TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

IDEA Innovations Deserving Exploratory Analysis Project

TRANSIT COOPERATIVE RESEARCH PROGRAM

OPERATIONAL TESTING OF INTELLIGENT RAIL LUBRICATION SYSTEM

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Tranergy Corp., Bensenville, IL

Report of Investigation

IDEA PROJECT FINAL REPORT
Contract TRANSIT-24

IDEA Program
Transportation Research Board
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INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS MANAGED BY THE TRANSPORTATION RESEARCH BOARD (TRB)

This investigation was completed as part of the TRANSIT-IDEA Project, which is one of four IDEA programs managed by the Transportation Research Board (TRB) to foster innovations in surface transportation. It focuses on products and results for transit practice in support of the Transit Cooperative Research Program (TCRP). The other three IDEA programs areas are: ITS-IDEA, which focuses on products and results for the development and deployment of intelligent transportation systems (ITS), in support of the U.S. Department of Transportation's national ITS program plan; NCHRP-IDEA, which focuses on products and results for highway construction, operation, and maintenance in support of the National Cooperative Highway Research Program (NCHRP); and HSR-IDEA, which focuses on products and results for high speed railroads in support of the Federal Railroad Administration. The four IDEA program areas are integrated to achieve the development and testing of nontraditional and innovative concepts, methods, and technologies, including conversion technologies from the defense, aerospace, computer, and communication sectors that are new to highway, transit, intelligent, and intermodal surface transportation systems.

I INTRODUCTION

Project Transit 24 is very important for commuter rail, transit and high speed rail, in improving both the performance and safety. It is really disappointing that the project (Transit 24) funding is stopped after completion of Stage 1. Considerable initial effort has gone in completion of this important first stage. Interactions and agreements of work and designs suitable to Metra and Amtrak, actual designs and construction of the first system was undertaken and completed. Formation of the project review committee consisting of Metra, Amtrak and TRB engineers was another significant task that was accomplished. At this juncture the project funding is canceled/terminated. It is very disappointing that so much effort is to no avail.

The work on Stage I of this project has been completed. It includes the following activities:

Field Survey on Lubrication Needs.

Meetings with METRA to determine their needs.

Discussions with AMTRAK for their participation in the project including high speed rail.

Project Committee.

Design upgrade of SENTRAEN 2000™ for AMTRAK and METRA use and optimization of features.

Fabrication of SENTRAEN 2000™ T, ITS-controlled lubrication delivery system.

These are discussed individually below:

II FIELD SURVEY ON LUBRICATION NEEDS

Nine different systems including AMTRAK were contacted to determine their current practices/use of rail wheel lubrication. These were:

AMTRAK

Greater Cleveland Regional Transit Authority

Maryland Department of transportation , Mass Transit Administration (MTA)

Massachusetts Bay Transportation Authority (MBTA)

Metro-Dade County Transportation Administration

New Jersey transit Corporation

Niagara Frontier Transportation Authority

South Eastern Pennsylvania Transportation Authority (SEPTA)

Washington Metropolitan Area Transit Authority

Amtrak operates over the tracks of other carriers, except in the North East corridor. Way side grease applicators are used on curves of the freight railroad tracks. Amtrak trains get the benefit of these wayside lubricators. They do not use any onboard lubricators, including on the North East Corridor.

Out of all the systems contacted, two do not use any form of rail lubrication, three use wayside lubricators and several are using or trying out the use of stick lubricators mounted on trucks. No system to date are using an intelligent, computer controlled lubrication system.

Details of the survey of the various systems are given in Appendix I.

III MEETING WITH METRA TO DETERMINE THEIR NEEDS

A meeting was held to discuss the above project and to determine what will be suitable for METRA for the adaptation of SENTRAEN 2000™ to a METRA train.

Present: **Tranergy**

Sud Kumar, Principal Investigator

METRA

Bill Tupper - Department Head, Engineering

Bill Archer - Director, Engineering Department

Rich Soukup - Chief Mechanical Officer.

After some discussion, it was resolved that the SENTRAEN 2000T™ unit adapted to commuter passenger system should have the following characteristics:

Computer control of lubrication should:

- Apply lube to the rail gage side
- Apply lube on the high rail on curves
- Increase the application rate as speed increases
- Be able to compute flow for an average number of cars
- Control lube flow rate such that it is not affected much by lube temperature
- Increase the rate of lubrication for sharper curves
- Apply lubricant from the nozzles of both the short and the long hoods of the locomotive

to permit locomotive wheel flange lubrication when it is moving in either direction.

- Apply a water based environmentally safe clean lubricant which has no solids such as graphite or Molybdenum Disulphide.

Discussions were also held about the specific parameters to be measured for the determination of benefits. These are:

- Friction coefficient on the high rail gage side

  This will be measured with a tribometer on the rail gage side...

  before the lube train,

  after the lube train,

  after the 2nd train,

  after the 3rd train, -- and so on --

  until the friction coefficient on the rail gage side nearly equals the value of friction for the dry rail.

- Electrical energy used by the locomotive for operation with and without the lube system for the same train. The locomotive will be wired for measurement of volts and amps being used for a certain trip. Data files will be saved to determine the KWHrs used.
- Wear particles will be collected by a specially designed magnetic device mounted on the rail both for dry rail conditions and for a limited number of trains after the lube train has passed. A comparison of the weights of these wear particles will give us a comparison of rail wheel wear for trains running with and without lube.
- Wheel profiles of the locomotive wheel will be taken at a three month interval for operation with and without lube to compare the effect of lube on wheel wear/profile degradation.

IV DISCUSSIONS WITH AMTRAK FOR THEIR PARTICIPATION IN THE PROJECT INCLUDING HIGH SPEED RAIL

Discussions were held with:

Mr. Terrence Brunner

Assistant Chief Mechanical Officer

Locomotive/Mechanical Services - NEC

AMTRAK,

Philadelphia, PA 19104

Mr. Brunner is familiar with the testing and progress of SENTRAEN 2000™, the Intelligent Rail Lubrication System of Tranergy developed for freight railroad through a Locomotive Maintenance Officers Association (LMOA) Committee on advancements. The LMOA reviewed the progress of this system for a year at the end of which a paper was presented at a 1996 LMOA annual meeting. Mr. Brunner participated in that review. Mr. Brunner is very interested in the system because of the high wear that develops in Amtrak locomotive wheels used in the North east Corridor. He would like to see the SENTRAEN 2000T developed and tested so that Amtrak can take advantage of it. He recommended participation of Mr. Ron Cless, General Manager Locomotives Amtrak Chicago, in the project via membership in the panel. Mr. Brunner wants to follow the project progress through the reports and attend the meetings when he can.

V PROJECT COMMITTEE

After discussions with Metra and Amtrak the following project committee was formed:

1. Dr. Selwyn Berg, Technical Project Advisor from IDEA Program
2. Rich Soukup, Chief Mechanical Officer of Metra
3. James Stinson, Director Mechanical, Milwaukee Line, Metra
4. Bill Tupper, Director of Engineering Department, Metra
5. Von Schuster, Asst Chief Engineer, Milwaukee Line, Metra
6. Ron Cless, General Mnager Locomotives, Amtrak - Chicago
7. Terrence Brunner, Asst Chief Mechanical Officer Amtrak - Philadelphia

Amtrak will normally be represented by Mr. Ron Cless in project meetings. Mr. Brunner would like to receive reports of the project and will attend when he cad.

VI DESIGN UPGRADE OF SENTRAEN 2000™ FOR METRA & AMTRAK

The SENTRAEN 2000™ system developed for the freight railroads needs adaptation for passenger service. The requirements for passenger service were determined and are given in Section III. To satisfy these requirements not only the hydraulic hardware needed to be changed, the controlling computer also needed to be changed.

The computer used in the freight application SENTRAEN 2000™ is a Motorola CPU #332

which has 32 bit logic. It was needed because of extra complexity required for switching in handling direction of travel issues. The computer is designed to handle lubrication from either the short or the long hood end of the locomotive automatically in the train consist. The electronics circuitry needed is therefore considerably increased and so is the expense.

For Metra/Amtrak application use of a single ended unit will be satisfactory. It can also be simpler and less expensive. A computer design based on a Motorola CPU processor #68HC11, which is an eight bit processor, was designed and developed. Figure 1 shows the block diagram of the computer for this project. A description of the new single ended Tranergy controller is given below.

VII FABRICATION OF SENTRAEN 2000T, ITS-CONTROLLED LUBRICATION DELIVERY SYSTEM

The SENTRAEN 2000T unit suitable for Metra/Amtrak trains designed above has been built. Photographs of some of the key components of the system are shown in Figures 2, 3 and 4. Figure 2 shows the Motorola HC11 chip based new computer/controller for the unit. Figure 3 shows the communication keypad for the computer and Figure 4 shows the hydraulic controller box. Software for the lube application has also been written.

VIII IMPORTANCE OF THIS RESEARCH FOR HIGH SPEED RAIL

The system developed in this research project has important implications in the improvement of performance and safety of high speed rail in the following areas:

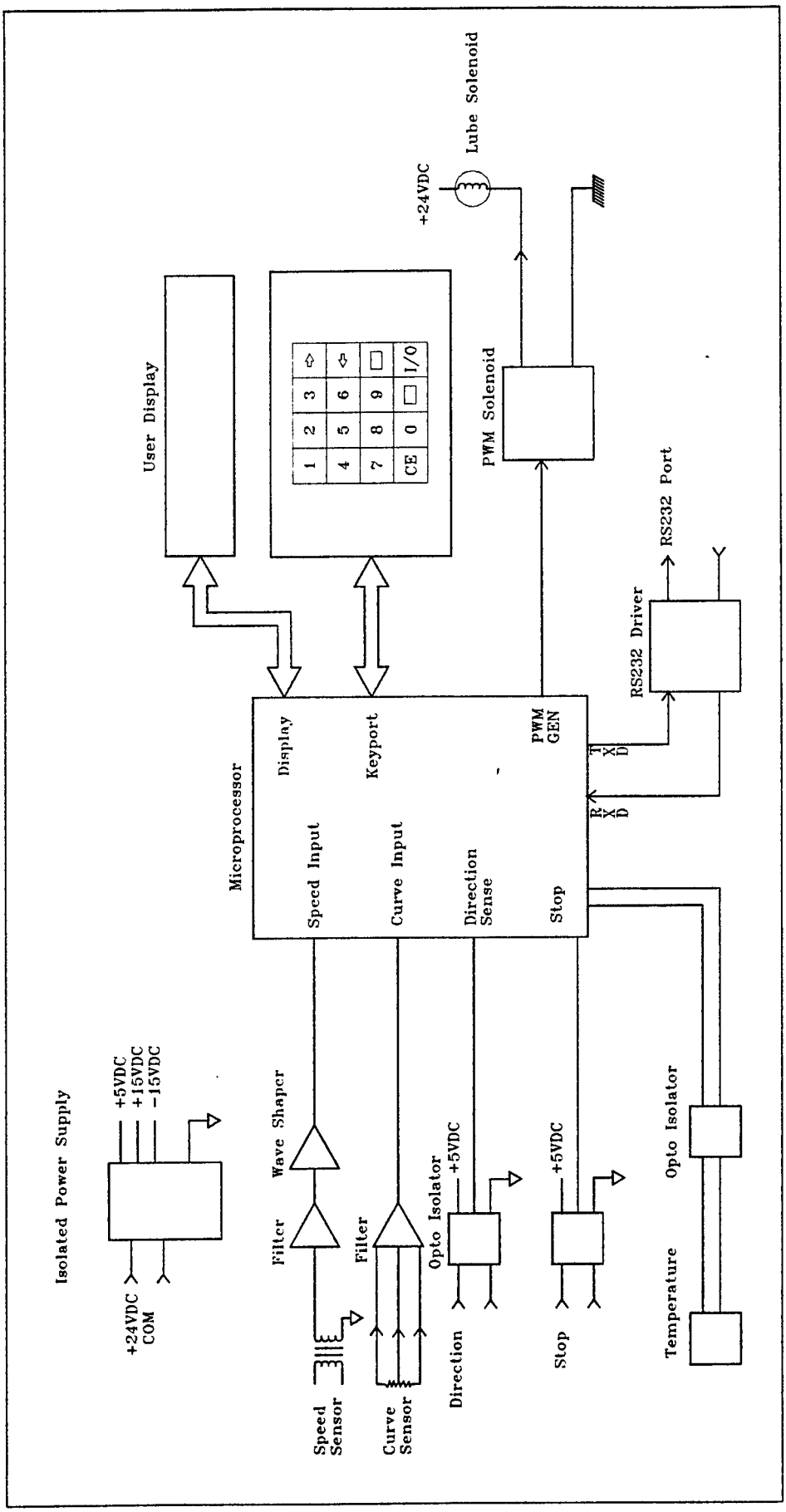
1) Reduction of wheel flange and rail gage side wear.
2) Reduction of energy consumption by reducing the train resistance.
3) Enabling higher speeds by increasing the threshold speed of hunting of trains at higher speeds.
4) Improvement of safety by reducing the lateral creep forces produced on wheels and simultaneously increasing the hunting speed as in 3) above.

Hunting of trains is a major limiting factor in restricting achievement of higher speeds. The theoretical basis for this is given in the appendix II titled "Excessive Lateral Creep Force also Produces Early Hunting:.

FIGURE 1

BLOCK DIAGRAM

COMPUTER FOR TRB/METRA RAIL LUBRICATION SYSTEM



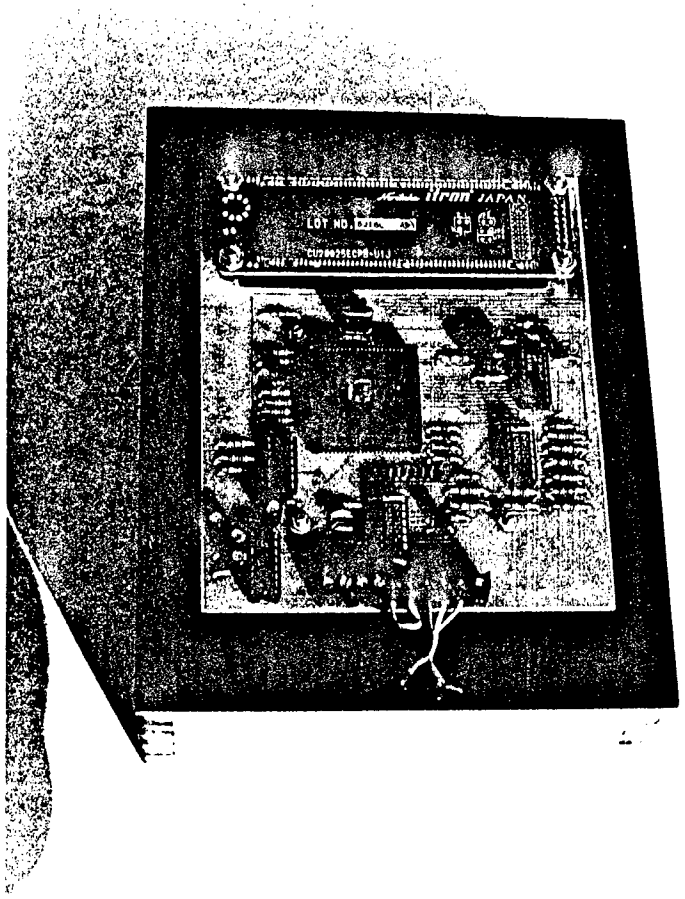


Fig.2. Computer/Controller for SENTRAEN 2000T

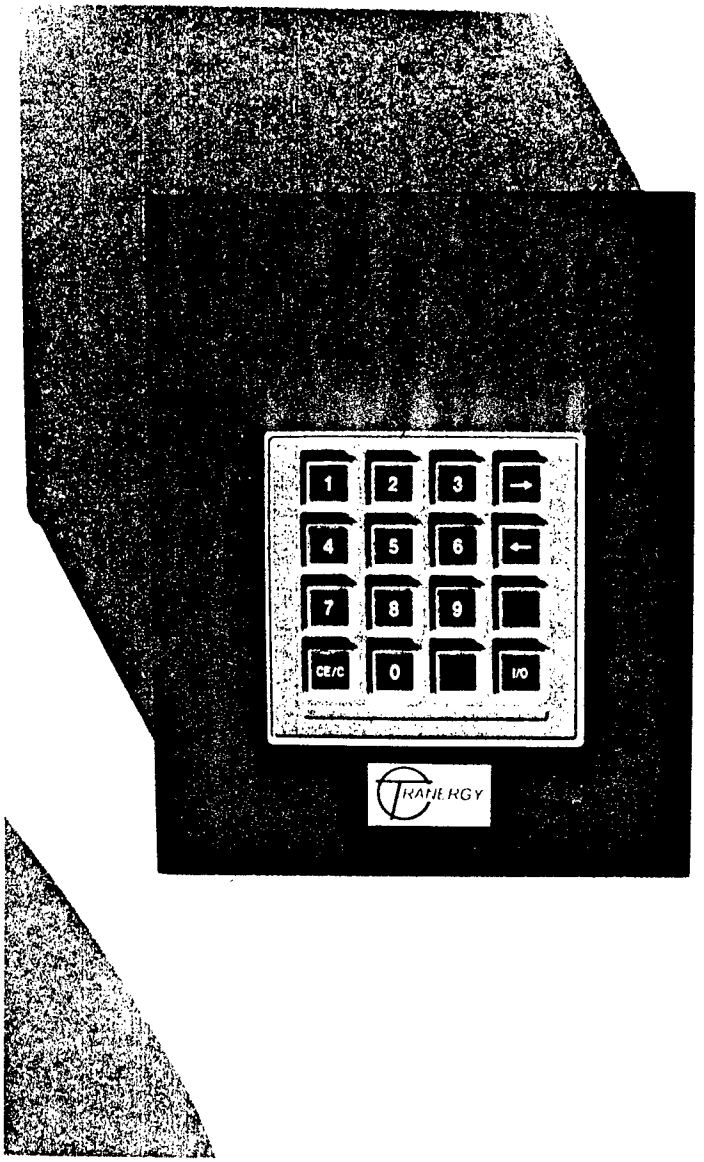


Fig.3. Communication Keypad for SENTRAEN 2000T

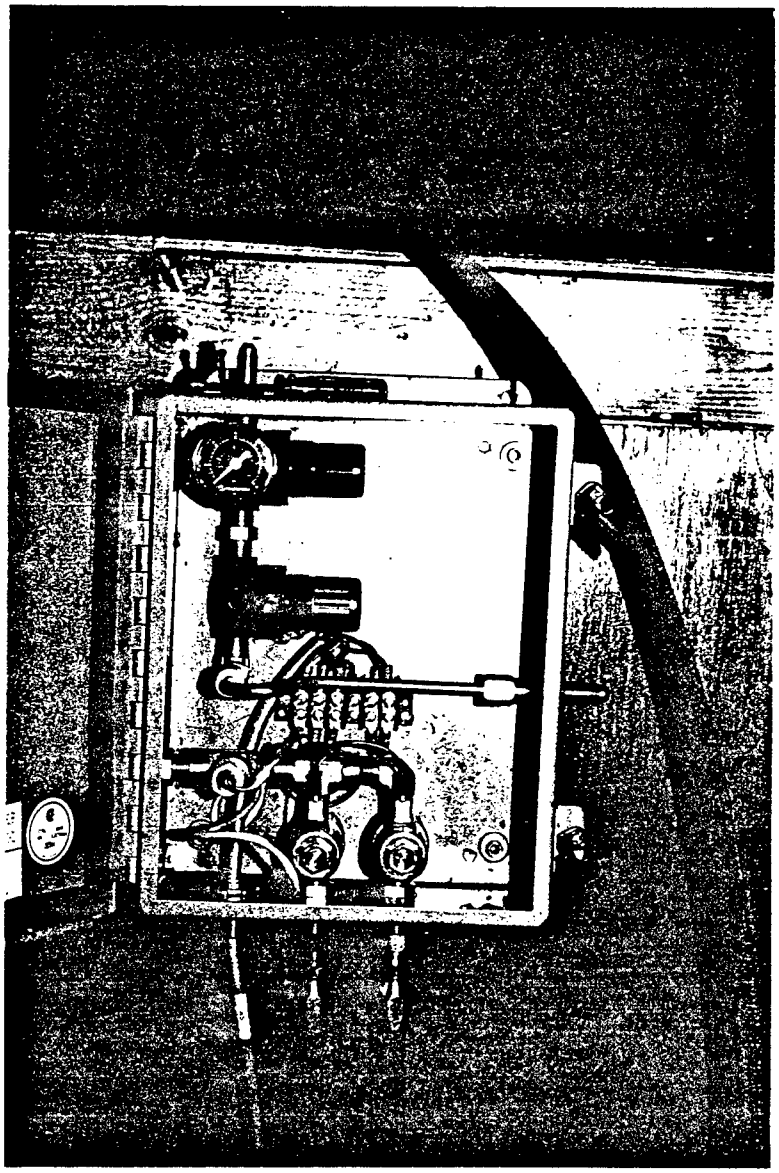


Fig.4. Hydraulic Control Box for SENTRAEN 2000T

APPENDIX 1

Field Survey on Current Rail-Wheel Lubrication Practices

AMTRAK - National Railroad Passenger Corporation

Mr. Bernard Hefferman (215) 349-1362

As you are aware, AMTRAK operates over the tracks of other carriers, except in the northeast corridor, where they maintain the right-of-way. They use wayside applicators, spreading grease to the rail flange and gauge side of the rail. In the fall when contamination from leaves becomes a problem, they use a top-of-the-rail friction enhancement product which contains a metallic grit. This is to improve traction. The wayside applicators are located just prior to the curves into the spiral. They do not use any on-board applicators.

During construction on their New England division, they used a liquid grease dispensed from a hi-rail vehicle. This represented nothing more than a wayside applicator mounted on a truck with hoses directed toward the rail flange. They claimed that this worked well. Following completion, they returned to the use of wayside dispensers.

In their judgment, this lubrication practice has succeeded in extending rail life, which they described as the most expensive part of the system.

GREATER CLEVELAND REGIONAL TRANSIT AUTHORITY

Mr. Alan Soukup (216) 575-3812

They use wayside applicators, that dispense a grease. The brand or formula is unknown, as their Stores Department purchases in bulk. He believes that they are using a new company, but all purchasing decisions are made by the Stores Department.

The wayside applicators are located on the tangent track approximately 10-15 feet before the curve spiral. The applicators are hydraulic and electric over hydraulic. They lubricate the rail flange and guide rail face.

They have noticed a reduction in rail wear. They put in a new line two years ago and noticed the filings around the curves. Subsequent to the installation of the wayside applicators, there has been no further evidence of filings. In addition, there has been a significant reduction in noise. They are convinced that the wayside applicators have provided an improvement in rail wear; therefore, it is their intention to install additional wayside applicators. This program will be done over a period of 2-3 years, due to budget constraints.

MARYLAND DEPARTMENT OF TRANSPORTATION, MASS TRANSIT ADMINISTRATION (MTA)

Mr. Patrick Albright (410) 333-7640

They lubricate the wheels using a truck mounted stick(grease) lubricant. The Maintenance of Way (MoW) group lubricate the track at known problem/trouble areas only. They do not have any fixed applicators, i.e., wayside applicators. The lubricant used by the MoW is a grease.

They have been very satisfied with the results, especially with reduced wheel wear, and would not recommend any changes to their current practice. Wheels are lasting over 300 miles.

The only complaint and concern with their current practice is with the cost of the lubricant. They would like to find "a cheaper stick".

MASSCHUSETTS BAY TRANSPORTATION AUTHORITY (MBTA)

Mr. Ed Mc Donald (617) 222-5884

Mr. Mark O'Hara (617) 222-5468

The lubrication practices depend on the particular line. Their operations are decentralized. They have found the grease to be messy and not precise. It gets on the rail head and tread of the wheel, causing problems. The objective of lubrication is noise mitigation and rail/wheel wear. They are looking at using the grease sticks.

As a general practice, they use wayside applicators to lubricate the back of the wheel and face of the restraining rail. The lubricant is applied on tangent track in advance of curves or switches. They use a Mobil supplied grease, the exact formula was not known.

The most significant results experienced has been reduced wear of the restraining rail. They have been advocating further lubrication for the wheel and gauge face. This to be accomplished by use of the truck mounted sticks.

Until they have experience with the sticks, they are not in a position to say whether this would represent a substitute for the wayside applicators or in addition to them. The current feeling is that use of the sticks may eliminate the need for the wayside applicators.

METRO-DADE COUNTY TRANSPORTATION ADMINISTRATION

Mr. Daniel Wilson (305) 884-7583

Presently, they are applying lubricant in the yards, crossovers and on curves. This is being done manually with graphite sticks. They have been testing the graphite sticks mounted on the trucks and applying the grease to the flange of the wheel. They now have 40 installed and are in the process of ordering the balance from Portec. They have also tested the KLS and Phymet sticks. A Japanese produced wayside applicator, which was designed to spray a fine oil on the wheel flange, has been discarded. They found it very "messy" to use. It was spraying oil on the side of the car and "everywhere else". They have limited experience with wear, but stated that statistics are showing that use of the graphite stick will double wheel life. The feeling is that once all of their vehicles are equipped with the truck mounted sticks, that will be all that will be required.

NEW JERSEY TRANSIT CORPORATION

Mr. Dave Carter (973) 491-7738

Mr. Bruce Wigod (973) 491-8015

They use wayside dispensers located just before the curve spirals to lubricate the rail flange. They do not lubricate switch points. They have no detailed studies to support system reduced wheel/rail wear. They do have a 5 mile rail piece running from Princeton Junction to Princeton. When the wayside applicator is not working properly, they change the wheels in 30 days; otherwise, every 60 to 92 days. It would be tough for them to quantify the true benefits of their lubrication practices. It is policy on their system to turn off the wayside applicators anytime there are problems with leaves, light rain, etc. that create slip sliding problems. Although the wayside applicators, by design, lubricate the flange and gauge face and not the top, anytime there is any condition that would offer a potential for sliding, the applicators are turned off. Another problem with quantifying benefits is the fact that they have been rebuilding their system over the past 10 - 12 years, including track. The joint bolted rail has been replaced with CWR. Since there is no available data (some of the track was in place since 1920-1930), historical comparisons are not possible. In addition, the nature of their traffic has changed dramatically. They formerly ran heavy freight trains over some of their lines. Now, although the frequency may be the same or more, the amount of tonnage on rail has been reduced. Still, as they perform their programmed maintenance, and replace rail at sundry locations, they do install wayside applicators.

They are in the process of ordering and testing a truck mounted graphite stick. They intend to use the tread attachment. While this attachment is designed to enhance the traction effort, it allegedly improves the lubrication process by causing the wheel to slide against the flange, thereby improving the flange lubrication process.

Information described as very confidential was gleaned during the interviews relative to a new product being introduced. This product takes the shape of the wheel profile and incorporates a lubrication dispenser with the brake shoe. NJ Transit has opted to initially try the stick lubricator as a separate system to determine its benefits before moving to the more sophisticated brake shoe/lubrication combination.

NIAGARA FRONTIER TRANSPORTATION AUTHORITY

Mr. Anthony Schill (716) 855-7631

Mr. Ben Antonio (716) 842-3502

They formerly had wayside applicators at two curve locations. One was triggered by the passing train and the other was turned on by a timer. These devices, which dispensed a grease, did not work very well.

They recently, past couple of months, installed Portec's graphite stick on the cars for the purpose of lubricating the wheel flange. Portec recommended that they also use an attachment designed to lubricate the tread. They have not yet installed the additional device.

It is too soon to determine whether their action will produce any benefits. Therefore, they do not intend to do anything further, other than program maintenance, until they can determine the benefits, if any, of the wheel flange lubrication.

SOUTHEASTERN PENNYLVANIA TRANSPORTATION AUTHORITY (SEPTA)

Mr. Ed Murphy (215) 580-8415

They are currently lubricating the rail flange on curves only. They use automatic wayside applicators. He was not sure as to the type grease being applied, but did volunteer that they were investigating an EM product which was described as "super grease". He is not sure whether they are currently using it.

They are not recommending any changes in their current practice. They had a program whereby they checked the applicators to insure their working performance, checked the gauge on curves changing any worn rail, checked the wheels, etc. and found that they were able to significantly decrease the wear, increasing the life by a factor of four. In other words, life was increased from one year to four years.

They are not sure if their success was the result of their lubrication practices, their maintenance programs or a combination. The fact is they are satisfied with the results and are continuing both the wayside lubrication and maintenance program. What they are witnessing is tread wear, but flange wear has been significantly reduced.

They do not worry as much as some others about grease on the railhead. In their opinion, "on tight curves, it don't matter".

The problem with sticks is getting started, i.e., you cannot put them on only a couple of cars. They do not have dynamic brakes on all of their equipment and the wheels get quite hot. The sticks did not work well with the hot wheels, so they abandoned the stick.

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

Mr. Joseph Krempasky (202) 962-5958

Except for the yards where wayside applicators dispense grease at tight radius curves, they do not provide any other form of rail/wheel lubrication. The lubrication in the yards was prompted by their desire to reduce noise, as they have yards several hundred yards from residential areas.

They attribute their reduced wear success primarily to their planned maintenance programs. They are now achieving more than 500,000 miles per wheel set. Part of this achievement is attributed to their improved slip slide control on the cars, which they are proud of improving in-house. They were formerly only getting 300,000 miles from their wheel sets. With improvements to 500,000 miles, they experienced a failure with the journal lubricant, i.e., the journal bearing lube did not hold. They now have the wheel sets and journal bearings lasting for more than 500,000 miles of service.

They are satisfied with the results of their programs and find improvements in both wheel and track wear. Due to their service territory, they found that the public is extremely sensitive to "clicky" noises. Therefore; when wheel flats became greater than one inch, they would cut the wheels. They are now finding that they are no longer cutting wheels.

APPENDIX II

Excessive Creep Force Also Produces Early Hunting

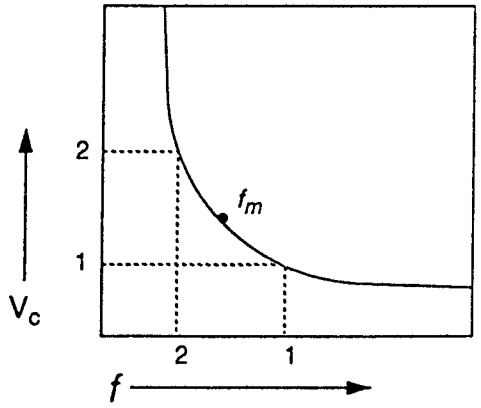
Excessive Lateral Creep Force also Produces Early Hunting

The approximate hunting speed is determined by:

$$V_c^2 = \frac{a^2\left((I_w + m_w a^2)\left[k_\theta + a^2(k_x + k_g)\right]\right)}{\left(\frac{a\lambda}{r_o}(I_w + m_w a^2)^2 + \frac{a}{2f}\left[m_w k_\theta - I_w(k_x + k_g)\right]^2\right)}$$

Where the symbols have the following definitions:

- V_c - Hunting Speed
- a - 1/2 Length of wheelset
- r_o - Rolling radius of wheels
- λ - Wheelset conicity
- m_w - Wheelset mass
- I_w - Wheelset yaw moment of inertia
- f - Creep coefficient
- f_m - Target creep coefficient value
- k_θ - Stiffness in θ
- k_x - Lateral stiffness



The hunting speed is reduced by increasing the creep coefficient *f*. The creep coefficient below a value, f_m , is necessary for enabling large values of hunting speeds. In other words, the lateral creep force must be reduced below a certain value that is proportional to f_m.