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Overview: the FAST Lubrication Study

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16. Abstract

From October 1983 to November 1984, a lubrication study funded by the Federal Railroad Administration was conducted by the Association of American Railroads at the Facility for Accelerated Service Testing (FAST) at the Transportation Test Center in Pueblo, Colorado. The FAST Lubrication Study involved:

- Wayside Lubricator Pumps - Five designs tested for reliability under normal (train pass) actuation.
- Lubricator Blade Configurations - Three types evaluated for lubricant distribution characteristics.
- Alternate Lubricant Application Systems - Two locomotive-mounted lubricators (spray and roller types), a lubricator vehicle (boxcar), and a hi-rail lubricator system tested for overall performance.
- Track Lubricants - Eight common and non-conventional types tested for overall performance.
- Overlubrication - Measurement of high rail lateral forces after deliberate overapplication of lubricant.

The study focused on lubricant distribution (the level, uniformity, and location of grease on the rail) and effectiveness (ability of the lubricant to reduce rail wear and decrease train resistance). A "goop gauge" served to monitor distribution. Lubrication effectiveness was determined by measuring wheel-rail longitudinal force (instrumented wheelset) and rail head temperature rise (thermal sensors).

The wayside systems had actuator linkage and adjustment problems. Some lubricator blade types and track locations performed better than others but all had position-in-curve differentials of effectiveness. The spray type locomotive flange lubricator performed best overall, but showed a possible need for supplementary lubrication in some curves. The boxcar lubricator did similarly well, but had further practical limitations. The hi-rail system was generally not satisfactory because the lubricant, sprayed directly on the rails, could not be distributed properly under all track conditions. "Off-the-shelf" greases performed most effectively, particularly an open gear type. Overlubrication tests linked excess high rail lateral forces with the typical operation of some wayside lubricators.

Results are aiding lubrication studies, especially the issue of extended wear life (due to wear reduction through lubrication) versus rail fatigue life, in order to discover any dangers in keeping lubricated rails in service longer than non-lubricated rails under traditional wear-based replacement criteria.

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EXECUTIVE SUMMARY

Historically, rail metallurgy experiments at the Facility for Accelerated Service Testing (FAST) have called for alternating periods of dry and lubricated running. Data show that lubricated running, including tangent track, required less fuel and lower locomotive throttle settings and produced significantly lower wear rates for standard carbon rail.

To examine the implications of these results, a FAST Lubrication Study was planned and conducted at the Transportation Test Center (TTC), Pueblo, Colorado, from October 1983 to November 1984. The goals were to develop ways of determining lubrication effectiveness, to establish the reliability and effectiveness of conventional trackside lubricators in various track locations and configurations, to evaluate several alternative lubricant application systems and various track lubricants, and to identify a combination of lubricator features especially suited to the closed-loop configuration at the FAST track.

Five designs of trackside lubricator pumps and three separate lubricator blade configurations were tested. Two different locomotive-mounted lubricators (one spray type and one roller type), a lubricator (boxcar) vehicle, and a hi-rail lubricator system were tested for overall performance. Eight different track lubricants were tested in cold and warm temperatures, and limited testing was conducted under conditions of deliberately-induced overlubrication.

Measurement methods included using a "goop gauge" to monitor lubricant placement and distribution on the rail, measuring longitudinal wheel-rail force with an instrumented wheelset, and monitoring rail head temperature rise with thermal sensors during each train pass over a measurement area. In this test, decreased longitudinal force and smaller rail temperature rises were an indication of greater lubrication effectiveness.

The first "mobile" system examined was the lubricator (boxcar) vehicle, wherein a pump transfers grease from a reservoir to the flanges of the boxcar wheels. A curve sensing device increases grease output during curve negotiation and determines which wheel flange is greased. The particular car tested had a rather complex system for doing all this, but it performed reliably. The better of the two lubricants tested gave adequate lubrication if the car was remotely "turned on" to dispense grease during one of four passes through a curve.

Two types of locomotive-mounted flange lubricators were tested. One sprayed lubricant onto the flange; the other applied lubricant to the flange by means of a roller/pump system. In both cases, lubricant was then transferred from the flange to the rail at the wheel-rail contact point. The spray type flange lubricators on three FAST locomotives were adjusted to dispense 0.4 cc of lubricant per rail (0.8 cc total per locomotive) and, after at least twenty train passes over the 4.7-mile FAST loop, the steady state level of lubrication was produced that was sufficient for the 90-car FAST consist. The spray type flange lubricating system satisfactorily maintained that level of lubrication.

The hi-rail lubricator system tested sprays grease directly onto the rails and eliminates transferring the lubricant from wheel flange to rail. The concept

has its advantages, but any direct-to-rail spray system of this sort must cope with problems of assuring proper lubrication on tangent track having gage face metal flow, and must be able to compensate for wheel-to-rail spacing variations caused by rail wear. Spray nozzle aiming is a critical feature. Under these constraints, the particular hi-rail system tested gave unsatisfactory results.

Trackside lubricators, the most common lubrication means currently in use on North American railroads, employ pump mechanisms actuated by passing train wheels to force lubricant onto various blade configurations, where it is then transferred to the flanges of the train wheels.

In testing strictly for reliability, five trackside lubricator designs installed at FAST were altered so their output, upon normal train-pass actuation, was discharged into barrels. These sytems were hard to adjust and all of them were subject to erratic output or complete failure because of various problems in their pump actuator mechanisms.

Testing of long, medium, and short lubricator blades at various locations with respect to the curve showed that blade configuration and location do affect distribution of the lubricant throughout the curve. The best measured lubrication was produced by four short blades in the spiral going into the curve. All configurations and locations, however, produced some form of overlubrication nearer the point of application, with lubrication levels decreasing with distance from the point of application.

Standard lubricants and several unconventional types were evaluated on the basis of their ability to spread around a curve, their uniformity of effectiveness from beginning to end of the curve, and the effects of sanding. During both cold and warm weather testing, standard "off the shelf" lubricants performed better than unconventional types.

Deliberate overlubrication was induced by applying lubricant to the (high) rail with a paint brush, simulating a malfunctioning (or, in some cases, typical) lubricator. With normal lubrication, high rail lateral forces will increase by 10%. With overlubrication, high rail lateral forces increased by 20% to 40%. The AAR plans further study on this topic because of the detrimental effects of improper lubrication and excess high rail lateral forces.

Based on results of the FAST Lubrication Study, the system providing the greatest overall control of lubricant placement and uniformity of lubricant levels was the spray type locomotive-mounted flange lubricator. In some curve situations, however, this system alone may not always guarantee adequate lubrication unless it is complemented by some other system, such as the trackside lubricator.

Results of the FAST Lubrication Study are being used in a number of research efforts. One such study involves a growing concern that wear reduction through lubrication will forestall normal, wear-based rail replacement to the degree that some rails, under extended service, will experience fatigue failures. In response to this issue, the TTC's Defect Occurrence and Growth Experiment includes testing of selected rails under high tonnages and controlled lubrication conditions.

OVERVIEW - FAST LUBRICATION STUDY

INTRODUCTION

A number of wheel-rail lubrication studies have been performed at the Transportation Test Center (TTC) since late 1983. This report provides a brief overview of each of the major experiments and presents author recommendations for further study, applications to field use, and relationships to energy studies.

The ability of proper lubrication to reduce not only rail wear but produce significant reduction in wheel flange resistance forces has developed significant interest in the railroad community. A number of tests were subsequently performed to quantify these energy savings as well as determine effects on train handling and braking in revenue railroad operations.

The FAST lubrication study was funded primarily by the FRA, with significant support from the railroads and supply industry in the form of donated equipment, lubricant products, and personnel assistance.

With documented energy savings of up to 25% over existing non-lubricated conditions at several revenue service sites, a number of railroads are in the process of improving their lubrication controls. With this in mind, a follow-up test to document possible rail fatigue problems developing from excessive continued lubrication has been initiated. During the FAST lubrication study, techniques for controlling and monitoring lubrication effectiveness were developed and used to impart controls on the defect occurrence and growth test.

BACKGROUND

In the past, rail metallurgy experiments at FAST were operated under alternating lubricated and non-lubricated conditions. Because of test objectives primarily concerned with wheel wear, dry rail conditions were used to obtain a higher resolution of data in an accelerated wear environment. Analyses of rail wear during these periods of dry and lubricated conditions provided some interesting findings. Rail wear rates during dry periods were quite predictable; that is, the wear rate of standard carbon rail varied by only 20% from one dry period to another. During lubricated operation, however, wear rates for the same identical rail were observed to vary by a factor of 100; that is, gage face wear varied from 0.001 to 0.00001 or more per MGT.

Train handling techniques were also examined at FAST and found to vary tremendously between dry and lubricated periods. During lubricated conditions, the amount of time the train was required to be in "Run 8" (full throttle) was reduced by almost 25%. Examination of FAST refueling records indicated that over 30% less fuel was required to operate during lubricated tests than during dry tests.

That lubrication produces fuel savings on train operation is not a new discovery, having been reported in AREA bulletins as early as 1939. Tests using steam locomotives indicated significant (15%+) reductions in train resistances on at least one occasion. The AAR elected to perform a number of energy tests from 1983 to 1985 to confirm energy savings under current train operations.

During lubricated conditions, rail fatigue is often a concern because lubrication extends rail life. This was a concern that was difficult to address on FAST during these tests because of the alternating dry to lubricated test conditions. This difficulty was compounded by the lack of definition of "proper" or "adequate" lubrication level and the inability of the lubricators to maintain a constant grease level.

There were a number of lubrication-related concerns raised: rail flaw detection, train handling, and economic and safety considerations. The potential for fuel savings stimulated sufficient interest to make the railroad industry reconsider its present lubrication policies. In order to address these concerns, the FRA and AAR together undertook the FAST lubrication study, with emphasis on the following objectives:

- Develop methods for measuring lubrication effectiveness.
- Assess the reliability of present trackside lubricators.
- Assess alternate modes of lubrication application.
- Assess the effects of placement and configuration (of trackside lubricators) on lubrication effectiveness.
- Assess performance of track lubricants.
- Identify a combination of lubricator features especially suited for use on FAST in its unique closed loop configuration.

TEST ELEMENTS

The FAST lubrication study was conducted from October 1983 until November 1984. During that study, a number of alternate and conventional lubrication systems, lubricants, and application modes were examined, as follows:

(Alternate Systems)

- Boxcar lubricator - an in-train lubricator car, operated behind the locomotives.
- 2 generically different types of locomotive flange lubricators, a spray type and a roller type.
- Hi-rail lubricator vehicle.

(Conventional Systems)

- 5 different trackside mechanical lubricator pumps tested for reliability and consistent output.

- 5 locations for trackside lubricators in a tangent and at various locations in and around spirals.
- 3 blade configurations - 1 long (6'), 2 medium (2') and 4 short (6") blades.
- 8 types of track grease - cold and warm weather tests.
- Limited tests on the effects of overlubrication.

During these tests, a number of methods of monitoring lubrication effectiveness were examined. Because conditions at FAST can be maintained at a relatively constant level, measurement systems that are ordinarily influenced by outside variables can be utilized without as much concern for undesired variables. However, it should be noted that, due to these constant conditions, many of the testing techniques will provide comparable data only at FAST or under FAST conditions unless the effects of other parameters such as train weight and track curvature can be assessed.

Tangent Track Lubrication

One of the more interesting findings to emerge during the AAR "lubrication energy savings tests" was the effect of train resistance on tangent track. A number of runs were made on the FAST track using a 6-car mini-consist. The locomotives used in these tests were equipped with calibrated data collection equipment to monitor main generator power output, traction motor power, throttle position, wind speed, wind direction, and train speed.

The short consist allowed the entire train to be in the full body of a curve or tangent for a sufficient time to monitor train energy.

Tractive effort for the entire 4.7-mile loop was monitored under dry rail conditions and under fully lubricated conditions. At a constant 40 mph, the average energy required to keep the test train moving was 550 hp for dry track and 362 hp for lubricated track. This resulted in a savings of 34%.

By knowing the track grade and position of the train with respect to curves, and eliminating train acceleration, the 'raw' energy required to move the train over a hypothetical section of level track for a given curvature could be computed. Results showing the difference between dry and lubricated segments can be found in Table 1.

TABLE 1. ENERGY SAVINGS, DRY TO LUBRICATED.

Curvature	Savings: Dry to Lubricated
3°	38%
4°	39%
5°	51%
Tangent	30%

The FAST results indicated significant savings of train energy on tangent track with gage face lubrication. However, the FAST track does not have long tangents between curves; the longest is about 2000'. Other (offsite) tests have been conducted by the AAR to determine if similar savings are obtainable on long (5 miles or more) tangent track.

The important information learned here was that lubrication of tangent track could result in sizable train energy savings. The alternate lubrication application systems should therefore be able to apply lubrication on both tangent and curve, a requirement not previously addressed.

TEST REVIEW

After examination, the following three measures of lubrication effectiveness were selected:

1. Goop gauge
2. Instrumented wheelset data
3. Rail temperature

The first objective of the lubrication study was to develop a method of assessing effectiveness of lubrication. Methods such as monitoring overall fuel consumption, train handling, or rail/wheel wear are accurate but do not provide quick and convenient readings of lubrication effectiveness.

Goop Gauge

In the past, FAST has tried numerous methods of monitoring lubrication levels. The "goop gauge", Figure 1, was used for several years to monitor and control the level of visible grease on the rail. In the course of the FAST rail wear experiment, an attempt was made, during lubricated periods, to maintain a lubricant level of at least "+0", but no higher than "+10" on the goop gauge scale.

A trackman periodically inspected curves and adjusted the lubricators to maintain desired grease levels. The goop gauge is a useful tool for measuring and, thus, maintaining a constant level of lubrication, but it does not indicate the effectiveness of the visible lubricant. Moreover, the goop gauge is practically useless for establishing the level of non-graphite based greases because after they have been deposited they are usually extremely difficult to see.

Wheel-Rail Longitudinal Force

Alternative methods of measuring lubrication effectiveness were examined, and the two ultimately adopted for FAST tests were: train car longitudinal force of the leading axle and rise in railhead temperature due to train passes.

Longitudinal force is monitored by a specially instrumented wheelset mounted in a standard truck (leading axle) under a 100-ton car and recorded by a data collection vehicle.

At FAST, on a 5° curve at 45 mph, longitudinal wheel force provides a very uniform means of comparing dry and lubricated rail. A 'dry' rail will result

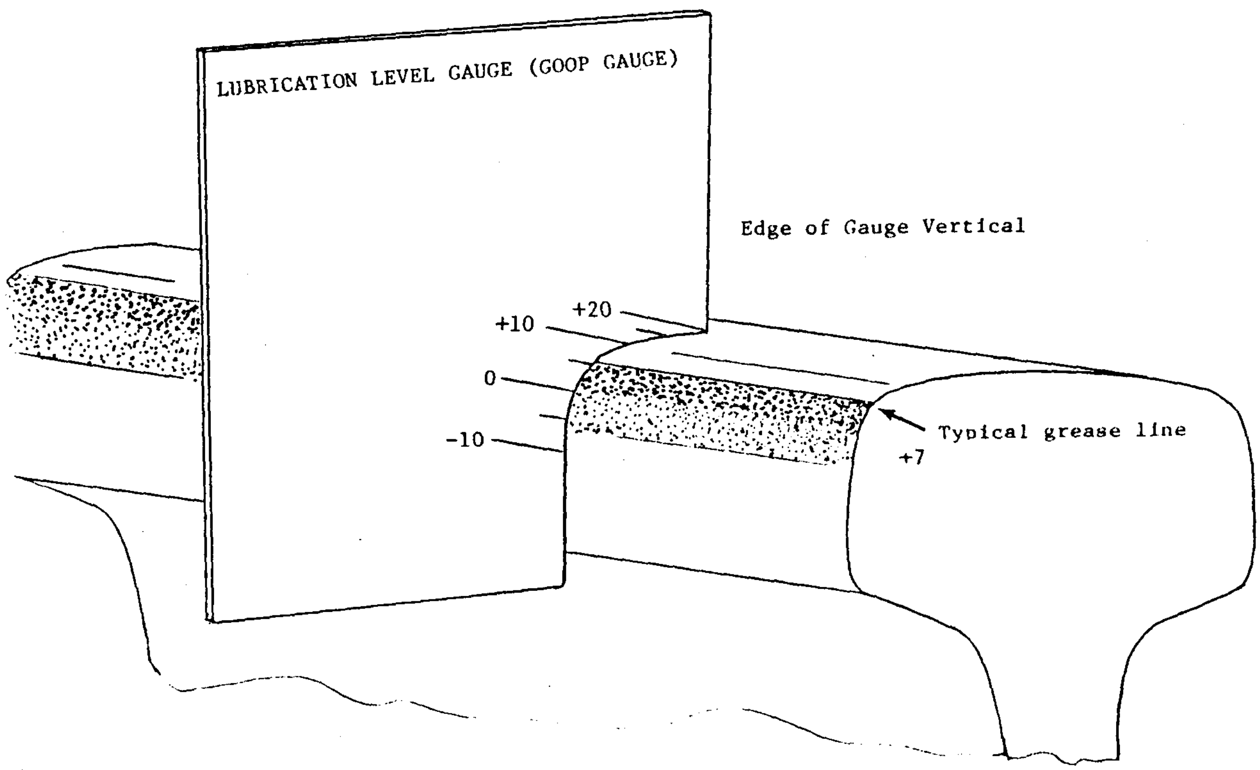

FIGURE 1. FAST LUBRICANT LEVEL MEASUREMENT, GOOP GAUGE.

in longitudinal values of 5,400 to 10,000 lbs. The same curve, fully lubricated, will result in longitudinal forces of 1,700 to 2,000 lbs. Predictable values of longitudinal force are observed between these two extremes at intermediate lubrication levels.

Longitudinal wheel-rail force measurements, although accurate and apparently indicative of lubrication conditions, would be costly to obtain on a day-to-day, revenue service basis, and are, therefore, not practical for most railroads. The equipment necessary to measure, record, and reduce the wheel force data is expensive and requires a large amount of manpower. The AAR is attempting to provide a low cost alternative wheelset. However, the only currently available instrumented wheelsets require significant hardware and software support capabilities. Installation of an instrumented wheelset on anything but a full size car with a full load (such as is now accomplished in a standard 3-piece truck under a loaded 100-ton hopper) may not replicate the full loads and contact patterns seen by typical vehicles. Railhead temperature rise was selected as an additional verification method.

Rail Temperature

Frictional forces present during the flanging action as a train negotiates a curve result in heat at the rail/flange interface. The amount of heat produced by a passing train is a function of the following: track curvature, speed, superelevation, truck characteristics, train weight, and lubrication. At FAST it is possible to control these variables and, with the exception of lubrication, all other variables were held constant during the lubrication experiment. Thus, the resulting temperature rises are an excellent indication of lubrication effectiveness. The field side of the high rail is used for temperature measurements because results obtained there would translate easily into portable system applications by the railroad industry.

At FAST, the rolling resistance, as measured by the increased longitudinal force, results in increased friction to heat up the railhead with each train pass. The temperature rise can be related to rolling resistance, and work is progressing to determine this relationship.

LUBRICATION APPLICATION SYSTEMS

In addition to the conventional trackside system, three "alternative" portable lubrication systems were evaluated:

- Lubricator car
- On-board (locomotive-mounted) systems
- Hi-rail lubricator vehicle

Lubricator Car

The lubricator car (donated for use by the Norfolk Southern Railway) was the first lubrication system examined as part of the lubrication study. In this particular configuration, a lubrication pump system was installed in a boxcar and conventional track grease was pumped onto the flange of one of the wheels. Sensors determined the curve direction and lubricated the appropriate wheel flange to allow the outside rail of the curve to be lubricated. In this test mode, only curves were directly lubricated.

Two types of grease were tested with this car: a standard grease (20% graphite) and a lubricant made with recycled oil that contained a small amount of graphite.

The FAST train was operated around the full 4.78 mile loop at 45 mph with the lubricator car directly behind the locomotive. To determine how many train runs could be made on a given territory before a lubricator car run was necessary, the TTC equipped the car with a remote control on-off switch. The car could then be operated for any number of laps either lubricating (on) or not lubricating (off) while onboard and wayside measurements were made. While using the 20% graphite grease, the lubricant applied by the first train provided adequate lubrication for the next three trains. Thus, one train in four (every fourth train) would require a lubricator car. The amount of grease applied during the initial pass was quite high and some wheelslip occurred on subsequent passes.

Using the alternate oil lubricant, effectiveness values indicated no lubrication after one train pass; that is, the thinner lubricant with little or no graphite did not hold up to repeated train passes, and would require application by each train. The thinner lubricant did not cause wheelslip problems, but it also did not last as long on the rail.

Many railroads may not want to place an extra car on <u>every</u> train, thus other lubricants or application systems may be desirable. For instance, alternative lubricants that can be applied in sufficient quantity without flowing over the top of the rail might be investigated. Subsequent tests on other systems at FAST indicate that any open gear lubricant may work in such cases. This type of lubricant incorporates a carrier that evaporates, leaving a dry film base. It must be properly applied to the flange/rail to avoid top-of-rail contamination. Additional investigations should be made on lubricants to determine their performance when applied by a lubricator car.

The complexity of the lubricator car could be reduced by eliminating the curve sensing systems, and lubricating at all times. FAST and other test results have indicated significant fuel savings on tangent as well as curved track. This consideration of tangent track lubrication would simplify lubricator car operation. Another option would be for the lubricator car to lubricate constantly at a low level, with a curve sensor dictating increased grease output on curves.

Operation of a lubricator car in every train leads to a discussion of the next FAST lubrication study, the locomotive lubricator. If overlubrication is a problem, then, rather than including a lubricator car on every train, a small lubricator could be installed on every locomotive so that sufficient lubrication could be applied to serve only that train.

<u>Locomotive Flange Lubricators</u>

Two different types of locomotive lubricators were tested: a pressurized spray type incorporating a nozzle aimed at the locomotive wheel flange to apply lubricant periodically; and a system employing a mechanical roller in continuous rolling contact with the wheel flange. The roller type operates a pump which also periodically applies a small amount of lubricant to the wheel flange.

When the FAST lubrication study was started, only foreign (German, other European, and Japanese) locomotive-mounted lubricators were considered because they were designed to apply sufficient lubrication for an entire train. Flange stick and other lubricators have been available in the U.S. since the days of the steam locomotives, but their primary function was to reduce wear only on locomotive wheels; i.e., grease output was not sufficient to reduce wheel wear on the remainder of the train or wear of rails in the curves. It should be noted that, since the FAST lubrication studies have been initiated, at least one U.S. lubricator manufacturer has begun development of a locomotive-mounted lubricator.

Several items were learned from the locomotive lubrication tests at FAST and from a number of field tests in which locomotive lubricators were used on revenue service trains.

Output/Capacity. The output level of the spray type lubricators had to be significantly increased over the levels that were considered acceptable for European and Japanese operating conditions. The combination of heavier axle loads and longer trains on North American railroads (compared to other locations worldwide) necessitated more grease output than was originally thought adequate by the manufacturers.

At FAST, with 3 out of the 4 locomotives equipped with flange lubricators on one axle, an output of 0.8 cc per locomotive was used. That is, 0.4 cc of grease was applied per rail, per nozzle. This provided effective lubrication for a 90-car train, but at least 20 train passes with operating lubricators were required to apply a sufficient amount of grease to obtain an acceptable steady state level of lubrication.

Some offsite tests have attempted to lubricate a train with one or two lubricator-equipped locomotives. There were also attempts at lubricating dry track using just one pass of the consist, thereby using the locomotive-mounted system to simulate the concept of the lubricator car. Results were mixed, the most noticeable effect being locomotive wheelslip caused by overlubrication.

Grease Type. A limited number of lubricants were examined during the locomotive lubricator tests. The roller system and one of the spray systems did not obtain an adequate level of lubrication with the lubricant supplied by the manufacturer. An alternative, open gear lubricant that left, upon application, a relatively thick layer of grease proved to be an improvement. Here, again, was an example of a product that had worked well under foreign loading conditions, but required modification (in this case, the lubricant type) in order to function effectively under North American conditions.

Operating Mode. The overall conclusion regarding the use of locomotive-mounted lubricators is that they can provide an excellent level of lubrication, but a significant proportion of the road locomotives in a fleet (maybe as high as 80% or more) would have to be equipped with such lubricators. This would result in a high probability that most of the traffic over a territory would see 50% or more of the trains equipped with operating, properly functioning lubricators. The regulation of lubricant would be semi-automatic, as light shorter trains tend to be assigned fewer locomotives than long, heavy trains. Thus, the longer, heavier trains (which require more lubricant) would conceivably, by default, have more locomotives and dispense more lubricant.

After a period of time, the rail in a given territory will remain lubricated as each passing train applies a small amount of lubricant to replenish what is removed. Unless misaligned spray nozzles applied grease on the wheel treads instead of the flanges, there is little danger of overlubrication because all locomotive lubricators would be set for low rates of application. The average application rates for all trains equipped with lubricators, some "over" and others "under", will tend to keep a constant grease level. Periodic track inspection will reveal if the overall system output needs to be adjusted up or down. Adjustment can be accomplished whenever a unit is refueled or serviced.

In conclusion, the commitment to utilize locomotive lubricators must be at least territory-wide, if not system-wide, because running just an occasional train with a lubricator in operation will not provide an adequate and uniform level of lubrication.

Hi-rail Lubricator

All lubrication systems discussed to this point require lubrication to be applied, then transferred and/or transported to the desired location on the rail as additional steps in the lubrication process. These extra processes can be eliminated by placing lubricant directly on the gage face of the rail with a hi-rail lubricator. The term hi-rail, as it is used here, is somewhat nebulous because most units of this type are basically automotive vehicles that have been adapted for on-track use (see Figure 2). However, the same lubricator system used on a typical hi-rail vehicle has been installed on a locomotive and could be used on a track car.

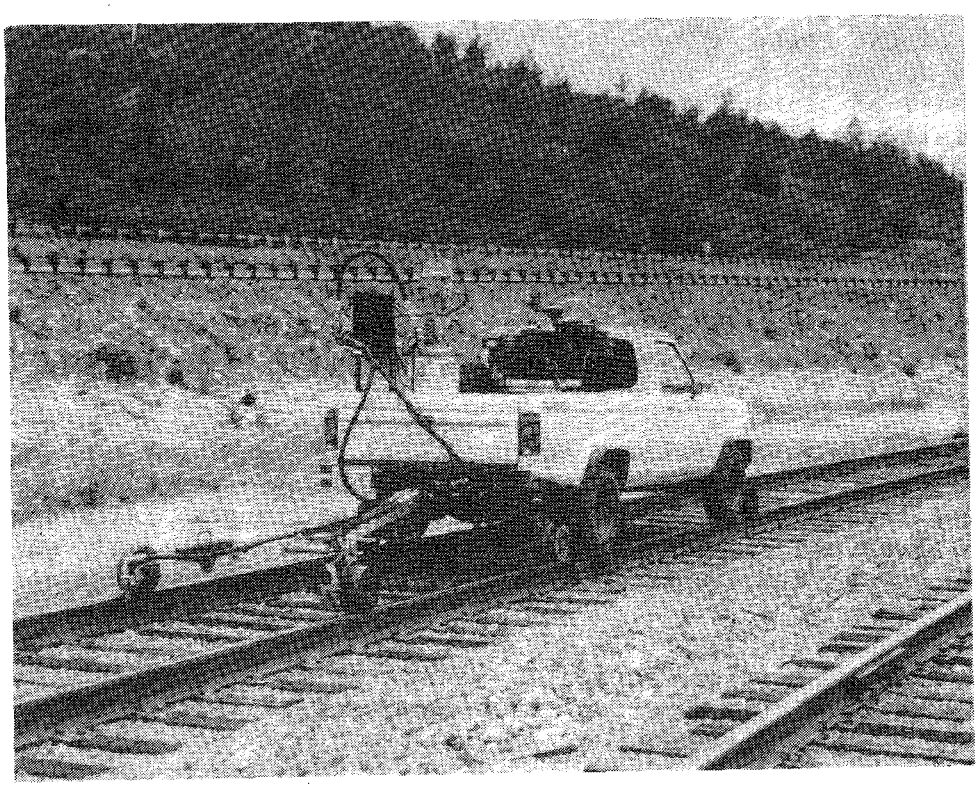

FIGURE 2. HI-RAIL TYPE VEHICLE.

The advantages of a hi-rail lubricator are as follows:

1. The lubricant application is controlled by the vehicle operator. Areas not requiring lubrication (for whatever reason) can be skipped.

2. The vehicle operator can inspect track as part of the lubrication duties, thus insuring a nominal savings in manpower usage.

Three major drawbacks of such a system are:

1. The vehicle must be operated on the track that is to be lubricated. If inspection schedules are changed or double track/sidings are present and used, additional trips may be required for proper coverage. This also means inspection of sidings must consider the mainline lubrication requirements.

2. Tangent track lubrication is very difficult in areas where gage face metal flow is present. Also, rail wear shape can be a critical factor in determining where the spray nozzle should be aimed.

3. Vehicle speed must be relatively constant to insure a uniform application of lubricant.

Original test results at the FAST track using hi-rail equipment indicated some of these inherent problems:

1. When enough grease was applied to allow 30 to 40 train passes between lubricant application, all the test lubricants tended to flow over the top of the rail.

2. Because of hi-rail speed and wheel-to-rail spacing inconsistencies caused by railwear, the grease pattern was variable and proper adjustment of the nozzle aim was difficult.

Alternative lubricants were tested at a later date, with the best control obtained from an open gear lubricant. This 'grease' was sprayed onto the gage face, where the carrier quickly evaporated, leaving behind a tacky film. No migration of the dry film to the top of rail was observed. Still, the only problem was altering the nozzle aim to correspond with the gage face of the rail.

A U.S. manufacturer of railway equipment has developed an application system that significantly improves the control of lubricant to the wheel-rail contact area, thus reducing adjustments when rail shape changes. Although not tested at FAST, field observations of this system are favorable and, in combination with the proper lubricant, a controlled lubrication application system is possible.

The only remaining disadvantage to using the hi-rail vehicle would be the necessity of obtaining repeated track occupancy so that grease reapplication runs could be made as needed.

In the case of FAST, reapplication was attempted every 30-40 train passes, allowing the lubricant to wear away. The last 10 to 15 train passes were usually operated in an essentially dry mode. This suggests that a hi-rail pass every 20 to 25 loaded trains (approximately 0.25 MGT) would be required to maintain adequate lubrication on a rail curve area similar to FAST. With the proper lubricant (such as a version of the open gear lubricant tested) and a hi-rail device with a revised aiming system, adequate lubrication levels could be achieved without danger of overlubrication. A territory which allows reasonable on-track access to be scheduled, such as secondary mainlines and branches, appears to be better suited for such a system than a heavy mainline.

Trackside Lubrication

The trackside lubricator is currently the most common form of lubricant application system employed by North American railroads. In this system, lubricant is applied to the wheel flange by means of a lubricant-laden blade.

FAST utilized a number of trackside lubricators during the rail metallurgy test period of 1978 to 1983. The experience using trackside lubricators at FAST was relatively poor because the lubricators were subject to breakdown, and all required frequent adjustment to maintain a constant level of lubrication. Lubrication levels during FAST metallurgy tests were monitored by a roving track inspector while the train was in operation. During ambient temperature fluctuations and seasonal changes in climate, lubricators often required adjustment after every 10 to 20 train passes to avoid dry rail or overlubricated rail conditions.

A number of conventional trackside lubricator types were installed at FAST to monitor the consistency of output from each lubricator pump, as well as adjustment and repair requirements. Blade configuration (long, medium, and short) and lubricator in-track placement were also investigated.

Five standard lubricators were installed, with the output of each directed into a barrel instead of onto the track. The remainder of the track installation was the same as if the lubricator were set up to actually lubricate the rail. The barrels were weighed daily to determine lubricator output. Likewise, each lubricator repair and/or adjustment activity was recorded. As expected, over a period of time all lubricators displayed a very large variation in output. Some required a substantial number of adjustments to maintain an acceptable and uniform output. All lubricators suffered mechanical system breakdowns and required repair during the 6-month test period.

The results of this test revealed a need for improvements in uniform lubricator output and mechanical reliability. Almost all failures observed at FAST occurred between the device that was triggered by passing wheels and the drive/clutch mechanism to the pump. No actual pump failures were recorded. One manufacturer has developed a trackside system that does not use a mechanical drive activated by the striking of passing wheels; however, it was not tested at FAST.

The trackside lubricator applies grease from a stationary location onto passing wheel flanges that carry the lubricant to the curve. The major difficulty in this process is its inability to apply a uniform level of lubrication around a section of track with multiple curves. The beginning of the first curve will, by the nature of its position, receive more lubricant than the far end of the same curve and more yet than curves further down track.

An objective of this test was to assess the in-curve lubrication differential as well as the effectiveness of the applied lubricant for different blade configurations. A very uniform lubricant level around a curve is desirable and is described as low in-curve differential. A high in-curve differential is less desirable, in that the beginning of the curve is receiving more lubricant than is the end of the curve.

In general, the multiple short blades provided a slightly lower over-all level of lubrication than did the single long blade; however, the short blades applied lubricant in a way that produced a lower in-curve differential than did the other blades tested. The twin medium-length blades performed midway between the two extremes. The pump, pump setting, grease type (graphite 12%), and time of the year of the test were all the same. The location of lubrication application also had an effect on in-curve differential. The closer a blade was located to the curve, or when the lubricator was located in a spiral, the higher was the over-all level of lubricant and the greater the in-curve lubrication differential.

The best measured uniform level of lubrication from a trackside lubricator system at FAST used 4 short blades near the spiral. However, in all cases, there was some form of overlubrication at the beginning of the curve and less lubrication effectiveness at the end, with respect to the beginning, of the curve.

In conclusion, when using trackside lubricators, there are some blade configurations that will reduce (but not eliminate) position-in-curve lubrication differential effectiveness.

Lubricants for Trackside Application

A number of different lubricants were examined for use in trackside lubricators.

Graphite and other standard lubricants normally utilized by railroads were tested along with several unconventional lubricants containing various additives. All data were obtained under the same conditions, by applying lubricants from an identical trackside lubricator, pump, and location.

For each lubricant tested, measurements were taken to determine:

1. the ability of the lubricant to spread around a curve, starting with dry rail,

2. the differential in lubrication effectiveness, beginning-to-end of curve, and

3. the effect of sanding.

All tests were performed twice for each lubricant. The first run during cold weather, the second during warm weather.

The overall best performance was obtained by "off the shelf" greases used by most railroads. Alternate lubricants, which performed significantly better in the lab, did not fare as well in the railroad environment.

OVERLUBRICATION

In these tests, the increase in lateral forces under conditions of normal lubrication was in the neighborhood of 10%. A limited investigation on the effects of overlubrication was also undertaken. Lateral forces were measured in two separate experiments, one test used the FAST train on the FAST track and measured lateral forces on the high rail using a single rail bending circuit. Another test was performed by the AAR at the TTC on an access spur with a similar curvature, but with an instrumented locomotive wheelset.

In both tests, the test procedure called for the use of a paint brush to achieve deliberate excess application of lubricant.

Data from these tests indicate that lateral high rail forces increased between 20 and 40 percent when an excess of lubricant was applied to the head and gage of the outside (high) rail while the low rail remained dry. This artificially imposed condition simulates what would occur, either at a typical single-rail trackside lubricator site, or whenever one side of a mobile lubricator or hi-rail system, not properly aimed, applied lubricant to the rail top.

The AAR intends to continue investigation of these lateral force changes because they indicate that improper lubrication application is not only detrimental to train operation and handling but might also induce higher lateral forces into the rail seat area.

SUMMARY/CONCLUSIONS

The AAR has performed a number of additional tests to verify the energy savings potential of proper lubrication. "Proper lubrication practice" is a term that is difficult to define and often depends on who is describing the lubrication condition. The AAR ad-hoc working group has taken the first step in defining "proper lubrication practice." Included are some fundamental requirements: no lubricant can be on the top of the rail, there must be sufficient lubricant to control gage face wear, lubrication spills must be avoided, and the level of lubrication must be uniform. How to attain and measure the proper levels of these parameters has been a goal of this lubrication study.

Locomotive/Lubricator Car Systems

The most controllable lubrication levels at FAST have been applied by the locomotive-mounted lubricator systems. With these systems, the level of lubrication, high or low, has been uniform around the entire loop and can be adjusted by system output (quantity and/or cycle per track length) and by lubricant type. The system with second best control was that used in the lubricator car. The disadvantages of over-lubrication may not be a major concern to those railroads that do not operate in territories with heavy grades. The economics of installing locomotive lubricators versus those of hauling around an additional lubricator car can best be addressed by those railroads having to deal with the problem of "proper lubrication practice."

Subsequent tests by AAR on a railroad with very sharp (10°) back-to-back curves, with adjacent 5° curves separated by relatively long tangents 3000' to 4000', indicate that a mobile system (in this case a locomotive lubricator) cannot always provide a uniform level of lubrication. Curves that occurred back-to-back had less lubrication than those located between long tangents. This suggests that the output of a mobile lubrication system may require adjustment on curves. Lubrication of tangent and curved track with a mobile lubricator that has a set output per distance traveled (be it locomotive or lubricator car) provides a level of lubrication that will eventually reach a steady state. Selected track areas, especially those in severe curved territory, will require some additional lubricant since the lubricant wears off faster because of the higher flange forces. Although there are a number of alternative routes that can be taken, the best option depends on the individual railroad's operating economics.

a. A curve sensor can be installed on the lubricator (locomotive or lube car) that causes grease output to be increased on curves, as mandated on the basis of specified curve degree. This addition, although ideal in theory, could add considerable cost, complexity, and maintenance to such systems. For proper operation, curve direction (left/right) would have to be determined. To check the lubricator operation at servicing terminals would require moving the vehicle around a curve and along a tangent to ascertain if the grease were being applied properly.

b. The use of backup lubricators, wayside or hi-rail, could be investigated. The operation of a hi-rail lubricator over selected curves, based on a periodic track inspection, could "touch up" under-lubricated track segments.

c. Once the trackage lubricated by a mobile system (locomotive or lube car fleet) reaches a steady state, trackside lubrication could be installed at selected curves to "fine tune" the lubrication pattern in that area.

Hi-Rail

The hi-rail lubricator system can be a viable means of lubricating if the problem of lubricant on top of the rail is solved. The single "second generation" system observed to date has addressed the problem of aiming the lubricant and it appears that alternate lubricants are available that will reduce the tendency to flow over the top of the rail.

A hi-rail system does require repeated application at specified intervals--the actual time interval will be a function of train mix, lubricant, and amount of application. For this reason, hi-rail application does not appear to be feasible for heavy mainline traffic conditions where track time at specified intervals cannot be guaranteed. A secondary mainline or branch line track appears to be best suited to the use of a hi-rail, and, as stated before, for use in "touching up" areas where a locomotive/lube car system does not provide adequate coverage.

Wayside Systems

The wayside (trackside) system can provide adequate lubrication over a limited amount of track, but most available systems require a significant amount of attention to maintain a constant level of lubrication. The trackside system is not considered a viable alternative for tangent track lubrication. Environmental concerns must be addressed, as the excess grease not picked up by passing wheels often ends up in the ballast.

The inherent position-in-curve differential of effectiveness with lubrication applied by trackside lubricators is utilized to obtain the desired grease pattern in support of the Defect Occurrence and Growth Experiment. Determining the extent of the rail fatigue evident in similar rails under varying lubrication levels was one of the requirements of this experiment. The trackside lubricator position and lubricant utilized for this test was specified based on results of the FAST lubrication study.

There have been some new trackside lubricators developed that address some of the problems inherent in the conventional systems, but these have not been tested at FAST.

FUTURE RESEARCH

A number of programs have been instituted by both the FRA and the AAR to address wheel-rail lubrication concerns. Of primary concern to much of the railroad industry, is the effect of long term extension of rail life due to lubrication. It is feared that, with significantly extended rail life, curve-related rail failure will change from wear to fatigue failure.

Rail Fatigue

To address this issue, the FRA has sponsored a "Defect Occurrence and Growth Experiment" at FAST. The elements of this test include high tonnage operation over rail in a 2700' 6° curve under continuous lubrication conditions.

Track from identical steel rail heats has been placed at several locations around the curve. A high to low lubrication differential is to be maintained around this curve during the 200-MGT test period.

Data analysis will address rail quality as well as how lubrication levels influence wear and fatigue. Operation over this test rail started in July of 1985. Data from this test are expected to provide lubrication application designers with an improved idea of what level of lubrication is desirable.

Lubrication Systems

To allow more efficient testing of lubrication systems (trackside and mobile, including onboard systems) and lubricant types, the AAR has constructed a lubrication research vehicle.

This vehicle is built on the chassis of a former locomotive that had been converted for use as a steam generator for passenger train use. The steam generators have since been replaced by a new boiler. Steam jets are used to rid test curves of previous lubricants to allow for comparisons between lubricant types and/or application systems. The locomotive "shell" is used as a test bed for alternate locomotive lubricators; this unit is equipped with non-powered EMD 2-axle locomotive trucks.

Demonstration tests of this vehicle were completed in early August 1985, at which time the vehicle became available for use by the railroad industry.

Updated information on these and other lubrication tests conducted by the AAR/TTC can be obtained by contacting the TTC information office.