running rail, while the vehicle is in motion. Measurements of the track gage, under both loaded and unloaded conditions, will permit a real-time analysis of the track's resistance to gage widening, and the subsequent evaluation of the "strength" of the track. The on-board hydraulic system can also be operated to apply a net lateral load to the track, which can be used to determine its resistance to lateral shift.

A comprehensive series of tests, using this new vehicle, is planned for late 1979 [15], with the following objectives.

a) To evaluate the feasibility of continuous track strength measurements, by measuring individual rail head displacements and the total gage widening.
b) To compare these dynamic field measurement data with similar data, obtained from laboratory and static field tests.
c) To evaluate the feasibility of detecting defective ties, or loose/inadequate fasteners.

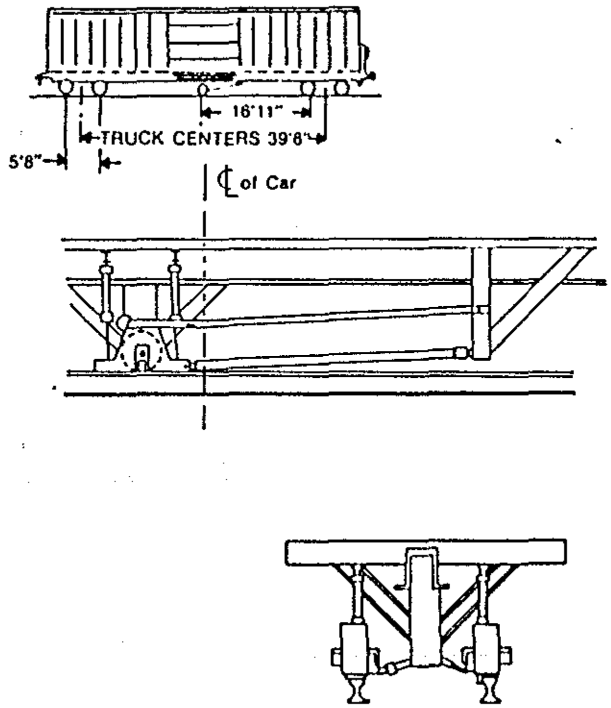

Figure 9.

Schematic Drawing of TTD/AAR Prototype Track Strength Measurement Test Vehicle and Associated Hydraulic Lateral Rail-Loading Apparatus.

To achieve these objectives, a section of mainline track, that has been scheduled for tie and surface work, will be tested both prior to, and after completion of, the maintenance activities.

Subsequent tests will examine the effects of track curvature, various fastener configurations and track deterioration, resulting from traffic. A similar test program, involving lateral track shift measurements, has been planned to follow the gage-widening tests.

In conjunction with these field tests, a new series of laboratory tests are planned for the AAR's Track Laboratory. These tests, which will be directed towards gage widening, vertical track deflections, lateral track shift and longitudinal track resistance measurements, are intended to provide data that will be complementary to the data from the field testing programs. Thus, a better understanding of track structure failure mechanisms, and the track's response to various loading conditions, will help to define the scope and limitations of these in-track inspection techniques.

Further research activities are also planned in the area of nondestructive measurements of longitudinal rail forces. Additional laboratory testing of the rail vibration technique, described earlier, and additional investigations of the magneto-mechanical acoustic emission technique will be directly aimed at developing practical rail force measurement systems.

Finally, in the area of subsurface radar investigations, the Track Strength Group, working with the U.S. Corps of Engineers' Waterways Experiment Station, are planning a series of system evaluation tests on track with known subsurface problems. The objective here is also to develop a practical track inspection system.

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